Pest Management in Horticultural Ecosystems
Vol. 27, No.2 pp 201-208 (2021)

Management of thrips through strategically developed IPM modules in cumin (*Cuminum cyminum* L.) in a semi-arid region

N. K. MEENA*, K. KANT, R. S. MEENA, R. SINGH, R.D. MEENA and S. N. SAXENA

ICAR-National Research Centre on Seed Spices, Ajmer-305206, Rajasthan, India

***E-mail**: narottammeena@gmail.com

ABSTRACT: Thrips species *viz.*, *Thrips tabaci* Lind., *Scirtothrips dorsalis* Hood and *Frankliniella schultzei* Trybom (Thysanoptera: Thripidae) cause significant damage to cumin crop in India. In this study, eight IPM modules were evaluated against thrips mixed population. The IPM module (M-5) consisting seed treatment with imidacloprid 600FS @ 3ml/kg seed followed by foliar spray of *ker* plant extract @ 10ml/lit., *Lecanicillium lecanii* ($1x10^8$cfu/g) @ 6g/l, and fipronil 5%SC @ 0.035% at definite interval was effective for management of thrips (93.67 and 91.78% mortality in thrips population) and was relatively safe to natural enemies, pollinators and minimized pesticide residue in the seeds. Two years data also revealed the effectiveness of IPM modules M-5 resulting in higher seed yield (934 kg/ha) and B: C ratio (3.69:1). It is inferred that IPM modules including botanical product, entomopathogenic fungi based bio-pesticides and need based insecticides are effective for thrips management.

Keywords: *Cuminum cyminum*, thrips, management, IPM modules, economics

INTRODUCTION

Cumin (*Cuminum cyminum* L.) is also known as 'Zeera' that belongs to Apiaceae family is an important seed spice crop. It is a native of the Levant and Upper Egypt and now grown mainly in hot countries, like India, Iraq, Iran, Turkey, Pakistan, Syria, China, Italy and Israel (Meena *et al*., 2018). It is low volume and high value crop and India is one of the largest producers, and exporter of cumin seed (Meena *et al*., 2018) as it grown in 12.76 lakh hectare area produced 9.12 lakh tonnes seed in 2019-20 (Anonymous 2021a) also exported 2.14 lakh tonnes cumin seed, valued for 3328 crore, play a vital role in Indian's agricultural economy. Cumin is solely cultivated in Rajasthan and Gujarat states, contributing > 95% of total country's cumin production. Cumin seed contains 60% cumin aldehyde and 2-5 % volatile oil liable for flavouring in various food preparations. It has huge nutritional value *viz*., protein (17.7%), carbohydrate (35.5%) and minerals (7.7%) along with several medicinal properties used as stimulant, antidiabetic, antioxidant (De *et al*., 2009), antiseptic, antihypertensive herb, cholesterol level reducer (Nalini *et al*., 1998), carminative, stomachic, astringent and constructive in diarrhea and dyspepsia. Cuminaldehyde is good detoxicant which help in the regular removal of toxins from the body.

Cumin crop is infested with several insect-pests, and among them, thrips is a major problem. *Thrips tabaci* Lind., *Scirtothrips dorsalis* Hood and *Frankliniella schultzei* (Thysanoptera: Thripidae), are three important species of thrips that cause significant yield loss in cumin (Meena *et al*., 2018; Kant *et al*., 2015). These species are geographically distributed throughout the world and considered as cosmopolitan in habitat (Nakahara, 1997 and EPPO, 2021). *S. dorsalis* is recorded on more than 100 plant species in 40 families, although the original wild host plants were probably *Acacia* species (Palmer 1990). Thrips infestation starts at early growth stage about 20 days after germination and causes damage to cumin (Meena *et al*., 2018), coriander, okra, cotton, eggplant (Abang *et al*., 2018; Meena *et al*., 2017; Meena and Kumar 2011), field and horticultural crops and several weed plants year round. The nymph and adult of this insect crash the epidermis layer of leaves, stem and shoots by rasping and sucking type of mouth parts and suck the out coming sap (Meena *et al*., 2019). Infested plant parts show discoloration in patches and growth stunted.

Cumin thrips cannot be control only by the use of single insecticide and repeated use of chemical pesticides cause resistance to insecticide and mortality of natural enemies. Harvested cumin seeds retained heavy pesticide residue. Hence integrated pest management is an alternate way for sustainable management of thrips on cumin. Keeping this in view, the present study was carried to develop a suitable IPM module using cultural, botanicals, mechanical means, bio-control agents and chemical insecticides in a compatible manner for development of eco-friendly and cost effective IPM module for thrips management and enhancement of cumin yield.

Table 1. Details of IPM modules applied for the management of thrips on cumin (2018-19 and 2019-20)

IPM Module	Treatment components
M-1	Cultural method+ yellow sticky trap @25 traps/acre + ker plant extract @ 10ml/lit. + acetamiprid 20%SP @0.025%
M-2	Neem cake @500kg/ha (SA) + cultural method + NSKE (5%)+ fipronil 5%SC @ 0.035%
M-3	Castor cake @ 300kg/ha (SA) + azadirachtin 0.03 EC @ 3ml/lit. + tumba fruit extract @ 10 ml/lit. + thiacloprid 240 SC @0.025%
M-4	Neem oil 3% @ 5 ml/lit. (ST) + yellow sticky trap 25/Acre + *Coccinella* larvae @5000/acre + imidacloprid 17.8 SL @ 0.003%
M-5	Imidacloprid 600FS @ 3ml/kg seed (ST) + Ker plant extract @ 10ml/lit. + *Lecanicillium lecani* (1x10^8cfu/g) @ 6g/lit. + fipronil 5%SC @ 0.035%
M-6	*Trichoderma viride* @6g/kg seed (ST) + *Coccinella* larvae @ 5000/acre + *Beaveria bassiana* @ 6g/lit. + fipronil 5%SC @ 0.035%
M-7	Thiamethoxam 25 WG @ 5g/kg seed (ST) + *Azadirachtin* 0.03EC @ 5ml/lit. + *Metarrhizium anisopliae* @ 6g/lit. + acetamiprid 20 SP @0.025%
M8	Control (Untreated)

+ Two local wild plants: Ker plant is botanically known as *Capparis decidua* (Forssk.) Edgew., and tumba plant (*Citrullus colocynthis* Lin.), SA- soil application, ST- seed treatment

MATERIALS AND METHODS

Field experiments were carried out at Research Farm, ICAR-National Research Centre on Seed Spices, Ajmer (Rajasthan) in *rabi* season for two consecutive years 2018-19 and 2019-20. Experimental location is surrounded by Aravalli hill range, lying under the coordinates between 74^0 35' 39" to 74^0 36' 01" E longitude and 26^0 22' 12" to 26^0 22' 31" N latitude with an altitude of 486 m (Meena et al. 2019). The study area falls under semi-arid region of the country; where summers are extreme hot and winters are cold. Area receives annual average rainfall of 300-550 mm, where as relative humidity was ranged from 60-80% (Meena et al., 2018).

The trials were conducted to find out the effectiveness of strategically developed eight different IPM modules for thrips management in cumin under field conditions. Field experiments were laid out in RBD and replicated three times. The seeds of cumin variety GC-4 were sown in well prepared splitted in plots sized of 5 x 4 meters keeping 30 x 20 cm row to row and plant to plant crop geometry. All recommended package of practices of cumin were applied to the crop for quality production. Eight different IPM modules consisted with cultural practices (uprooting weeds- an alternate host of thrips), botanical products, bio-control agents, mechanical means and chemical insecticides in a compatible manner were evaluated under four application schedules at different intervals. The details of each IPM modules are given in Table 1. In application schedule, first application of each IPM module was applied as seed treatment as well as soil application at the time of seed sowing; second treatment at 35 d after germination and third and fourth treatment applications were applied at 50 and 65 d after germination, respectively when sufficient thrips population was observed. One year old plant foliage of ker [*Capparis decidua* (Forssk.) Edgew] and fresh ripen fruits of tumba [*Citrullus colocynthis* (L.) Schrad.] were collected and brought into the laboratory. Plant sap of collected material was extracted with juice extracting machine by adding 200 ml water per kg ker foliage and 300 ml water per kg tumba fruit pulp and then filtered through muslin cloth. Spray solution of these botanicals were prepared by dissolving recommended doses of extracts in one litre of water and also added sticker @ 1 ml/l., of water for spraying on the crop. Fungus based biopesticides were taken from bio-control laboratory, ICAR-NRCSS, whereas, local population of *Coccinella septempunctata* were released on cumin plants, while remaining insecticides and materials were procured from the market.

Observations on thrips population were recorded right from 10 d after germination to 50 d after germination at 10 days interval by visual counting of thrips on 5 randomly selected and tagged plants per plot in all replications. Initially whole plant was taken into account for observations but in later vegetative growth stages, three branches/ plant were considered for the observations. Pre treatment population was recorded 1 day prior to third and fourth applications of treatments and the post treatment data were recorded at 1, 3, 7 and 10 days after each spray application and then per cent reduction in thrips population was worked out. Yield data was recorded from individual plot of each replication, harvested separately for each IPM module. Economics of each IPM modules was also worked out based on two years pooled yield.

Table 2. Field efficacy of first and second applications of different IPM modules against thrips on cumin in *rabi* 2018-19

IPM module	Thrips population (No. of thrips/plant up to 40 DAG and per branch at 50 DAG)				
	1st Application			IInd Application	
	10 DAG	20 DAG	30 DAG	40 DAG	50 DAG
M_1	0^{b}	0.2^{bc}	1.2^{c}	3^{c}	4.6^{b}
M_2	0.2^{ab}	0.4^{b}	2^{b}	4.2^{b}	4.4^{b}
M_3	0^{b}	0^{c}	0.2^{de}	1.6^{d}	2^{d}
M_4	0.2^{ab}	0.2^{bc}	0.6^{cde}	2^{d}	2.8^{cd}
M_5	0^{b}	0^{c}	0^{e}	0.67^{e}	0.8^{e}
M_6	0.2^{ab}	0.4^{b}	1^{cd}	2.6^{c}	3.2^{c}
M_7	0^{b}	0^{c}	0^{e}	0.8^{e}	1.13^{e}
M_8	0.4^{a}	1^{a}	3.6^{a}	5.8^{a}	8.6^{a}

*Mean of 15 plants from three replications.

In column, means followed by common letters are not significantly different at ($P \leq 0.05$) by Duncan's Multiple Range test (DMRT).

Data analysis

The reduction percentage of thrips population was calculated by using Abott (1925) formula:

$$P = \frac{T - C}{100 - C} \times 100$$

Where,

P = Corrected per cent mortality; T = Observed per cent mortality in treatment; C = Percent mortality in control.

IPM module-wise marketable seed yield of each year was recorded, and converted in to kg per ha. The data collected was subjected to statistical analysis as randomized block design after suitable transformations. The corrected per cent mortality so obtained were analyzed after converted into arc sin values and tabulated to statistically analysis to determine the various treatment effects. The mean separation of number of thrips till 50 d after germination and per cent mortality in thrips in third and fourth applications and seed yield was performed using Duncan's Multiple Range test DMRT ($P \leq 0.05$). The statistical analysis was performed using the SPSS statistical software.

RESULTS AND DISCUSSION

In 2018-19, results showed that, all IPM modules significantly maintained the thrips population ($P \leq 0.05$, Duncan's Multiple Range test DMRT) under check over untreated control at 10, 20, 30, 40 and 50 d after germination in first and second applications (Table 2). In first application, mean thrips population per plant was ranged from 0.2 to 0.4 while IPM modules M-3, M-5 and M-7 were kept cumin plants free from thrips infestation at 10 d after germination. Further at 20, and 30 d after germination, there was an increase in its infestation in all the treatments ($P \leq 0.05$), but significantly less than the control. Meena *et al*. (2018) reported that thrips infestation appeared on cumin at 20 days after germination with meagre population. At 30 d after germination, no thrips infestation was recorded in IPM module M-5 and M-7 included imidacloprid 600 FS and thiamethoxam 25 WG as seed treatment, respectively. The next effective models were M-3, M-4, and M-6 with soil application of caster cake (0.2 thrips/plant), neem oil 3% (0.6 thrips/plant) and *Trichoderma viride* (1.0 thrips/plant) as seed treatment, respectively. No information was available on effect of these chemical as seed treatment against thrips on cumin, however, seed treatment with imidacloprid 600 FS @ 5 ml/ kg seed in blackgram was found effective against whitefly (Men *et al*., 2005), leafhopper and thrips on cowpea with highest gross and net returns (Anusha *et al*., 2016). Sujatha and Bharpoda (2017) reported that seed treatment of moongbean with thiamethoxam 25WG (0.01%) was found to be more effective against the sucking pests are evident to the present finding. In second application made on 35 d after germination and thrips population was recorded at 40 and 50 d after germination, showed that there was an increase in thrips infestation in all the treatments lowest in M-5 ($P \leq 0.05$), but significantly less than to control. At 50 d after germination, all tested IPM modules were found significantly superior over untreated control in thrips management in cumin. The minimum thrips population (0.8 thrips/plant) was recorded in IPM module M-5 (ker plant extract @ 10ml/lit) followed IPM module M-7 (azadirachtin 0.03 EC) with 1.13 thrips/plant mean population but statistically on par with each other. Meena *et al*. (2016) reported that foliar application

Table 3. Field efficacy of third and fourth applications of different IPM modules against thrips on cumin in *rabi* 2018-19

IPM module	PTC	Per cent mortality of thrips population				Per cent mortality of thrips population			
		IIIrd Application				IVth Application			
		1 DAT	3 DAT	7 DAT	10 DAT	1 DAT	3 DAT	7 DAT	10 DAT
M_1	11.40	46.82 (43.16)^{b}	53.43 (46.95)^{b}	61.60 (51.69)^{c}	55.38 (48.07)^{bc}	57.02 (49.02)^{b}	64.00 (53.13)^{c}	70.32 (56.97)^{c}	63.11 (52.59)^{e}
M_2	12.00	48.14 (43.92)^{b}	52.60 (46.47)^{b}	62.30 (52.10)^{c}	56.16 (48.52)^{bc}	57.47 (49.29)^{b}	65.53 (54.03)^{c}	73.26 (58.85)^{c}	64.37 (53.34)^{de}
M_3	6.00	48.85 (44.33)^{b}	54.17 (47.37)^{b}	66.36 (54.53)^{b}	60.44 (51.01)^{ab}	64.69 (53.53)^{a}	71.09 (57.45)^{b}	87.71 (69.48)^{b}	69.59 (56.51)^{cd}
M_4	10.80	47.95 (43.81)^{b}	53.58 (47.04)^{b}	64.46 (53.39)^{bc}	52.39 (46.36)^{c}	64.01 (53.12)^{a}	72.10 (58.12)^{b}	86.16 (68.2)^{b}	70.56 (57.13)^{bc}
M_5	2.40	54.22 (47.41)^{a}	66.67 (54.73)^{a}	73.33 (58.91)^{a}	65.56 (54.05)^{a}	67.22 (55.06)^{a}	80.56 (63.91)^{a}	93.67 (75.67)^{a}	76.44 (60.95)^{a}
M_6	7.80	50.31 (45.16)^{ab}	54.06 (47.31)^{b}	62.38 (52.15)^{c}	50.53 (45.29)^{c}	54.51 (47.57)^{b}	63.47 (52.8)^{c}	74.11 (59.39)^{c}	65.30 (53.89)^{cde}
M_7	4.00	53.33 (46.89)^{a}	66.11 (54.38)^{a}	71.67 (57.83)^{a}	64.44 (53.43)^{a}	65.44 (53.98)^{a}	77.44 (61.64)^{a}	91.22 (72.81)^{a}	75.16 (60.2)^{ab}
M_8	16.20	0.00 (0.00)^{c}	0.00 (0.00)^{c}	0.00 (0.00)^{d}	0.00 (0.00)^{d}	0.00 (0.00)^{c}	0.00 (0.00)^{d}	0.0 (0.00)^{d}	0.00 (0.00)^{f}

*Mean of 15 plants from three replications.

PTC = Pre treatment count; DAT = days after treatment, values in parentheses are angular transformed values.

In PTC, the difference in thrips population between treatments is due to the impact of first & second applications of different IPM modules.

In column, means followed by common letters are not significantly different at ($P \leq 0.05$) by Duncan's Multiple Range test (DMRT).

of ker plant extract @ 10ml/lit., was found effective against aphid on coriander are conformity with present findings. *Capparis decidua* Edgew (Forssk.) plants contain insecticidal compounds triacontanol and Tetrahydropyran-2-one shown enormous insecticidal activity against a wide range of insect pests (Upadhyay 2012; Upadhyay 2013). The next effective IPM modules were M-3 (2 thrips/plant), M-4 (2.8 thrips/plant) and M-6 (3.2 thrips/plant), whereas IPM module M-1 was performed least effective module at this stage in management of thrips on cumin (Table 2).

The mortality per cent in thrips population due to third and fourth applications of IPM modules (Table 3) showed that all treatments were significantly reduced the thrips populations ($P \leq 0.05$, Duncan Multiple Range Test) in all replications as compared to control at 1, 3, 7, and 10 d after treatments. There was a significant increase in per cent mortality of thrips till 7 d after third treatment application, and then decreased at 10 d after treatment. At 7 d after treatment, thrips populations were reduced in all treatment applications in comparison with the control. The highest mortality (73.33%) in thrips population was recorded with IPM module M-5 (*Lecanicilium lecanii*) followed by 71.67% mortality in M-7 (*Metarhizium anisopliae*) and both the treatments were statistically on par. Fungal strain *L. lecanii* (CS-625) was reported to cause 95% mortality in aphids after 10 days of treatment when applied as filtrate (Javed *et al*., 2019). The next effective IPM modules were M-3 (tumba fruit extract @ 10ml/lit) and M-4 (Coccinellid larvae) reduced 66.36 and 64.46 per cent thrips population, respectively and statistically on par. Cucurbitacin E glycoside content of *Citrullus colosynthis* shows insecticidal effect on aphids (Torkey *et al*., 2009). Fresh tumba fruit extract @ 10ml/lit., found effective in management of aphid in coriander (Meena *et al*., 2016) and thrips in fennel under integrated organic farming system (Meena *et al*., 2019) support the present result. The remaining IPM modules were recorded least effective module in management of thrips on cumin. A similar trend of mortality in thrips population was recorded in fourth application, where all IPM modules were found significantly superior in management of thrips over control (Table 3). At 7 days after treatment, the highest mortality (93.67%) in thrips

Table 4. Field efficacy of first and second applications of different IPM modules against thrips on cumin in *rabi* 2019-20

IPM module	Thrips population (No. of thrips/plant up to 40 DAG and per branch at 50 DAG)				
	1st Application			IInd Application	
	10 DAG	20 DAG	30 DAG	40 DAG	50 DAG
M_1	0^c	0.2^c	1^b	2^c	5^b
M_2	0^c	0^d	2^a	3^b	6.4^a
M_3	0^c	0^d	0^c	$1.2^{c\ e}$	2^d
M_4	0.2^b	0.2^c	0.6^{bc}	2^{cd}	3^c
M_5	0^c	0^d	0^c	0.53^e	0.87^e
M_6	0.2^b	0.6^b	2^a	3.2^b	5^b
M_7	0^c	0^d	0^c	1^e	1.6^{de}
M_8	0.4^a	1.2^a	2.4^a	4.6^a	7.2^a

*Mean of 15 plants from three replications.
In column, means followed by common letters are not significantly different at ($P \leq 0.05$) by Duncan's Multiple Range test (DMRT).

population was recorded with IPM module M-5 (fipronil as last treatment) followed by M-7 (acetamiprid as last treatment) reduced 91.22 per cent thrips population. Fipronil @ 2ml/l was also found effective in reduction of whitefly population (Meena and Raju 2014). Both modules were found statistically on par with each other in their efficacy. Among eight different IPM modules, M-1 was recorded least effective module in management of thrips in cumin.

Second year in 2019-20, the same IPM modules were evaluated against thrips and relevant data on thrips population and per cent population reduction in third and fourth treatment applications were present in table 4 and 5. At 10, 20, 30, 40 and 50 d after germination, the thrips population was recorded significantly lower to control in all IPM modules ($P \leq 0.05$). In first treatment, mean thrips population was recorded in the range of 0.2 to 0.4 thrips/plant in IPM module M-4, M-6 and M-8, remaining IPM modules were kept cumin plants free from thrips infestation at 10 d after germination. Similar results were also obtained at 20 and 30 d after seed germination, wherein thrips population was ranged from 0.2 to 1.2 thrips/plant. Application of treatments in IPM modules M-5, M-7 and M-3 escaped cumin plants from thrips infestation at this stage. At 30 d post germination, thrips infestation increased in range between 0.6 to 2.4 thrips/plant wherein, lowest population (0.6 thrips/plant) was in M-4 and highest (2.4 thrips/plant) in control. IPM modules M-5 (imidacloprid 600 FS as ST), M-7 (Thiamethoxam 25 WG as ST) and M-3 (Castor cake @300kg/ha as SA) showed zero thrips infestation (Table 4). In second treatment application, IPM module M-5 showed lowest thrips infestation (0.53 and 0.87 thrips/plant at 40 and 50 d after germination, respectively and was statistically on par to M-7 (1.0 and 1.60 thrips/plant) at both the intervals proved most effective module against thrips. However, thrips infestation in control plots steadily increased from 0.4 thrips/ plant at 10 d after germination to 7.2 thrips/branch at 50 d after germination. IPM modules M-3, M-4 and M-6 were found middle order of effectiveness against thrips. One day prior to treatment of third application, per plant thrips populations were ranged from 4.4 to 16.6 in all modules, showed significant difference in population due to treatment effect of first and second applications. Mortality in thrips population at 1, 3, 7, and 10 d after application showed that all IPM modules were found significantly better in reduction of thrips population over control, whereas highest reduction percentage in thrips population was recorded at 7 d after treatment (Table 5). At 7th day after third treatment application of IPM module, M-5 recorded highest mortality (78.11%) in thrips population followed by M-7 (77.33%) and both were on par with each other. The next effective IPM module was M-3 reduced 73.70% thrips population and on par with IPM module M-4 reduced 71.45 % thrips population. IPM module M-1 was found least effective in management of thrips on cumin followed by M-2 and M-6. In fourth application, all IPM modules consistently showed higher per cent reduction in thrips population than the control and IPM modules M-5 at 1, 3, and 7 d after treatment, reduced 69.22, 75.56 and 91.78% thrips population, respectively and was on par to M-7 at all intervals (Table 5). Other IPM modules were recorded as middle order of effectiveness in management of thrips on cumin field.

Table 5. Field efficacy of third & fourth applications of different IPM modules against thrips on cumin in *rabi* 2019-20

IPM module	PTC	Per cent mortality in thrips population				Per cent mortality of thrips population				B:C Ratio
		IIIrd Application				IVth Application				
		1 DAT	3 DAT	7 DAT	10 DAT	1 DAT	3 DAT	7 DAT	10 DAT	
M_1	8.4	49.28 (44.57)^{c}	55.98 (48.44)^{c}	57.54 (49.32)^{d}	48.66 (44.21)^{c}	53.09 (46.75)^{b}	62.59 (52.28)^{e}	69.42 (56.42)^{c}	65.24 (53.86)^{d}	1.71
M_2	10	50.93 (45.51)^{bc}	56.59 (48.77)^{bc}	62.57 (52.26)^{cd}	51.40 (45.78)^{c}	54.21 (47.39)^{b}	64.45 (53.38)^{de}	70.56 (57.14)^{c}	66.29 (54.5)^{d}	1.47
M_3	5	54.29 (47.45)^{b}	63.30 (52.75)^{abc}	73.70 (59.14)^{ab}	62.30 (52.12)^{b}	68.30 (55.72)^{a}	71.70 (57.85)^{ab}	84.70 (67.00)^{b}	72.75 (58.51)^{abc}	2.42
M_4	6.8	51.78 (46.00)^{bc}	61.18 (51.44)^{abc}	71.65 (57.82)^{b}	53.73 (47.12)^{c}	66.82 (54.81)^{a}	70.39 (57.02)^{bc}	82.76 (65.45)^{b}	70.12 (56.84)^{bcd}	2.05
M_5	3.6	59.22 (50.32)^{a}	68.11 (55.68)^{a}	78.11 (62.21)^{a}	69.78 (56.67)^{a}	69.22 (56.29)^{a}	75.56 (60.4)^{a}	91.78 (73.52)^{a}	76.78 (61.18)^{a}	3.70
M_6	11	53.04 (46.73)^{b}	58.38 (49.81)^{bc}	64.25 (53.26)^{c}	53.99 (47.27)^{c}	55.40 (48.08)^{b}	67.49 (55.22)^{cd}	71.41 (57.66)^{c}	68.27 (55.7)^{cd}	2.46
M_7	4.4	57.78 (49.47)^{a}	65.22 (53.85)^{ab}	77.33 (61.64)^{a}	67.22 (55.08)^{ab}	68.89 (56.09)^{a}	74.78 (59.83)^{a}	90.22 (71.82)^{a}	73.67 (59.13)^{ab}	3.08
M_8	15.6	0.00 (0.00)^{d}	0.00 (0.00)^{d}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{c}	0.00 (0.00)^{f}	0.00 (0.00)^{d}	0.00 (0.00)^{e}	1.46

*Mean of 15 plants from three replications.

PTC = Pre treatment count; DAT = days after treatment, values in parentheses are angular transformed values.

In PTC, the difference in thrips population between treatments is due to the impact of first & second applications of different IPM modules.

In column, means followed by common letters are not significantly different at ($P \leq 0.05$) by Duncan's Multiple Range test (DMRT).

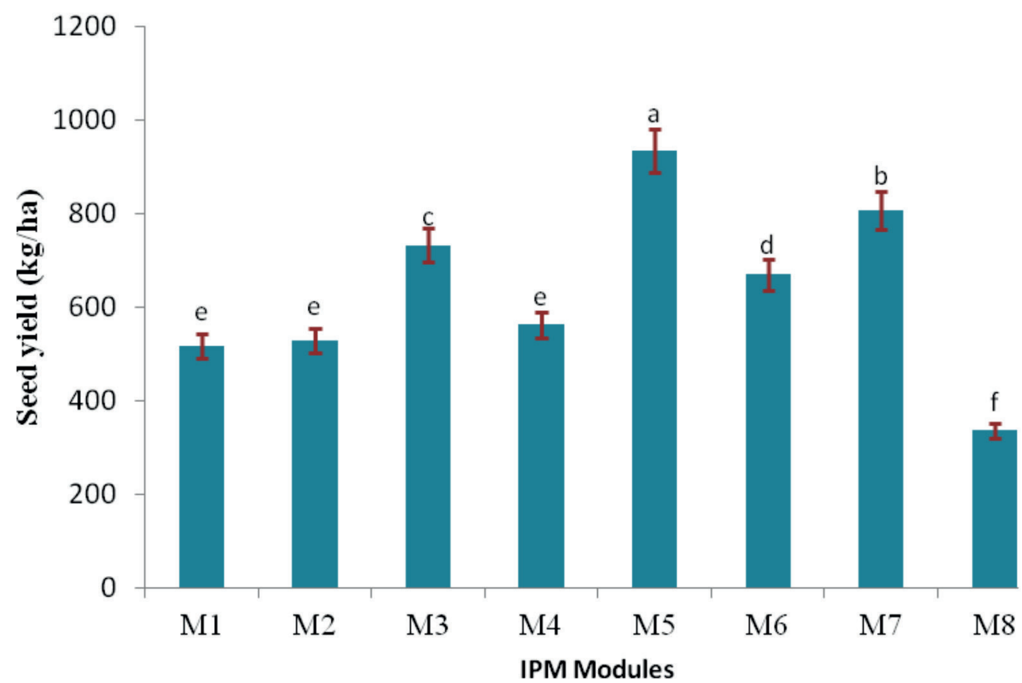

Fig. 1. Cumin seed yield in field efficacy treatments in rabi season (two year pooled)

Yield and Economics

Based on two years study pooled data of 2018-19 and 2019-20, it was found that all IPM modules were performed better in the management of thrips on cumin under field conditions. The seed yield cumin was harvested significantly higher in all IPM modules over untreated control (Fig. 1). M-5 recorded the higher seed yield of 935 kg per ha, which was significantly superior over rest of the IPM modules. The next most effective IPM module was M-7 which recorded cumin seed yield of 807 kg per ha and this IPM module was significantly superior over rest of the module and rated as second best effective module against thrips. The next efficient IPM modules were M-3 and M-6 recorded 732 and 671 kg per hectare with significant yield difference. The untreated control recorded the lowest 337 kg per ha seed yield (Fig. 1). The most effective and deliverable IPM module M-5 was also validated at farmers field for the management of insects including thrips on cumin variety GC-4 and it was found at farmers field that the IPM module enhanced the seed yield of cumin 21.19 per cent over farmers insect management practices.

The loss assessment due to thrips and economics of IPM modules was worked out and data presented in Fig.1 revealed that the highest yield 598 kg/ha was recorded in IPM module M-5 followed by M-7 (470 kg/ha). The highest B: C ratio 3.70 was also obtained in M-5 followed by M-7 and M-3 (3.08 and 2.42).

CONCLUSION

It is concluded from the study that IPM module consisting seed treatment with imidacloprid 600FS @ 3ml/kg seed at followed by foliar applications of *ker* plant extract @ 10ml/lit + *Lecanicillium lecani* (1x108cfu/g) @ 6g/lit. + fipronil 5%SC @ 0.035% at 35, 50 and 65 d after germination, significantly reduced thrips population on cumin in semi-arid region. This module also recorded highest seed yield (935 kg/ha) and B: C ratio. It was also provided effective over farmers management practices, validated the technology at farmers field.

ACKNOWLEDGEMENT

The authors are grateful to the the Director, ICAR-National Research Centre on Seed Spices, Ajmer (Rajasthan), India for providing support and facilities to carried out the research at institute's research fam. We also thank Dr. Balraj Singh, former Director of the institute for his comments on the draft of this manuscript.

REFERENCES

Abang, A.F., Srinivasan, R., Kekeunou, S., Hanna, R., Kamga, R. and Bilong, C.F.B. 2018. Influence of okra (*Abelmoschus* spp.) accessions on colonization by *Aphis gossypii* (Hemiptera: Aphididae) and their effects on aphid biological parameters. *Florida Entomologist*, **101** (4): 549-558.

Abott, W.S. 1925. A method of computing the effectiveness of insecticides. *Journal of Economic Entomology,* **18:** 265- 267.

Anonymous. 2021. Spices: area, production and productivity in India. Directorate of Arecanut and Spices Development (GOI), Calicut, Kerala.

Anusha, C.H., Balikai, R.A. and Patil, R.H. 2016. Insect pest of cowpea and their management- A review. *Journal of Experimental Zoology India*, **19** (2): 635-642.

De, M.L., De, F.V., Fratianni, F. and Nazzaro, F.2009. Chemistry, antioxidant, antibacterial and antifungal activities of volatile oils and their components. *Natural Product Communications,* **4**: 1741-50.

EPPO. 2021. EPPO global database. In: EPPO global database, Paris, France: EPPO. http://gd.eppo.int/

Javed, K., Javed, H., Mukhtar, T. and Qiu, D. 2019. Pathogenicity of some entomopathogenic fungal strains to green peach aphid, *Myzus persicae* Sulzer (Homoptera: Aphididae). *Egyptian Journal of Biological Pest Control,* **29** (1): 1-7.

Kant, K., Meena, S.R. and Kumar, V. 2015. First report of diversity of thrips species on seed spice crops. ICAR-NRCSS, Ajmer, *E-Newsletter*, **7** (6): 5.

Meena, L. K. and Raju, S.V.S. 2014. Bioefficacy of insecticides ag`ainst whitefly and leafhoppers of tomato under field conditions. *Annals of Plant Protection Sciences,* **22**: 14-17.

Meena, N.K. and Kumar, A. 2011. Field evaluation of alphacypermethrin (10%SC) against insect pests of okra and their phytotoxic effect on plants. *Indian Journal of Applied Entomology,* **25** (2): 139-143.

Meena, N.K., Lal, G., Kant, K., Meena, R.S. and Meena, S.R. 2018. Pest scenario of cumin (*Cuminum cyminum* L.) and population dynamics in semi-arid region of Rajasthan. *International Journal of Seed Spices,* **8** (1): 80-83.

Meena, N.K., Lal, G., Meena, S.S., Kant, K. and Meena, R.D. 2019. Screening of coriander varieties/entries for their relative susceptibility against aphids under field conditions. *Journal of Horticultural Sciences,* **14** (2): 39-43.

Meena, N.K., Singh, B., Lal, G., Kant, K. and Meena, R.D. 2016. Sustainable management of aphid in coriander (*Coriandrum sativum* L.) through botanicals and bio-pesticides. *International Journal of Seed Spices,* **6** (1): 25-31.

Meena, M.D. Lal, G., Meena S.S. and Meena N.K. 2018. Production and export performances of major seed spices in India during pre and post-WTO period. *International Journal of Seed Spices,* **8** (1): 21-30.

Meena, N.K., Lal, G., Meena, R.D. and Choudhary, M.K. 2019. Field evaluation of IPM modules for thrips management in fennel under integrated organic farming system. *International Journal of Seed Spices*, **9** (1):85-90.

Meena, N.K., Lal, G., Meena, R.S., Harisha, C.B. and Meena, S.R. 2017. Pest scenario of coriander (*Coriandrum sativum* L.) and population dynamics in semi-arid region of Rajasthan. *International Journal of Tropical Agriculture*, **35** (4): 779-783.

Men, U.B., Thakare, A.Y. and Deshmukh, S.D. 2005. Management of *Bemisia tabaci* Genn. and *Scirtothrips dorsalis* Hood on rabi summer sunflower with herbals and chemicals. *Crop Protection and Production,* **1** (2): 148.

Nakahara, S. 1997. Annotated list of the *Frankliniella* species of the world (Thysanoptera: Thripidae). *Contribution on Entomology International*, **2** (3/4): 355-389.

Nalini, N., Sabitha, K., Vishwanathan, P. and Menon, V.P. 1998. Influence of spices on the bacterial (enzyme) activity in experimental colon cancer. *Journal of Ethnopharmacology,* 62: 15-24.

Palmer, J. M. 1990. Identification of the common thrips of tropical Africa (Thysanoptera: Insecta). *Tropical Pest Management*, **36**: 27-49.

Sujatha, B. and Bharpoda, T.M. 2017. Evaluation of insecticides against sucking pests in greengram grown during kharif. *International Journal of Current Microbiology and Applied Sciences,* **6** (10): 1258-1268.

Torkey, H.M., Abou-Yousef, H.M., Abdel-Azeiz, A.Z. and Hoda, E.A.F. 2009. Insecticidal effect of Cucurbitacin E glycoside isolated from *Citrullus colocynthis* against *Aphis craccivora*. *Australian Journal of Basic and Applied Science,* **3**: 4060-4066.

Upadhyay, R.K. 2012. Insecticidal properties of kareel plant (*Capparis decidua*: Capparidaceae) a desert shrub: A review. *World Journal of Zoology,* **8** (1): 75-93.

Upadhyay, R.K. 2013. Kareel plant: A natural source of medicines and nutrients. *International Journal of Green Pharmacy,* **5**: 255-265.

MS Received 18 October 2021
MS Accepted 21 November 2021