Crop diversification for sustainable management of bud worm *Hendecasis duplifascialis* Hampson of jasmine (*Jasminum sambac* L.)

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ABSTRACT: A field trial was conducted to study the influence of crop diversification through intercropping on the incidence of jasmine budworm, *Hendecasis duplifascialis*. The results revealed that there was significant reduction in incidence of the pest in intercropped treatments over monocrop of jasmine. Marigold recorded significantly the lowest mean incidence of 15.21 per cent, followed by coriander (16.40 per cent) and gingelly (16.69 per cent)with jasmine as sole crop recorded highest budworm incidence (22.17 per cent). The population of natural enemies *viz.,*coccinellids, chrysopids, preying mantises and spiders were more recorded in marigold intercropped jasmine with 8.70, 3.60, 4.40 and 5.30 no's/five plantsrespectively. Moreover, the emergence of the larval parasitoids, *Bracon brevicornis* (3.10 no's/five plants) and *Phanerotoma hendecasiella* (2.60 no's/ 50 infested buds) were more encountered in jasmine intercropped with marigold than sole jasmine crop. The pest defender ratio was highest in jasmine + marigold (1:3.50) and the order falls as jasmine + coriander (1:3.05) and jasmine + gingelly (1:2.34).The data indicated the supremacy of marigold in reducing the incidence of the jasmine budworm as well as attracting more natural enemy population, bagging the credit of eco-feast crop

Keywords: Jasmine, bud worm, *Hendecasis*

INTRODUCTION

Jasmine (*Jasminum sambac* L.) is traditionally as well as commercially cultivated for its sweet-scented flowers all over the world. Globally, jasmine is celebrated in many countries as their national flower and utilized as decoration for ceremonies and rituals as an important part of cultural heritage. Flowers and un opened buds are used for making garlands, bouquets, in religious and ceremonial functions, perfumed hair oils, attars, soaps, wine and drinks (Thakur *et al.,* 2014).The area and production of total flowers in India were increasing impressively over the years. The world production of jasmine concrete is around 20 tonnes per annum, out of which India is producing and exporting about 2 tonnes (Ray *et al.,* 2014). The largest area under jasmine cultivation is in Tamil Nadu and Karnataka from where it is distributed to metropolitan cities (Nimisha and Razia, 2014). Among the various pests recorded in jasmine, the bud worm, *Hendecasis duplifascialis* Hampson (Lepidoptera: Pyraustidae) pose serious threat to flower production, causing damage to a tune of 40-50 % and attributes to a yield loss of 30-70 % (Gunasekaran, 1989). The budworm, *H. duplifascialis* larva bores into closed immature buds and feed on the inner floral structures during initial stage. It makes a circular hole on the corolla tube, emerges and tunnels to move into other buds of the same shoot. Infested flowers turn pinkish violet in colour and fall off. In case of severe infestation, adjacent flower buds are webbed together by means of silken threads and feed on petals also. As these tiny larvae feed on flower buds, the marketable quality of the flowers is greatly reduced (Plate 1).

Jasmine growers completely rely on synthetic chemicals in managing jasmine budworm. In search of safer alternatives to chemicals considering their negative impacts, attention has been focused on exploration of diversified cropping system approaches, which is based on the principle of reducing pest incidence by increasing natural enemy activity through diversifying crop ecosystem. Diversification in agriculture is defined as diversion of a sizable acreage from the existing crop system to some alternative crops or cropping systems or farm enterprises (Halegundegowda, 2015). Intercropping is the agronomic practice of growing two or more crops in the same field at the same time. It is growing of two or more crops in close proximity to promote beneficial interactions between them (Andrews and Kassam, 1976). Intercropping is found to bring reduction of pest populations in the main crop principally in three ways, by delaying the onset of pest incidence, by inhibiting pest build up above ETL and finally increasing the abundance of natural enemies.

Table 1. Incidence of budworm, *Hendecasis duplifascialis* in jasmine ecosystem as influenced by intercrops

Intercropping system	Percent incidence						Mean	PROC
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS		
Jasmine + Cowpea	23.41(4.83)	19.15(4.37)^{bc}	16.36 (4.04)^{bc}	15.27 (3.90)^{bc}	14.23 (3.77)^{bc}	17.68(4.20)^{bc}	17.68(4.20)^{bc}	20.25
Jasmine + Black gram	25.31(5.02)	21.47(4.62)^{ab}	17.45 (4.17)^{abc}	16.17 (4.01)^{bc}	14.23 (3.76)^{bc}	17.36(4.16)^{bc}	18.67(4.31)^{abc}	15.78
Jasmine + Cluster bean	27.32(5.22)	20.56(4.53)^{ab}	12.47 (3.53)^{de}	14.26 (3.77)^{bc}	15.68 (3.96)^{b}	17.39(4.17)^{bc}	17.95(4.23)^{b}	20.38
Jasmine + Coriander	26.2 (5.11)	20.3 (4.50)^{abc}	15.17(3.89)^{bcd}	13.25 (3.63)^{bc}	11.36 (3.36)^{bd}	12.12(3.48)^{d}	16.40(4.04)^{bc}	21.69
Jasmine + Fenugreek	30.17(5.49)	23.4 (4.84)^{a}	16.52 (4.06)^{bc}	13.14 (3.62)^{bc}	14.69 (3.83)^{bc}	17.23(4.15)^{bc}	19.19(4.38)^{abc}	13.44
Jasmine + Gingelly	28.41(5.33)	16.69(4.08)^{cd}	12.36 (3.51)^{de}	13.47 (3.67)^{bc}	14.69 (3.83)^{bc}	14.52(3.81)^{cd}	16.69(4.08)^{bc}	24.71
Jasmine + Fennel	27.36(5.22)	24.36 (4.93)^{a}	19.36 (4.39)^{ab}	14.52 (3.81)^{bc}	13.58 (3.68)^{bcd}	16.39(4.04)^{bc}	19.26(4.38)^{ab}	13.12
Jasmine + Onion	23.78(4.87)	18.36(4.28)^{bcd}	14.52 (3.80)^{cd}	12.69 (3.56)^{c}	14.27 (3.77)^{bc}	18.96(4.35)^{b}	17.10(4.13)^{bc}	22.86
Jasmine + Marigold	24.37(4.85)	15.36(3.91)^{d}	11.34 (3.36)^{e}	13.23 (3.63)^{bc}	12.57 (3.54)^{cd}	14.36(3.78)^{cd}	15.21(3.89)^{c}	31.39
Jasmine sole crop	21.41(4.70)	23.45(4.83)^{a}	20.47 (4.52)^{a}	23.56 (4.84)^{a}	20.47 (4.52)^{a}	23.65(4.853)^{a}	22.17(4.70)^{a}	
	NS	NS	0.2123 0.4460	0.1903 0.3998	0.1873 0.3936	0.1819 0.3821	0.1993 0.4188	0.2013 0.4229

NS-Non significant; *Mean of three replications, DAS- Days after sowing;
Figures in parentheses are square root transformed values.
In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Farooq *et al.* (2011) indicated that some plants contained organic substances that act as pest repellent which keeps insects away from the crops and avoid potential damage. Diverse nature of plants not only obstructs the adults from egg laying but also the release of volatile allelochemicals from a crop deters the adult insect from damaging the crops. Intercropping is one of the important cultural practices in pest management for reducing insect pests by increasing the diversity of an eco-system (Altieri and Letourneau, 1982). Lakshminarayanan *et al.* (2005) investigated the intercropping of leguminous vegetables in a pruned field of jasmine (*Jasminum sambac* L.) and indicated that intercropping pruned jasmine with double rows of vegetable cowpea (*Vignaunguiculata*) fetched the highest equivalent yield of jasmine (5, 393 Kg ha^{-1}) land equivalent ratio (1.99), net returns (Rs. 1, 44,113 ha^{-1}) and benefit-cost ratio (3:1) with minimal pest incidence. Anburani and Priyadharshini (2011) explored the intercropping system with mullai (*Jasminum auriculatum*) and recorded the highest number of productive shoots per plant, flower yield per plant, flower yield per hectare and profitability in the mullai intercropped with cowpea trial and recorded minimum incidence of pests. Intercropping in jasmine ecosystem for pest management has not been experimented yet.Therefore, the present study was under taken to explore and assess the influence of intercropping on the infestation of jasmine bud worm and the occurrence of natural enemies.

MATERIALS AND METHODS

A field experiment was conducted during July-November, 2015 at farmer's holding in Manjampati, Madurai. The experiment was carried out in a randomized block design (RBD) and each treatment was replicated thrice. Seeds of the intercrops were sown in a young jasmine plantation of two-year-old crop. All the standard package of practices recommended for the crops was followed except plant protection measures. Nine intercropping systems were evaluated as detailed below:

1. Jasmine + Cowpea (*Vigna unguiculata* L.) (Co 2)
2. Jasmine + Black gram (*Vigna mungo* L.)(Local)
3. Jasmine + Cluster bean (*Cymopsis tetragonolaba* L.) (Local)
4. Jasmine + Coriander (*Coriandrum sativum*) (Local)
5. Jasmine + Fenugreek (*Trigonella foenumgraecum* L.) (Local)
6. Jasmine + Gingelly (*Sesamum indicum* L.) (Local)
7. Jasmine + Fennel (*Foeniculum vulgare* L.) (Local)
8. Jasmine + Onion (*Allium cepa* L.) (Local)
9. Jasmine + Marigold (*Tagetes erecta* L.) (Local)
10. Jasmine pure crop

The intercropping system was planted at 4:1 ratio with recommended spacing (Sujayanand*et al.,* 2015). Observations on per cent infestation of jasmine bud worm, *H. duplifascialis* and its their natural enemies in five randomly selected jasmine plants in each intercropping system and jasmine pure crop were recorded from flowering stage at ten days interval.

Pest: Defender ratio (P: D ratio)

The defender to pest ratio per cropping system was calculated for each plot by dividing the total number of defenders per cropping system by the total number of pests per cropping system. Total number of pests and natural enemies observed by sweep net and in situ counts was used for estimating P: D ratio (Lokesh *et al.,* 2017)

RESULTS AND DISCUSSION

Intercropping is one of the important cultural practices in pest management for reducing insect pests by increasing the diversity of an eco-system (Altieri and Letourneau, 1982).

Incidence of budworm in intercropping system

The crop diversification studies in jasmine ecosystem revealed that the incidence of *H. duplifascialis*, was significantly lower with a mean incidence of 15.21 per centin jasmine intercropped with marigold (4:1), whereas jasmine as sole crop recorded highest budworm incidence (22.17 per cent) (Table 1). The per cent incidence recorded in jasmine intercropped with marigold were 24.37, 15.36, 11.34, 13.23, 12.57 and 14.36 per cent on 20, 30, 40, 50, 60 and 70 days after sowing. The intercrop with more efficacies falling next in the order was coriander recording 26.2, 20.3, 15.17, 13.25, 11.36 and 12.12 per cent incidence with a mean incidence of 16.40 per cent. Sesamum crop intercropped in jasmine field also had potential in minimizing jasmine budworm incidence recording 28.41, 16.69, 12.36, 13.47, 14.69 and 14.52 per cent incidence with a mean incidence of 16.69 per cent. Among the intercrops examined, jasmine + fennel recorded maximum jasmine budworm incidence (19.26 per cent), followed by jasmine + fenugreek (19.19 percent) indicating their poor efficiency in repelling the pest (Fig 1).

Table 2. Incidence of natural enemies in jasmine ecosystem as influenced by intercrops

Intercropping system	No./ five plants					No. emerged from 50 infested buds
	Coccinellids	Chrysopids	Preying mantises	Spiders	*Bracon brevicornis*	*Phaneratoma hendeicasiella*
Jasmine + Cowpea	7.50(2.73)^{b}	1.30(1.14)^{d}	3.70(1.92)^{cd}	4.90 (2.21)^{ab}	1.50 (1.22)^{cd}	1.50(1.22)^{e}
Jasmine + Black gram	4.60 (2.14)^{d}	1.40 (1.18)^{d}	3.30 (1.81)^{fg}	4.40 (2.09)^{b}	1.60 (1.32)^{cd}	2.10(1.45)^{cd}
Jasmine + Cluster bean	3.70 (1.92)^{e}	1.70(1.30)^{c}	3.10(1.76)^{ef}	4.50 (2.12)^{ab}	1.80 (1.47)^{c}	2.10(1.45)^{cd}
Jasmine + Coriander	4.90 (2.21)^{d}	3.50(1.87)^{a}	3.50 (1.87)^{de}	4.80 (2.19)^{ab}	2.60 (1.61)^{ab}	2.30(1.51)^{b}
Jasmine + Fenugreek	4.90(2.21)^{d}	1.90 (1.38)^{c}	2.90 (1.70)^{g}	4.90 (2.21)^{ab}	1.30 (1.14)^{d}	1.80(1.34)^{c}
Jasmine + Gingelly	3.60(1.89)^{e}	2.50(1.58)^{ab}	4.20 (2.05)^{b}	5.40 (2.32)^{a}	2.20 (1.49)^{bc}	2.30(1.51)^{b}
Jasmine + Fennel	3.20 (1.79)^{f}	1.30(1.14)^{d}	2.70 (1.64)^{g}	4.30 (2.07)^{b}	1.20 (1.06)^{d}	1.60(1.26)^{cd}
Jasmine + Onion	6.10 (2.47)^{c}	2.30(1.51)^{ab}	3.90 (1.97)^{bc}	5.10 (2.25)^{ab}	2.40 (1.55)^{b}	2.40 (1.55)^{b}
Jasmine + Marigold	8.70 (2.95)^{a}	3.60(1.90)^{a}	4.40(2.10)^{a}	5.30 (2.30)^{a}	3.10 (1.74)^{a}	2.60(1.61)^{a}
Jasmine sole crop	1.10(1.05)^{e}	0.20 (0.45)^{f}	0.20 (0.45)^{h}	1.30 (1.14)^{c}	1.10(1.05)^{e}	1.20(1.09)^{a}
	0.1032 0.2169	0.0819 0.1722	0.0622 0.1306	0.0972 0.2043	0.0745 0.2147	0.0777 0.1632

*Mean of three replications, DAS: Days after sowing ;Figures in parentheses are square root transformed values. In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05

Incidence of natural enemies in intercropping system

Impact of intercrops on coccinellid population:

The mean population of coccinellids (*Cheilomenes sexmaculatus*, *Coccinella transversalis*, *Brumus sutularis, Scymnus* sp.,) in various intercropping systems ranged from 8.70 nos./5 plants (jasmine + marigold) to 3.2 nos./5 plants (jasmine + fennel) (Table 2) while it was 1.10 nos./5 plants in jasmine pure crop. The mean population of coccinellids was higher (from 8.70 nos./5 plants) in jasmine intercropped with marigold which was on par statistically with jasmine + cowpea (7.50 nos./5 plants). Jasmine intercropped with fennel, gingelly and cluster bean recorded least coccinellid population (3.2, 3.6, 3.7 no's/ 5 plants) (Plate 2).

Impact of intercrops on *Chrysoperla zastrowisillemi* (Esben-Peterson) population:

Jasmine intercropped with marigold recorded the highest mean population of *C. zastrowi sillemi* (3.60 nos./5 plants), followed by jasmine + coriander (3.50 nos./5 plants) which was on par with jasmine intercropped with gingelly (2.50 no's./5 plants) and onion (2.30 no's/5 plants) (Table 2). The *C. zastrowi sillemi* mean population of 1.30 no's/5 plants were recorded in jasmine intercropped with fennel and cowpeas, respectively, while it was 0.20 no's/5 plants in jasmine pure crop recording the least incidence.

Impact of intercrops on preying mantis population:

The mean population of preying mantises was highest in jasmine intercropped with marigold (4.40 no,s /5 plants) followed by jasmine intercropped with gingelly, onion and cowpea registering 4.20, 3.90 and 3.70 no's / 5 plants as against 0.20 no's/ 5 plants in jasmine sole crop (Table 2).

Impact of intercrops on spider population:

Jasmine intercropped with marigold recorded maximum spider population of (5.30 no's/5 plants), but there was no significant difference noticed among various intercropping systems on spider population, with the least population being recorded in jasmine sole crop (1.30no's / 5 plants) (Table 2).

Impact of intercrops on the larval parasitoid, *Bracon brevicornis* population:

The mean emergence of the larval parasitoid, *Braconbrevicornis* from pupae collected from jasmine intercropped with marigold and coriander were 3.10 and 2.60 no's / five plants, registering the maximum population as against 1.10 parasitoids from five plants in jasmine sole crop (Table 2). Jasmine intercropped with fennel and fenugreek (1.20 and 1.30 no's / five plants) registered the least parsitoid emergence among the intercrops examined (Fig 2)

Impact of intercrops on the larval parasitoid, *Phanerotoma hendecasiella* population:

Among all the nine intercrops evaluated, jasmine intercropped with marigold recorded maximum parasitoid emergence of 2.60 no's / 50 infested buds.There was no significant difference observed among various intercropping systems on the emergence of parasitoid population, with the least population being recorded in jasmine sole crop (1.20 no's / 50 infested buds) (Table 2).

Pest Defender Ratio

The total number of pests (all the insects and mites with the potential to damage the plant) and natural enemies (all the natural enemies observed including coccinellids, chrysopids, preying mantises, spiders, *Systasis dasyneurae,* Geocoris bugs, larval parasitoids, *Bracon brevicornis, Phanerotoma hendecasiella*) were recorded in all the jasmine based intercropping systems and pest defender ratio was worked out.

The highest population of pests was recorded in jasmine intercropped with fenugreek, blackgram and cowpea (11.33, 9.33 and 7.33 no's / 5 plants). The least population of pests in intercrops was observed in fenugreek and coriander (no pest) and highest in jasmine intercropped with cowpea and blackgram (5.33 and 4.66 no's/ 5 plants) (Table 3).

The total number of pests in jasmine and intercrops was more in jasmine + cowpea and jasmine + fennel intercropping system, recording 13.33 no's/ 5 plants and the least number being in jasmine + marigold, jasmine + onion and jasmine + gingelly (5.99, 6.33 and 9.33 no's/ 5 plants). Among all the nine intercrops evaluated, the total natural enemy population was more in jasmine + marigold (20.99 no's/ 5 plants), followed by jasmine + clusterbean (18.99 no's/ 5 plants) and jasmine + gingelly (18.66 no's / 5 plants). The pest defender ratio was highest in jasmine + marigold (1:3.50) and the order falls as jasmine + coriander (1:3.05) and jasmine + gingelly (1:2.34). The ratio was least recorded in jasmine + fennel (1:1.02) and jasmine + fenugreek (1:1.18) intercropping systems (Fig 3).

Marigold attracted lot of natural enemies and bagged the credit of ecofeast crop. Jasmine intercropped with marigold recorded the highest mean population of

Table 3. Total number of pests and natural enemies in intercropping system

Intercropping system	No./plant						P:D ratio
	Pests in jasmine	Pests in intercrops	Total pests	Natural enemies in jasmine	Natural enemies in intercrops	Total natural enemies(Defenders)	
Jasmine + Cowpea	8.33 (2.70)^{c}	5.33 (2.28)^{d}	13.66(3.69)^{e}	4.33(2.08)^{c}	10.33 (3.21)$_{b}$	14.66 (3.82)^{de}	1:1.07
Jasmine + Black gram	7.33 (2.58)^{bc}	4.66 (2.06)^{d}	11.99 (3.46)^{e}	2.66 (1.63)^{d}	9.66(3.10)^{c}	12.32 (3.50)^{ef}	1:1.03
Jasmine + Cluster bean	6.66 (2.51)^{ab}	1.66 (1.21)^{bc}	8.32 (2.88)^{cd}	5.33(2.31)^{b}	13.66 (3.69)^{a}	18.99 (4.35)^{bc}	1:2.28
Jasmine + Coriander	6.33 (3.05)^{ab}	0.00 (0.00)^{a}	6.33 (2.51)^{ab}	5.66(2.37)^{b}	13.66 (3.69)^{a}	19.32 (4.39)^{ab}	1:3.05
Jasmine + Fenugreek	9.33 (2.58)^{c}	0.00 (0.00)^{a}	9.33 (3.05)^{d}	2.33(1.53)^{d}	8.66(2.94)^{d}	10.99 (3.31)^{f}	1:1.18
Jasmine + Gingelly	6.66 (3.65)^{ab}	1.33 (1.10)^{bc}	7.99 (2.82)^{bcd}	5.33(2.31)^{b}	13.33 (3.65)^{a}	18.66(4.32)^{bc}	1:2.34
Jasmine + Fennel	11.33(3.36)^{d}	0.33 (0.53)^{ab}	13.66 (3.69)^{e}	3.66(1.91)^{cd}	10.33 (3.21)^{b}	13.99 (3.74)^{de}	1:1.02
Jasmine + Onion	6.00 (2.45)^{a}	1.33 (1.19)^{ab}	7.33 (2.70)^{abc}	4.33(2.08)^{bc}	11.33 (3.36)^{b}	15.66(3.95)^{cd}	1:2.14
Jasmine + Marigold	5.33 (2.30)^{a}	0.66 (0.80)^{ab}	5.99 (2.44)^{a}	6.33(2.51)^{a}	14.66 (3.82)^{a}	20.99(4.58)^{ab}	1:3.50
	0.1057 0.2221	0.0866 0.1820	0.1574 0.3307	0.1146 0.2407	0.1585 0.3329	0.1954 0.4106	

**NS: Non significant; **Each value is the mean of three replications, DAS: Days after sowing;Figures in parentheses are square root transformed values. In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

coccinellids (*Cheilomenes sexmaculatus*, *Coccinella transversalis*, *Brumus suturalis, Scymnus* sp., (8.70 no's. / 5 plants), *C. z. sillemi* (3.60 nos./5 plants), preying mantises (4.40 nos /5 plants) and spider population (5.30 nos. /5 plants). The mean emergence of the larval parasitoid, *Bracon brevicornis* from jasmine intercropped with marigold field collected pupa was highest (3.10 no's. / five plants) and similar trend was noticed for the larval parasitoid, *Phanerotoma hendecasiella*(2.60 nos. / 50 infested buds). Among all the nine intercrops evaluated, the total natural enemy population was more in jasmine + marigold (20.99 no's / five plant) recording highest pest defender ratio (1:3.50).

Attraction of predators and parasitoids to diversified cropping system is previously substantiated by several workers. The specific larval parasitoid of bud worm, *Phanerotoma hendecasiella* was more reported in jasmine intercropped with marigold (2.60/ 50 infested buds) followed by onion (2.40/ 50 infested buds) and gingelly (2.30/ 50 infested buds). The larval parasitoid, *Bracon brevicornis* was more recorded in marigold intercropped in jasmine (3.10/five plants) followed by coriander (2.60/ five plants) and onion (2.60/ five plants)

DISCUSSION

Pest outbreaks are rare in polyculture condition due to the ability of the diverse plant culture to self-sustain through natural pest control by increasing the occurrence of natural enemies (Altieri, 1994; Scherr and McNeely, 2008). Polyculture offers alternate prey or hosts and alternate food sources such as pollen and nectar (Root, 1973). Polycultures that support high densities of natural enemies might have increased incidence of predation and parasitization of herbivores. Diverse environmental conditions would provide a greater diversity of habitats and victims to predators and parasitoids through time as well as alternate food sources such as pollen and nectar (Van Emden, 1965), and so sustain more stable populations of natural enemies than monocultures.

The present study identified marigold as the eco-feast crop by reducing budworm incidence and increasing natural enemy population. The present result endorsed the findings of Sujayanand *et al.,* (2015) who reported that intercropping of eggplant with marigold is a successful strategy for reducing the fruit and shoot borer and sucking pest especially jassids and whiteflies. Marigold has shown promising results in companion planting (Hooks *et al.,* 2010). Marigold has demonstrated to behave as natural pest deterrents by secreting the toxic chemical α-terthienyl through their roots and thus fending of surrounding threats (Gommers and Baher, 1988). Additionally, they give off a very pungent odour, which is thought to detract most above ground insects (Parker *et al.,* 2013). Density of phytophagous insects on non-marigold plants were less noticed as being reduced by more than 50 per cent when grown in close proximity to *Tagets patula* (Silveira*et al.,* 2009). Allelochemicals emanated from the intercrop might be responsible to repel the herbivores in jasmine ecosystem, as pointed out by Gomez *et al.* (2003) who reported that volatile allelochemicals are exuded from aerial parts of marigold (*Tagetes erecta* L.). When intercropped with tomato, marigold suppressed, repelled and changed the oviposition behaviour of lepidopteran pests by more than 90 per cent. Allelopathic effect of marigold in pest management was supported by Farooq *et al.* (2011). The findings emerged from the present study is supported by Lakshminarayanan *et al.* (2005) who explicated that raising intercrops in jasmine ecosystem recorded less incidence of pests with additional income in yield.

Intercropping has been reported to reduce insect pest populations due to deterrence in crop fields with increased plant diversity that creates unsuitable habitat or unfavourable environment to pest species (Khan *et al.,* 1997). Intercropping particularly with four row of jasmine to one row of marigold developed less population of sucking and lepidopteran infestations.

The present results are in agreement with the findings of Silveria *et al.* (2009) who reported marigold as a plant that is potentially useful to maintain arthropod biodiversity. Additionally, marigold plants in-between rows of onion crop have been shown to promote the reduction of aphid, nematode and whitefly populations and virus diseased plants (Abidand Magbool, 1990). Moreover, marigold plants host other phytophagous species that are alternative prey for entomophagous species. Some organic growers raise marigold for its pollen and nectar, which increase natural enemy fecundity and survival (Baggen *et al.,* 1999).

Sujayanand *et al.,* (2015) confirmed the results of the present study that marigold in brinjal ecosystem attracted natural enemies and checked the shoot and fruit borer naturally. Kennedy *et al.* (1997) endorsed that intercropping groundnut with pearl millet favoured the predators and parasites of groundnut insect pests. Duffield and Reddy (1997) reported an increased activity of coccinellids and spiders in leguminous intercrops. The migratory nature of ladybird beetles was shown by Lin *et al.* (2003) in China, when cotton intercropped with alfalfa which attracted greater number of ladybird beetles, lacewings and spiders, when alfalfa was cut to force migration of natural enemies to cotton. Hanumantharaya *et al.* (2008) also found that

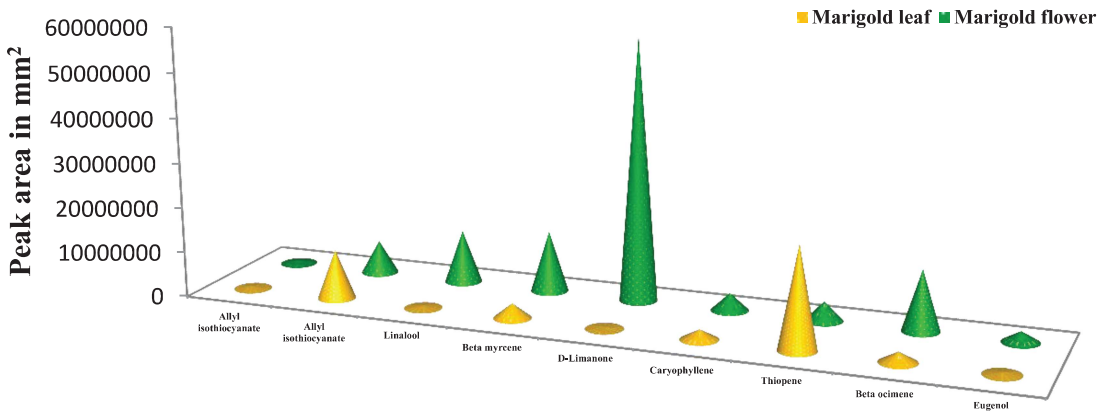

Fig 4a. Comparison of the common hydrocarbons present in marigold *(Tagetus erecta)*

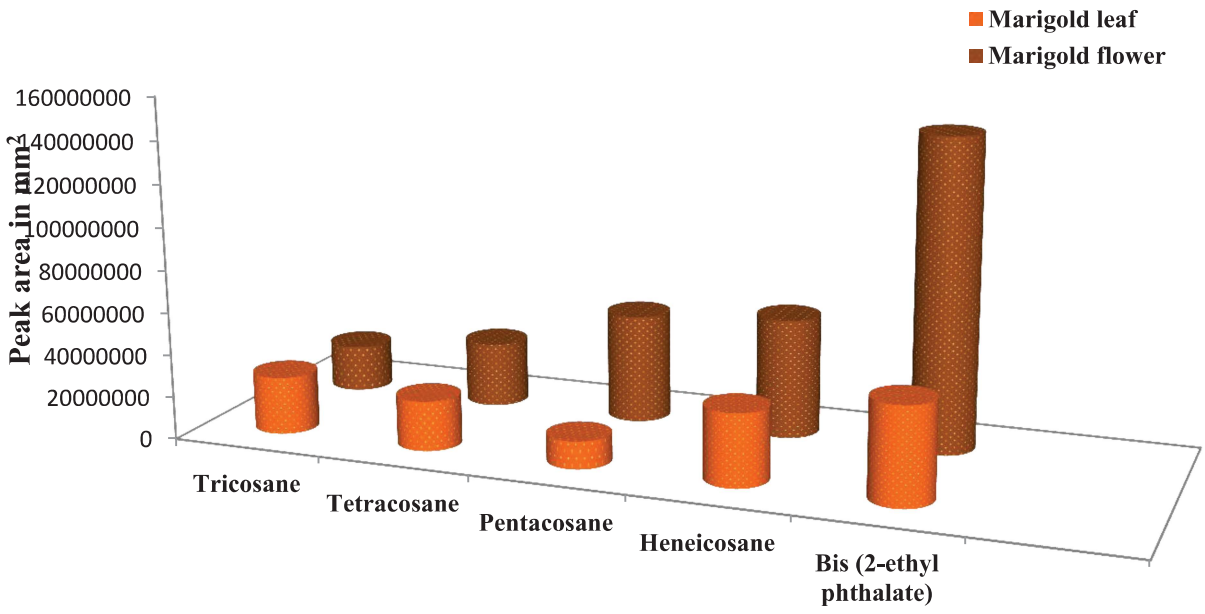

Fig 4b. Comparison of the common hydrocarbons present in marigold *(Tagetus erecta)* flower and leaf

intercrop of cotton with lucerne @ 1:1 ratio increased the effectiveness of green lacewings. A rich diversity in predatory insect and parasitoid species was recorded from intercropping system like groundnut + maize and groundnut + bajra wherein intercrop supplied pollen and nectar as supplementary feed to the natural enemies (Bianchi *et al.,* 2006). This supplementary food resource increases the parasitoid fecundity, longevity (Tylianakis *et al.,* 2004) and also favours rapid colonization of generalist predators (Symondson *et al.,* 2002).

To identify the compounds responsible for the repellence of pests and attraction of natural enemies, the marigold flower and leaf extracts were analyzed in GC-MS. The chemical profile of marigold flower and leaf extracts contributed 43 and 33 compounds respectively. Allylisothiocyanate, linalool, caryophyllene, beta myrcene, tumerone, D-limanone and trans beta ocimene were the compounds of interest present, of which, linalool, beta farnesene, alpha farnesene, allyl isothiocyanate and caryophyllene were present in marigold leaves also. Chemically complex plant volatiles have multiple ecological roles in plant-insect interactions including attracting pollinators, acting as cues for foraging herbivores as well as functioning as direct defense, indirect defense, or interplant priming. Caryophyllene is an active component of marigold flowers and leaves and its potential in attracting two types of herbivore enemies *viz.,* entomopathogenic nematodes and parasitic wasps in maize ecosystem was demonstrated by Kollner *et al.* (2008).The chemical fraction containing (E)-β-caryophyllene attracts egg parasitoid, *Trissolcus basalis* ♀s that parasitizes *Nezara viridula* eggs (Colazza *et al.,* 2004; 2009). Comparing the compounds present in marigold leaves and flowers, 9 compounds were present in common *viz.,*allylisothiocyanate, detected twice, linalool, beta myrcene, L-limanone, caryophyllene, thiopene, beta ocimene, eugenol, tetracosane, tricosane, pentacosane, heneicosane and bis (2 ethyl hexyl phthalate) with quantity in abundance in marigold flowers (Fig 4).

There is an increasing interest in plant volatile compounds and its implications in pest management, as they can directly influence insect behaviour. The study suggested that the plant biodiversity is an important factor that influences the presence of pests as well as natural enemies influencing the former negatively and the latter positively. Thus, habitat manipulations could be used to reduce budworm incidence and conserve natural enemies in jasmine ecosystem.

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