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Evaluation of different insecticides against *Agrotis segetum* (Denis and Schiffermuller) and *Spoladea* (=*Hymenia*) *recurvalis* (Fabricius) on amaranthus

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Abstract: A field experiment was laid out in a randomized block design at the College of Horticulture, University of Horticultural Sciences, Bagalkot, during 2013-14 to study the bio efficacy of different insecticides against *Agrotis segetum* (Denis and Schiffermuller) and *Spoladea* (=*Hymenia*) *recurvalis* (Fabricius) on amaranthus. The experiment consisted of ten treatments, among all the treatments the green labelled or newer molecules *viz.,* emamectin benzoate 5 SG @ 0.25 g/l, indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 1 ml/l were found very effective in minimizing the larval population and superior in reducing foliage damage throughout the period of experiment and also fetched higher yields of 21.67, 21.49 and 20.67 t/ha. The highest incremental cost benefit ratio (93.33) was obtained from the treatment malathion 50 EC @ 2 ml/l.

Key words: Amaranthus, Emamectin benzoate, Fipronil, Indoxacarb

Introduction

There are several species under the genus *Amaranthus* which belongs to the family Amaranthaceae. It has been widely regarded as a stubborn weed or food in many parts of the world. However, for the past one decade, there has been a sharp rise in the demand and consumption of amaranthus (Bosch *et al.,* 2009). This can be attributed to increased awareness about the importance as a valuable source of food, medicine and income for all small-scale farmers (Ouma, 2004). Popularity of the many leafy vegetables particularly amaranthus is due to early maturity, palatability and high nutritive value, as this is a good source of vitamins and minerals, being exceptionally rich in calcium, magnesium, iron, phosphorus, â-carotene and folic acid containing higher grain protein (13-19%), with high lysine (6.09/100 g protein) and other sulphur containing amino acids (4.4%) which are limiting factors in the conventional food grains. Hence, daily inclusion of grain amaranth in the diet of children can help to alleviate the blood haemoglobin level. Amaranth grain contains 6 to 10 per cent oil, which is found in the germ. Predominantly, it is unsaturated oil (76%) and linoleic acid are in high quantity, which are very much essential for human nutrition. Therefore, the regular consumption of amaranthus reduces the blood pressure, cholesterol levels and improves the body's antioxidant status and immunity (Martirosyan *et al.,* 2007). Amaranthus is a crop with multiple uses; its tender leaves are used as vegetable, while grain is being used in different culinary preparation and elaborately in various bakery products and lysine rich baby foods. It has great potential for application in high quality plastics, cosmetics, pharmaceuticals and natural dyes.

Material and methods

The experiment was conducted in field at Udyanagiri campus of College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India during summer season of 2014, to evaluate the efficacy of different insecticides, bio-pesticides and botanical against defoliators on amaranthus. Amaranthus variety, Green Rajagira was used for this experiment. The package of practices for crop management was followed as prescribed by the University of Horticultural Sciences, Bagalkot (Anon., 2013). The experiment was laid out in randomized block design consisting of eleven treatments replicated thrice. Each plot size was about 2 x 2 m. First spray was given on 25th day after sowing of seeds and second spray on 35th day after sowing by using knapsack sprayer. Pre-treatment count of larvae was made prior to the spray. The post treatment counts were made at one, three, five and seven days after each spray. Observations were made on number of larvae per plant and the per cent foliage damage. For recording larval population, ten plants were selected randomly in each treatment and average per plant was worked out. Similarly, percentage of foliage damage was recorded by using visual grades (0 to 5) before and after spray. Data obtained from various studies were subjected to either arc sine or square root transformation as the case may be before suitable statistical analysis using WASP statistical software. Data pertaining to management trial were analyzed by using one way ANOVA and treatment means were separated by using DMRT.

Results and discussion

Synthetic insecticides, botanicals and bio-pesticides were evaluated against defoliators on amaranthus. The larval population was uniform before imposing the treatments throughout the experimental field as indicated by non significant ANOVA (F-test). The larval population ranged from 0.93 to 1.89 larvae per plant before spray and the per cent foliage damage ranged from 8.00 to 10.33 and there was no significant difference between the treatments.

A day after first spray, all the treatments were found to be superior over untreated control. Significantly less larval population was recorded in the treatment fipronil 5 SC @ 1 ml/l (0.50 larvae/plant) and it was on par with indoxacarb 15.8 EC @ 0.25 ml/l (0.60 larvae/plant) followed by emamectin benzoate 5 SG @ 0.25 g/l, dichlorvos 76 EC @ 0.5 ml/l, malathion 50 EC @

2 ml/l and *Beauveria bassiania* @ 2 g/l (0.73, 0.97, 1.13 and 1.17 larvae/plant, respectively). Maximum number of larval population was recorded in the treatment, Neem seed kernel extract (NSKE) @ 5% (2.73 larvae/plant) which was on par with untreated control (2.87 larvae/ plant) (Table 1). Similar trend was noticed with respect to per cent foliage damage. Fipronil 5 SC @ 1 ml/l was found to be significantly superior over all other treatments by recording least per cent foliage damage (2.67%) and it was on par with indoxacarb 15.8 EC @ 0.25 ml/l (3.00 %) and emamectin benzoate 5 SG @ 0.25 g/l (4. 67%). Foliage damage was high in the treatments *viz.,* deltamethrin 2. 8 EC @ 0.5 ml/l and *B. bassiana* @ 2 g/l (14.33 and 14.67%, respectively) being at par with untreated control (21.67% foliage damage) (Table 2).

After three days of first spray, once again treatment with emamectin benzoate 5 SG @ 0.25 g/l, registered superiority over all other treatments recording 0.23 larvae per plant and it was at par with fipronil 5 SC @ 0.25 ml/l and indoxacarb 15.8 EC @ 0.25 ml/l (0.47 and 0.48 larvae/plant, respectively). While *B. bassiana* @ 2.0 g/l recorded 1.10 larvae per plant followed by NSKE @ 5% (0.93 larvae/plant) and untreated control (1.73 larvae/plant). Fipronil 5 SC @ 0.25 ml/l was found to be significantly superior over all other treatments by recording least (3.67%) foliage damage and it was on par with indoxacarb 15.8 EC @ 0.25 ml/l (4.00 %). Treatments like azadirachtin 1500 ppm @ 3 ml/l, *Bacillus thururingiensis* @ 2 g/l and dichlorvos 76 EC @ 0.5 ml/l (8.67, 10. 67 and 10.67% foliage damage/plant, respectively) were on par with each other. *B. bassiana* @ 2.0 g/l as recorded highest 14.67 per cent foliage damage and it was at par with untreated control (21.67%).

Indoxacarb 15.8 EC @ 0.25 ml/l was found to be superior in recording the less larval population (0.67 larvae/plant) at five days after first spray and it was on par with fipronil 5 SC @ 0.25 ml/l and emamectin benzoate 5 SG @ 0.25 g/l (0.77 and 1.07 larvae/plant, respectively). NSKE @ 5% was significantly inferior treatment compared to the other treatments by recording maximum of 2.33 larvae per plant, which was at par with deltamethrin 2.8 EC @ 0.5 ml/l, azadirachtin 1500 ppm @ 3 ml/l, dichlorvos 76 EC @ 0.5 ml/l, malathion 50 EC @ 2.0 ml/l and *B. bassiana* @ 2.0 g/l (1.73, 1.47, 1.37, 1.33, 1.27 and 1.17 larvae/ plant, respectively). Similar trend was noticed with respect to per cent foliage damage. Indoxacarb 15.8 EC @ 0.25 ml/l recorded the minimum per cent foliage damage (9.00%) and was on par with emamectin benzoate 5 SG @ 0.25 g/l and fipronil 5 SC @ 0.25 ml/l both recording 12.33 percentage of foliage damage. Significantly maximum damage (23.00%) was recorded in the treatment of *B. bassiana* @ 2.0 g/l and dichlorvos 76 EC @ 0.5 ml/l while untreated control recorded 23.67 per cent damage being at par (Table 2).

At seven days after first spray, emamectin benzoate 5 SG @ 0.25 g/l recorded significantly less number of larval population (1.00 larvae/plant) on par with indoxacarb 15.8 EC @ 0.25 ml/l (1.30 larvae/plant) and fipronil 5 SC @ 0.25 ml/l (1.87 larvae/ plant). While, significantly higher (4.47) number of larvae per

Table 1. Bio-efficacy of different synthetic insecticides, botanicals and bio- pesticides against defoliators * on amaranthus during 2013-14

Treatments	Dosage	Day before spray	**Mean number of larvae per plant at different days after spray							
			First spray				Second spray			
			1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS
Neem Seed Kernal Extract	5%	1.17	2.73	0.93	2.33	2.60	1.03	0.83	1.77	1.03
		(1.07)	(1.64)^{a}	(0.97)^{bc}	(1.49)^{ab}	(1.60)^{b}	(1.24)^{bc}	(1.14)^{bc}	(1.48)^{a}	(1.01)^{b}
Azadirachtin (1500 ppm)	3.0 ml/l	1.57	2.67	0.90	1.37	1.63	1.40	0.50	0.27	0.73
		(1.23)	(1.46)^{ab}	(0.95)^{bcd}	(1.15)^{bc}	(1.26)^{b}	(1.38)^{b}	(0.99)^{cd}	(0.88)^{cd}	(0.86)^{bc}
Bacillus thuringiensis	2.0 g/ l	1.89	1.67	0.87	1.47	2.73	0.77	2.13	0.53	1.00
		(0.93)	(1.26)^{abc}	(0.9)^{bcd}	(1.20)^{bc}	(1.63)^{b}	(1.10)^{bcd}	(1.60)^{a}	(1.02)^{bcd}	(0.94)^{bc}
Beauveria bassiana	2.0 g/l	1.27	1.17	1.10	1.17	3.00	0.83	1.30	1.17	0.77
		(1.09)	(1.08)^{bcd}	(1.03)^{b}	(1.08)^{bc}	(1.62)^{b}	(1.15)^{bcd}	(1.34)^{b}	(0.95)^{bcd}	(0.78)^{bcd}
Deltamethrin 2.8 EC	0.50 ml/l	1.63	1.77	0.90	1.73	2.60	0.60	0.57	0.57	0.83
		(1.27)	(1.30)^{abc}	(0.95)^{bcd}	(1.29)^{bc}	(1.604)^{b}	(1.05)^{cde}	(1.03)^{cd}	(1.31)^{abc}	(0.90)^{bc}
Emamectin benzoate 5 SG	0.25 g/l	1.27	0.73	0.23	1.17	1.00	0.23	0.37	0.13	0.67
		(1.13)	(0.85)^{cd}	(0.49)^{e}	(0.99)^{c}	(0.97)^{c}	(0.85)^{efg}	(0.91)^{de}	(1.00)^{bcd}	(0.81)^{bc}
Indoxacarb 15.8 EC	0.25 ml/l	0.93	0.60	0.48	0.67	1.30	1.33	0.07	0.03	0.23
		(0.96)	(0.72)^{d}	(0.69)^{cde}	(0.79)^{c}	(1.11)^{c}	(0.77)^{fg}	(0.75)^{e}	(0.73)^{d}	(0.49)^{d}
Fipronil 5 SC	1.0 ml/l	0.97	0.50	0.47	0.77	1.87	0.03	0.07	0.03	0.37
		(0.97)	(0.70)^{d}	(0.68)^{de}	(0.88)^{c}	(1.36)^{bc}	(0.73)^{g}	(0.75)^{e}	(0.73)^{d}	(0.65)^{cd}
Dichlorvos 76 EC	0.50 ml/l	1.17	0.97	0.90	1.33	2.43	0.53	0.43	0.40	0.73
		(1.06)	(0.97)^{cd}	(0.91)^{bcd}	(1.11)^{bc}	(1.64)^{ab}	(1.02)$^{c-f}$	(0.97)^{cde}	(0.94)^{bcd}	(0.95)^{bc}
Malathion 50 EC	2.0 ml/l	1.03	1.13	0.63	1.27	1.93	0.43	0.50	0.67	1.00
		(0.99)	(1.02)^{bcd}	(0.90)^{bcd}	(1.10)^{bc}	(1.35)^{b}	(0.97)$^{d-g}$	(0.99)^{cd}	(0.89)^{cd}	(0.98)^{b}
Untreated control	-	1.27	2.87	1.73	3.53	4.47	3.80	2.00	1.67	3.10
		(1.12)	(1.68)^{a}	(1.32)^{a}	(1.85)^{a}	(2.09)^{a}	(2.05) ^{a}	(1.58)^{a}	(1.39)^{ab}	(1.76)^{a}
S.Em.±		-	0.152	0.094	0.155	0.152	0.079	0.060	0.158	0.103
C.D. at 5%		NS	0.466	0.271	0.456	0.465	0.246	0.221	0.473	0.323

Agrotis segetum* and *Spodalea recurvalis*,Mean of three replications, DAS- Days after spray, NS- Non significant,

Figures in parentheses indicate square root transformed values ($\sqrt{x+0.5}$)

Means followed by the same alphabet(s) are not significantly different (P=0.05)

Table 2. Effect of different synthetic insecticides, botanicals and bio-pesticides on foliage damage by defoliators*on amaranthus during 2013-14

Treatments	Dosage	Day before spray	**Mean percent foliage damage at different days after spray							
			First spray				Second spray			
			1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS
Neem Seed Kernal Extract	5%	7.83	8.00	11.33	19.00	28.33	25.00	19.67	13.00	18.67
		(18.28)	(16.30)^{b}	(19.66)^{bc}	(25.80)^{b}	(32.04)^{ab}	(29.83)^{b}	(26.37)^{bc}	(21.10)^{c}	(22.54)^{bcd}
Azadirachtin (1500 ppm)	3.0 ml/l	9.67	7.33	9.33	20.67	22.00	13.67	15.00	15.00	14.33
		(18.10)	(15.49)^{bc}	(17.70)^{bcd}	(27.28)^{b}	(27.96)^{bc}	(21.43)^{cd}	(22.46)^{bc}	(22.69)^{bc}	(22.24)^{cde}
Bacillus thuringiensis	2.0 g/ l	10.33	7.67	10.67	21.67	23.33	16.00	21.33	16.67	20.00
		(18.75)	(15.97)^{bc}	(19.05)^{bcd}	(27.68)^{b}	(28.70)^{bc}	(23.44)^{c}	(27.37)^{b}	(24.06)^{bc}	(26.47)^{bcd}
Beauveria bassiana	2.0 g/l	10.33	11.00	14.67	23.00	23.33	9.67	22.67	20.33	22.67
		(18.75)	(18.71)^{b}	(22.37)^{ab}	(28.58)^{b}	(28.70)^{bc}	(17.82)^{d}	(28.13)^{b}	(26.67)^{b}	(28.40)^{b}
Deltamethrin 2.8 EC	0.50 ml/l	9.17	8.33	14.33	18.67	25.33	26.33	13.67	13.67	19.67
		(17.77)	(16.65)^{b}	(22.13)^{abc}	(25.49)^{b}	(30.17)^{b}	(30.75)^{b}	(21.52)^{c}	(21.61)^{bc}	(26.30)^{bcd}
Emamectin benzoate 5 SG	0.25 g/l	9.17	4.67	6.00	12.33	15.33	11.33	6.00	6.67	11.00
		(18.42)	(15.08)^{cd}	(14.04)^{de}	(20.47)^{c}	(22.98)^{cd}	(19.36)^{cd}	(13.87)^{d}	(14.89)^{de}	(18.74)^{e}
Indoxacarb 15.8 EC	0.25 ml/l	8.00	3.00	4.00	9.00	11.67	9.33	2.00	4.00	9.33
		(17.07)	(9.72)^{d}	(1.28)^{e}	(17.33)^{c}	(19.84)^{d}	(17.62)^{cd}	(7.95)^{e}	(11.47)^{e}	(17.75)^{e}
Fipronil 5 SC	1.0 ml/l	8.67	2.67	3.67	12.33	15.33	13.33	6.67	12.33	13.33
		(19.21)	(9.26)^{d}	(10.78)^{e}	(20.50)^{c}	(22.98)^{cd}	(21.22)^{d}	(14.95)^{d}	(20.34)^{cd}	(21.19)^{de}
Dichlorvos 76 EC	0.50 ml/l	8.33	7.33	10.67	20.33	24.00	14.33	13.03	13.67	18.33
		(18.44)	(15.60)^{bc}	(19.04)^{bcd}	(26.62)^{b}	(29.09)^{b}	(22.17)^{cd}	(21.03)^{c}	(20.95)^{c}	(24.95)^{bcd}
Malathion 50 EC	2.0 ml/l	9.33	9.33	8.67	18.67	23.67	16.33	14.00	15.67	21.00
		(18.43)	(17.37)^{b}	(17.11)^{cd}	(20.60)^{b}	(29.10)^{b}	(23.70)^{c}	(21.56)^{c}	(23.31)^{bc}	(27.18)^{bc}
Untreated control	-	9.00	20.00	21.67	23.67	36.00	38.33	38.67	30.33	37.00
		(18.43)	(26.57)^{a}	(24.87)^{a}	(33.33)^{a}	(36.84)^{a}	(38.21)^{a}	(38.42)^{a}	(33.30)^{a}	(17.42)^{a}
S. Em.±		-	1.271	1.171	1.501	2.021	1.683	1.962	1.873	1.876
C.D. at 5%		NS	3.759	5.056	4.432	(5.96)	4.942	5.797	5.523	5.533

* *Agrotis segetum* and *Spodalea recurvalis*, **Mean of three replications, DAS: Days after spray, NS: Non significant

Figures in parentheses indicate arcsine transformed values, Means followed by the same alphabet(s) are not significantly different (P=0.05)

plant was recorded in untreated control than other treatments (Table 1). With respect to per cent foliage damage, indoxacarb 15.8 EC @ 0.25 ml/l, recorded 11.67 per cent foliage damage at seven days after first spray and it was at par with emamectin benzoate 5 SG @ 0.25 g/l and fipronil 5 SC @ 0.25 ml/l, with 15.33 per cent foliage damage in both the treatments. Amaranthus treated with deltamethrin 2.8 EC @ 0.5 ml/l, recorded of 25.33 per cent damage and it was on par with dichlorvos 76 EC @ 0.5 ml/l and malathion 50 EC @ 2 ml/l (24.00 and 23.67 % foliage damage, respectively). Untreated control recorded 36 per cent damage (Table 2).

One day after second spray, fipronil 5 SC @ 0.25 ml/l recorded minimum number of larval population of 0.03 larvae per plant and it was on par with indoxacarb 15.8 EC @ 0.25 ml/l (0.13 larvae/plant) being superior over other treatments. Treatments like emamectin benzoate 5 SG @ 0.25 g/l and malathion 50 EC @ 2 ml/l, recorded 0.23 and 0.43 larvae per plant, respectively and these treatments were at par with above treatments. Azadirachtin 1500 ppm @ 3 ml/l and NSKE @ 5% with 1.40 and 1.03 larvae per plant, respectively were superior over untreated control (3.80 larvae/plant) (Table 1). Significantly least per cent foliage damage was noticed when treated with indoxacarb 15.8 EC @ 0.25 ml/l (9.33 %) which was on par with *B. bassiana* @ 2.00 g/l, fipronil 5 SC @ 0.25 ml/l and emamectin benzoate 5 SG @ 0.25 g/l (9.67, 11.33 and 13.33 % foliage damage, respectively). Deltamethrin 2.8 EC @ 0.5 ml/l recorded maximum per cent foliage damage (26.33) and it was on par with NSKE @ 5% (25.00 %).

Three days after second spray, indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 0.25 ml/l were found to be effective chemicals against defoliators on amaranthus recording lowest (0.03) larvae per plant, besides being superior over all other treatments. Next best treatments in the rank were emamectin benzoate 5 SG @ 0.25 g/l and dichlorvos 76 EC @ 2 ml/l (0.37 and 0.43 larvae/plant, respectively). Whereas, *B. thuringiensis* @ 2.0 g/l treated plots recorded 2.13 larvae per plant, which was on par with untreated control (2.00 larvae/plant). The least per cent foliage damage was observed when treated with indoxacarb 15.8 EC @ 0.25 ml/l (2.00%) and was significantly superior over all other treatments. Next best treatment in the order was emamectin benzoate 5 SG @ 0.25 g/l (6.00%) and it was on par with fipronil 5 SC @ 1.00 ml/l (6.67%). The treatment with *B. bassiana* @ 2.00 g/l (22.67%) was on par with *B. thuringiensis* @ 2.00 g/l (21.33%) but superior than untreated control (38.67 %).

Similar trend was noticed at five days after second spray, plants treated with indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 0.25 ml/l recorded significantly less (0.03) number of defoliators on amaranthus compared to all other treatments followed by emamectin benzoate 5 SG @ 0.25 g/l with 0.13 larvae per plant and azadirachtin 1500 ppm @ 3 ml/l (0.27 larvae/plant). Amaranthus treated with NSKE @ 5% recorded significantly maximum number of larvae per plant (1.77) and it was at par with untreated control (1.67 larvae/plant) (Table 1). The foliage damage was significantly least in plants treated with indoxacarb 15.8 EC @ 0.25 ml/l (4.00 %) followed by emamectin benzoate 5 SG @ 0.25 g/l (6.67%) and it was at par with fipronil 5 SC @ 1.00 ml/l (12.33 %). *Beauveria bassiana* @ 2.00 g/l treated plants

Table 3. Economics of management of defoliators on amaranthus

Treatments	Dosage	Yield (t/ha)	Gross returns (₹/ha)	Incremental yield over control (t/ha)	Incremental benefit over control (₹/ha)	*Cost of plant protection (₹/ha)	Additional net profit (₹/ha)	IBCR
Neem Seed Kernal Extract	5%	12.22[cd]	122200	3.22	32200	1400	30800	22.00
Azadriachtin (1500 ppm)	3.0 ml/l	13.89[bc]	138900	4.89	48900	3200	45700	14.28
Bacillus thuringiensis	2.0 g/l	12.33[cd]	123300	3.33	33300	2656	30644	11.53
Beauveria bassiana	2.0 g/l	12.78[cd]	127800	3.78	37800	1000	36800	36.80
Deltamethrin 2.8 EC	0.50 ml/l	14.33[bc]	143300	5.33	53300	750	52550	70.06
Emamectin benzoate 5 SG	0.25 g/l	21.67[a]	216700	12.67	126700	3800	122900	32.34
Indoxacarb 15.8 EC	0.25 ml/l	21.49[a]	214900	12.44	124400	1956	122444	62.60
Fipronil 5 SC	1.0 ml/l	20.67[a]	206700	11.67	116700	2776	113924	41.03
Dichlorvos 76 EC	0.50 ml/l	17.49[ab]	174900	8.49	84900	900	84000	93.33
Malathion 50 EC	2.0 ml/l	17.77[ab]	177700	8.77	87700	1360	86340	63.49
Untreated control	-	9.00[d]	90000	-	-	-	-	-
S.Em.±	-	0.204	-	-	-	-	-	-
C.D. at 5%	-	0.595	-	-	-	-	-	-

IBCR- Incremental benefit cost ratio),*Cost of treatment + Cost of application,* Market price of Amaranthus leaves - ₹ 10/kg,
Neem Seed kernel extract 10 kg: ₹ 400, Azadirachtin 1500 ppm 1litre : ₹ 500, *Bacillus thuringiensis* 500 g: ₹ 307, Fipronil 5 SC 250 ml: ₹ 250, *Beauveria bassiana* 500 g: ₹ 100, Deltamethrin 2.8 EC 1 litre: ₹ 554, Malathion 50 EC 1 litre: ₹ 290, Dichlorvos 76 EC 250 ml: ₹ 175, Emamectin benzoate 5 SG 500 g: ₹ 3600, Indoxacarb 15.8 EC 200 ml: ₹ 828

recorded 20.33 per cent foliage damage and this treatment was at par with *B. thuringiensis* @ 2.00 g/l, malathion 50 EC @ 2.00 ml/l and azadirachtin 1500 ppm @ 3 ml/l (16.67, 15.67 and 15.00% foliage damage, respectively) and these treatments were superior over untreated control (38.67 %) (Table 2).

Again at seven days after second spray, indoxacarb 15.8 EC @ 0.25 ml/l, recorded 0.23 larvae per plant which was significantly superior over all other treatments, followed by fipronil 5 SC @ 1.00 ml/l and emamectin benzoate 5 SG @ 0.25 g/l (0.37 and 0.67 larvae/plant, respectively). Treatment with malathion 50 EC @ 2.00 ml/l, recorded maximum number of larvae per plant which was on par with NSKE @ 5% (1.03 larvae/ plant). Fipronil 5 SC @ 1.00 ml/l recorded least per cent foliage damage (9.33%) and it was on par with indoxacarb 15.8 EC @ 0.25 ml/l, emamectin benzoate 5 SG @ 0.25 g/l (11.00 %). Fipronil 5 SC @ 0.25 ml/l (11.00%) and azadirachtin 1500 ppm @ 3 ml/l (13.33%). *Beauveria bassiana* 2 g/l recorded 22.67 per cent foliage damage which was superior over untreated control (37.00%).

Singh and Singh (2004) tested malathion 50 EC and monocrotophos 36 SL and found effective in controlling the leaf webber. According to Rao *et al.* (2004) spraying of malathion 50 EC @ 1 ml/l or azadirachtin was effective in controlling the pest population on amaranthus, with safe period of one week for harvesting (Rao *et al.,* 2004). Srinivasiihr (2013) in a field trial, opined that the leaf eating caterpillar and aphids can be managed spraying malathion 50 EC @ 1 ml/l effectively but indicated that the waiting period of 15 days should be observed. Mishra (2013) evaluated bioefficacy of Solu neem™ (6% azadirachtin SP) against webber on amaranthus. The results showed that Solu neem™ (0.5 & 1.0 g/l) was more effective than B.t. spray, and as effective as chemical insecticide against leaf webber of amaranthus with no phytotoxicity symptoms. Solu neem ™ in the range of 0.5 g/l (250 g/ha) to 1g/l (500 g/ha) can be eco-friendly, alternative to toxic chemical insecticide for the effective management of leaf webber on amaranthus without affecting the productivity of the crop. However, the new molecules are tested in the present study. The treatment with indoxacarb 15.8 EC @ 0.25 ml/l, fipronil 5 SC @ 0.25 ml/l and emamectin benzoate 5 SG @ 0.25 g/l could reduce the foliage damage on amaranthus and these treatments were significantly superior over all other treatments. Azadirachtin 1500 ppm @ 3 ml/l and dichlorvos 76 EC @ 0.5 ml/l were also effective.

The foliage yield of amaranthus ranged from 9.00 to 21.44 tonnes per hectare. Plots treated with emamectin benzoate 5 SG @ 0.25 g/l, indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 1 ml/l, were found to be significantly superior over all the other treatments, fetching maximum leaf yield of 21.67, 21.44 and 20.67 t/ha, respectively. The next best treatments were malathion 50 EC @ 2 ml/l (17.77 t/ha) and dichlorvos 76 EC @ 0.5 ml/l (17.49 t/ha) and these treatments were at par with the deltamethrin 2.8 EC @ 0.5 ml/l and azadirachtin 300 ppm @ 3 ml/l (14.33 t/ha). Treatments like *B. bassiana* 2.0 g/l (12.78 t/ha), *B. thuringiensis* @ 2.0 g/l (12.78 t/ha) and NSKE @ 5% (12.22 t/ha) recorded higher yield but were on par with untreated control (9.00 t/ha) (Table 3).

The cost economics was worked out for various treatments used in the management of defoliators. Plots treated with emamectin benzoate 5 SG @ 0.25 g/l, indoxacarb 15.8 EC at 0.25 ml/l and fipronil 5 SC @ 1 ml/l produced maximum additional foliage yield (12.67, 12.44 and 11.67 t/ha, respectively) followed by dichlorvos 76 EC at 0.5 ml/l (8.49 t/ha) and malathion 50 EC @ 2 ml/l (8.77 t/ha). The treatments like deltamethrin 2.8 EC @ 0.5 ml/l azadirachtin 1500 ppm 3 ml/l (4.89 t/ha), *B. bassiana* 2.0 g/l (3.78 t/ha), *B. thuringiensis* 2.0 g/l (3.3 t/ha) and neem seed kernel extract (NSKE) @ 5% (3.22 t/ha) recorded lower yield as compared to other treatments (Table 3). The higher gross returns were obtained from the treatment emamectin benzoate 5 SG @ 0.25 g/l, indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 1 ml/l (₹ 216700, 214900 and 206700, respectively).

Other treatments like malathion 50 EC 2 ml/l fetched gross returns of ₹ 177700 followed by dichlorvos 76 EC @ 0.5 ml/l (₹ 174900), deltamethrin 2.8 EC @ 0.5 ml/l (₹ 143300), *B. bassiania* @ 2 g/l (₹ 127800), *B. thuringiensis* 2.0 g/l (₹ 123300) and NSKE @ 5% (₹ 122200). The net returns were highest in the treatments emamectin benzoate 5 SG @ 0.25 g/l, indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 1 ml/l (₹ 126700, 124400 and 116700, respectively). Dichlorvos 76 EC @ 0.5 ml/l fetched net returns of ₹ 84900 followed by malathion 50 EC @ 2 ml/l (₹ 87700), deltamethrin 2.8 EC @ 0.5 ml/l (₹ 53300), *B. thuringiensis* @ 2.0 g/l (₹ 33300) and NSKE @ 5% (₹ 32200). Highest IBCR of 93.33 was obtained from the treatment dichlorvos 76 EC @ 0.5 ml/l followed by other treatments like deltamethrin 2.8 EC @ 0.5 ml/l (70.06), malathion 50 EC @ 2 ml/l (63.49), indoxacarb 15.8 EC @ 0.25 ml/l (62.20), and fipronil 5 SC @ 1 ml/l (41.03). Even though higher benefits were obtained from the treatments emamectin benzoate 5 SG @ 0.25 g/l and indoxacarb 15.8 EC @ 0.25 ml/l and fipronil 5 SC @ 1 ml/l, ICBR was low due to higher market price of insecticides (Table 3). Fipronil 5 SC @ 1 ml/l, emamectin benzoate 5 SG @ 0.25 ml/l and indoxacarb 15.8 EC @ 0.25 ml/l were significantly superior throughout the period of investigation in their bio-efficacy against defoliators and in reducing the per cent foliage damage under field conditions. However, the toxicological studies and waiting period for consumption of amaranthus need to be done.

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