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Efficacy of natural products and biorationals against, *Tetranychus* spp Koch, (Acari: Tetranychidae) infesting okra under open field conditions

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Abstract
Okra is highly nutritious and commercial vegetable crop grown in open field conditions throughout the tropical and subtropical areas of the world. But tetranychid mites, *Tetranychus* spp (Acari: Tetranychidae) cause major problems in its cultivation resulting in significant losses. The objective of this study was to evaluate the efficacy of different biorationals and natural products against *Tetranychus* spp on okra under open field conditions. Results revealed that among all the natural products and biorational treatments, ginger (2.66mites/2cm^2 leaf-area) and pepper (3.55 mites/2cm^2 leaf-area) extracts followed by *Neemastra* (7.11 mites/2cm^2 leaf-area) and *Agniastra* (8.22 mites/2cm^2 leaf-area) caused more reduction of mites at the highest doses of 30ml/l in both ginger and pepper while 50ml/l in *Neemastra* and *Agniastra* respectively. Even the PAU home made neem extract and *Pongamia* extract both @ 12ml/l were found more effective as compared to the *Dherek* extract. All the treatments were found superior in reducing the population of pest mite over untreated control, so these biorationals can be integrated for effective mite management programmes.

Keywords: Okra, biorationals, mortality and *Tetranychus*

1. Introduction
Among vegetables, Okra, *Abelmoschus esculentus* L., is cultivated in most parts of the world and considered to be the only vegetable crop of significance in the Malvaceae family and is very popular in the Indo-Pak subcontinent [11].
be one of the world's oldest cultivated crops. Okra is
In India, okra or *bhendi* is intensively cultivated in Karnataka, Maharashtra, Tamil Nadu, Punjab and Uttar Pradesh. Various biotic, abiotic and physiological factors are the main constraints encountered by the farmers in getting higher productivity and good quality produce. Many insect and mite pests hamper the crop productivity of vegetable crops in almost all areas of the world. Among the mite pests, tetranychid mites are serious pests of horticultural crops and widely distributed in tropical and sub-tropical areas of the world. About 1250 species of these are known to feed on 3877 different plants, although about 100 species are of economic importance and nearly 150 Agri-horticultural crops are damaged [10, 5]. Among the Tetranychidae family, *T. urticae* is a highly polyphagous, cosmopolitan species and has been recorded from over 300 plant species worldwide and its damage includes appearance of characteristic yellowish-white chlorotic spots on leaves, webbing and decline in photosynthesis which finally affects the quality and quantitative yield of crop [23]. In India, okra is attacked by *Tetranychus urticae*, *Tetranychus macfarlanei* and *Tetranychus ludeni* [9].
Consumers's demand for healthy and 'green' produce is ever-increasing but farmers generally rely on chemicals for pest control, and the indiscriminate use of these chemicals leads to adverse effects like residues in the fruits, pest resurgence and destruction of natural enemies which suggest the need to develop alternative management strategies [15, 5].
At present, alternative to synthetic pesticides for efficient suppression of pests in different agro eco-systems is being investigated with more emphasis on organic farming so as to keep our environment safe [17]. In India, organic farming based on natural products and indigenous approaches has been practiced since many years and is now forming an important component of modern farming practices too. The organic farming system has cow as a key component and has gained importance among farmers mainly due to benefits of soil fertility, soil health and

sustainable productivity [15]. The natural preparations containing byproducts of cow are quite effective in enhancing crop productivity and at the same time suppressing the growth of many insect and mite pests [12]. In recent years, plant extracts and botanical pesticides have showed great importance in agricultural fields due to their cheap and low expenses, with no residual effects, environmentally friendly, and highly toxic against major pests such as thrips, aphids, jassids, whitefly, and mites. Botanicals like neem oil, *mohua* oil, *pongamia* oil, NSKE, neem cake based biopesticides, marigold, mentha, seed extracts of jatropha, black pepper, custard apple, turmeric and biorationals like neem-garlic and chilli-garlic aqueous extracts both @ 2% were found to be effective against many phytophagous mites [9]. Neem oils and extracts are considered as the best option for the insect pest management program in vegetables because they are safe for beneficial organisms, target-specific, and compatible for biological control agents. The efficacy of homemade botanical insecticides based on traditional knowledge has been reviewed and reported that *Azadirachta indica* A. Jussand and *Melia azadirachta* (Family – Meliaceae) have excellent insecticidal properties due to the presence of limonoids which interfere with various physiological processes and chemical pathways thereby offering feeding deterrence and toxic effects to the insect-pests [6]. Similarly, the efficacy of plant derivatives like garlic bulb extract @ 10%, *Pongamia* oil @ 3% and neem oil @ 3% against *T. urticae* on rose in Tamil Nadu has also been reported [14]. Spiromesifen is a reduced risk insecticide from a novel chemical class of Ketoenols with titronic acid derivative compounds. The pesticidal mode of action is inhibition of lipid biosynthesis, especially triglycerides and free fatty acids [4]. The cow urine and plant origin products have proved to be eco-friendly, residue free, bio-degradable, cost-effective and are known to impart resistance in plants against insect pests and diseases [8].

As no work on the management of mites using preparations of plant and animal origin, botanicals and safer acaricides has been carried out on okra in open field conditions in North India especially the state of Punjab, so the present studies were planned to develop an effective management strategy using biorational approaches. The natural products, and safer molecules having different modes of action can be successfully used in pest management programmes thus founding a basis for an eco-friendly way of pest management.

2. Materials and Methods

The present study on management of *Tetranychus* spp on okra using indigenous methods or natural products and biorational approaches was undertaken in the Department of Entomology, Punjab Agricultural University, Ludhiana during 2019.

2.1 Preparation of natural products

The different natural products and biorationals i.e. plant extracts namely, *Agniastra*, *Brahamastra*, *Neemastra*, PAU homemade neem extract, *Dherek* extract, *Pongamia* extract, ginger extract, garlic extract and pepper extract were prepared freshly. The composition and doses of these products is being presented in Table 1.

2.2 Evaluation of biorationals against mites on okra

Different biorationals including natural products and botanicals, along with chemical acaricide, spiromesifen was evaluated against *Tetranychus* spp. The different treatments comprised of homemade neem extract, *dhrek* extract, *pongamia* extract, *neemastra*, *brahamastra*, *agniastra*, pepper extract, ginger extract garlic extract, water spray and recommended spiromesifen (22.9 SC) @ 150ml/acre along with untreated control.

Table 1: Natural products/biorationals evaluated against mites on okra

Natural/ indigenous product	Composition and method of preparation	Dose (s), ml/l or %	Source /formulator
Cow urine and cow dung	cow urine and dung of Indian cow	Used for preparing different natural preparations	Dairy Farm, GADVASU, Ludhiana and School of Organic Farming, PAU, Ludhiana
PAU homemade neem extract	4 Kg of neem (*Azadirachta indica*) leaves/stems/fruits boiled in 10 litres of water for 30 minutes and filtered with a double layered muslin cloth	8,10,12 ml/l	Department of Entomology, PAU, Ludhiana
Dherek extract	4 Kg of *dherek* (*Melia azadirachta)* leaves/stems boiled in 10 litres of water for 30 minutes and filtered with a double layered muslin cloth	8,10,12 ml/l	Department of Entomology, PAU, Ludhiana
Pongamia extract	4 Kg of *Pongamia* leaves/stems boiled in 10 litres of water for 30 minutes and filtered with a double layered muslin cloth	8,10,12 ml/l	Department of Entomology, PAU, Ludhiana
Neemastra	Neem leaves/tender shoots (5 Kg), cow urine (5 litres), cow dung (2 Kg) and water (100 litres). Mix all the ingredients and keep in open for 48 hours. Stir the mixture in clockwise direction 3 -4 times a day. Filter using a double layer muslin cloth.	30,40,50ml/l	Department of Entomology, PAU, Ludhiana
Brahamastra	*Desi* cow urine (20 litres), paste of Neem leaves (2 Kg), paste of mango leaves 2 Kg), paste of guava leaves (2 Kg), paste of castor leaves (2 Kg), water (100 litres). Mix all the ingredients and boil for half an hour. Cool it and filter using a double layer muslin cloth.	30,40,50ml/l	Department of Entomology, PAU, Ludhiana
Agniastra	Green leaves of Neem (5 Kg), Desi cow urine (20 litres), Tobacco powder (500gm), paste of pungent green Chillies (500 g), paste of *desi* garlic (500 gm, water (200 litres). Mix all the ingredients and boil for half n hour. Cool it and filter using a double layered muslin cloth.	30,40,50ml/l	Department of Entomology, PAU, Ludhiana
Pepper extract	1, 2 and 3 kg of green pepper each grinded and dissolved in 100 litres of water respectively. Filtered in double layer of muslin	10,20,30ml/l	Department of Entomology, PAU, Ludhiana
Ginger extract	1, 2 and 3 kg each of fresh ginger grinded and dissolved in 100 litres of water respectively. Filtered in double layer of muslin	10,20,30ml/l	Department of Entomology, PAU, Ludhiana
Garlic extract	1, 2 and 3 kg each of garlic cloves with outer layer removed, grinded and dissolved in 100 litres of water respectively. Filtered in double layer of muslin	10,20,30ml/l	Department of Entomology, PAU, Ludhiana

2.2.1 Under field conditions

For evaluation of different biorationals against *Tetranychus spp* on okra crop under open field cultivation, variety *Punjab Suhawani* was raised under field conditions following recommended agronomic practices. The experiment was laid out in randomized block design (RBD) with each of the concentration of biorational as one treatment and three replications were kept for all the treatments. Application of biorationals was done on October 18, 2019 at the appearance of 20-25 per cent mite infestation on plants. Observations were recorded from randomly selected three leaves each from top, middle and bottom canopies. These leaves were collected and brought to the laboratory. The number of mites (active stages) was recorded per 2 cm^2 leaf-area leaf under stereo zoom binocular microscope (Carl Zeiss Discovery V 8) at pretreatment, 3, 7, 10 and 14 days after each spray.

2.3 Statistical analysis: The data were subjected to square root transformation and analyzed statistically for comparing treatments following Analysis of Variance (ANOVA) and the results were interpreted at 5 per cent level of significance.

3. Results

3.1 Evaluation of biorationals against okra under field conditions

The biorationals and natural products were tested under field conditions against *Tetranychus spp* on okra grown under open field conditions at Entomological Research Farm, PAU in 2019. The number of active stages of mites were counted under a stereo zoom microscope before treatment, 3, 5, 7 days after spray (DAS) and 2nd spray was given after 7 days of 1st spray. In addition, the effect of different treatments on phytotoxicity symptoms was also observed.

The number of mites per leaf was counted before spray/release and the number of mites per $2cm^2$ leaf-area varied from 35.67 to 69.50 mites/$2cm^2$ leaf-area in different treatments.

3.1.1 After first spray: In the first spray, among all the treatments, most effective was found to be acaricide i.e. spiromesifen with number of mites being mean of 1.44 mites/$2cm^2$ leaf area 7days after spray (Table 2). In case of biorationals or botanicals, significant low mean number of mites was observed in ginger extract @ 30ml/l (2.66 mites/$2cm^2$ area) followed by pepper extract @ 30ml/l (3.55 mites/$2cm^2$ area) whereas garlic extract was found to be moderately effective in reducing the mite population. The PAU homemade neem extract and *pongamia* extract both at the highest doses of 12ml/l proved highly effective in reducing the mite population 7 DAS (7.67 and 8.00 mites/$2cm^2$ leaf-area respectively). Similarly, in case of natural products, *neemastra* and *agniastra* both at the highest dose of 50ml/l were found highly effective in reducing the mite population (7.11 and 8.22 mites/$2cm^2$ leaf-area, respectively). However *dherek* extract was found inferior in reducing the mite population as compared to all the other treatments (Table 2). Even the water spray did not reduce the mite population much.

3.1.2 After second spray: The second spray of all the natural products and botanicals was given after seven days of first spray. The mean mite population seven days after the second spray revealed significant reduction of mites in all the treatments and the trend was similar to the first spray. Pepper extract @ 30ml/l was found to reduce the mite population maximum (0.0 to 0.22 mites/$2cm^2$ area). Among the natural products, *neemastra* at all the doses was highly effective in reducing the mite population (0.22 to 0.33 mites/$2cm^2$ area). *Dhrek* extract was found to reduce the mite population at the end of the second spray, but seeing the overall results, it was comparatively less effective in controlling the mite population (Table 3).

3.1.3 Pooled mean of both sprays: The mean number of mites of both the sprays in different treatments was pooled and it was observed that pepper extract, *neemastra*, and *agniastra* were found to significantly reduce the mite population and *dherek* extract was found comparatively less effective as compared to PAU homemade neem extract and *pongamia* extract and *brahamastra* (Table 4).

Table 2: Efficacy of natural products and biorationals against *Tetranychus spp* on okra after first spray during 2019.

Treatment(s)	Dose (ml/L)	Mean number of mites/$2cm^2$ leaf area			
		3 DAS	5 DAS	7 DAS	Mean of 1st spray
Agniastra	30	17.67(4.29)	15.67(4.06)	11.00(3.45)	14.78
	40	25.33(5.09)	10.00(3.30)	11.00(3.41)	15.44
	50	11.67(3.53)	8.00(2.97)	5.00(2.44)	8.22
Brahamastra	30	17.00(4.08)	17.00(4.04)	10.33(3.36)	14.77
	40	25.33(5.11)	17.00(4.21)	11.00(3.45)	17.77
	50	17.00(4.01)	11.67(3.45)	8.33(3.04)	12.33
Neemastra	30	1.33(1.41)	14.00 (3.85)	10.67 (3.37)	8.66
	40	13.00 (3.72)	19.67 (4.53)	13.33 (3.72)	15.33
	50	3.67 (1.96)	9.67 (3.22)	8.00 (2.69)	7.11
Homemade (neem)	8	16.00 (4.09)	21.67 (4.56)	11.67 (3.54)	16.44
	10	6.33 (2.70)	18.33 (4.37)	7.00 (2.76)	10.55
	12	5.00 (2.43)	6.33 (2.61)	11.67 (3.55)	7.67
Dhrek extract	8	24.67 (5.03)	31.67 (5.67)	37.00 (6.07)	31.11
	10	24.00 (4.94)	28.33 (5.40)	25.33 (5.06)	25.88
	12	23.33 (4.90)	27.00 (5.27)	24.67 (5.03)	25.00
Pongamia	8	17.67 (4.31)	11.67 (3.55)	10.00 (3.30)	13.11
	10	14.67 (3.88)	11.67 (3.56)	6.67 (2.72)	11.00
	12	9.00 (3.11)	10.00 (3.31)	5.00 (2.41)	8.00
Ginger	10	7.00 (2.81)	18.67 (4.33)	7.00 (2.80)	10.89
	20	7.33 (2.84)	8.67 (3.06)	7.00 (2.77)	7.66
	30	3.33 (2.06)	3.33 (2.06)	1.33 (1.41)	2.66

Garlic	10	15.33 (4.03)	21.67 (4.69)	12.00 (3.58)	16.33
	20	23.33 (4.86)	15.00 (3.88)	9.33 (3.09)	15.88
	30	17.00 (4.20)	12.67 (3.65)	5.33 (2.47)	11.66
Pepper	10	13.67 (3.82)	12.33 (3.62)	12.33 (3.55)	12.77
	20	5.33 (2.46)	8.33 (3.04)	6.67 (2.67)	6.77
	30	1.00 (1.33)	4.00 (2.23)	5.67 (2.51)	3.55
Water spray	-	29.67 (1.67)	27.33 (5.18)	42.00 (6.54)	33.00
Control	-	35.67 (6.03)	39.67 (6.37)	68.00 (8.27)	47.78
Oberon (Spiromesifen) 22.9SC	1.5/l	1.67 (1.58)	1.00 (1.33)	1.67 (1.58)	1.44
CD(p=0.05)		(1.24)	(1.31)	(1.24)	

DAS- days after spray

Table 3: Efficacy of natural products and biorationals against *Tetranychus spp* on okra after second spray during 2019.

Treatment(s)	**Dose (ml/L)**	**Mean number of mites/2cm^2 leaf area**			
		3 DAS	**5 DAS**	**7 DAS**	**Mean of 2nd spray**
Agniastra	30	2.67(1.82)	0.67(1.28)	0.67(1.24)	1.34
	40	0.67(1.24)	0.00(1.00)	0.67(1.24)	0.44
	50	0.33(1.14)	0.00(1.00)	0.00(1.00)	0.11
Brahamastra	30	1.67(1.58)	0.33(1.14)	1.33(1.47)	1.11
	40	2.67(1.79)	0.00(1.00)	0.67(1.24)	1.11
	50	1.00(1.33)	0.67(1.24)	0.00(1.00)	0.55
Neemastra	30	0.33 (1.14)	0.67 (1.24)	0.00 (1.00)	0.33
	40	0.33(1.14)	0.67 (1.24)	0.00 (1.00)	0.33
	50	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.22
Homemade Neem extract	8	2.33 (1.75)	0.00 (1.00)	0.00 (1.00)	0.77
	10	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.22
	12	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
Dhrek extract	8	9.33 (3.20)	5.67 (2.57)	8.67 (3.05)	7.89
	10	5.33 (2.50)	4.00 (2.22)	4.33 (2.28)	4.55
	12	3.67 (3.00)	3.67 (2.16)	3.33 (2.06)	3.55
Pongamia extract	8	1.00 (1.33)	1.33 (1.49)	1.33 (1.47)	1.22
	10	0.00 (1.00)	0.33 (1.14)	0.00 (1.00)	0.11
	12	0.67 (1.24)	0.67 (1.24)	1.00 (1.33)	0.78
Ginger extract	10	1.33 (1.49)	0.00 (1.00)	0.00 (1.00)	0.44
	20	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.22
	30	0.00 (1.00)	1.00 (1.38)	0.00 (1.00)	0.33
Garlic extract	10	0.67 (1.24)	0.33 (1.14)	1.00 (1.33)	0.66
	20	0.67 (1.24)	1.00 (1.38)	0.00 (1.00)	0.55
	30	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
Pepper extract	10	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.22
	20	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.11
	30	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
Water spray	-	9.00 (3.16)	9.67 (3.23)	9.33 (3.17)	9.33
Control	-	14.67 (3.94)	11.33 (3.49)	12.67 (3.65)	12.89
Oberon (Spiromesifen) 22.9SC	1.5/l	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00
CD(p=0.05)		(0.70)	(0.44)	(0.59)	

DAS – days after spray

Table 4: Pooled means of two sprays on efficacy of natural products and biorationals against *Tetranychus spp* on okra during 2019.

Treatment (s)	**Dose (ml/L)**	**Mean number of mites/2cm^2 leaf area**			
		3 DAS	**5 DAS**	**7 DAS**	**Pooled mean**
Agniastra	30	10.16	8.16	5.83	8.05
	40	13.00	5.00	5.83	7.94
	50	6.00	4.00	2.50	4.16
Brahamastra	30	9.33	8.66	5.83	7.95
	40	14.00	8.50	5.83	9.44
	50	9.00	6.17	4.16	6.45
Neemastra	30	0.83	7.33	5.33	4.50
	40	6.67	10.16	6.66	7.83
	50	2.16	4.83	4.00	3.67
Homemade Neem extract	8	9.16	10.83	5.83	8.61
	10	3.50	9.16	3.50	5.39
	12	2.50	3.16	5.83	3.83
Dhrek extract	8	19.33	18.50	25.66	21.16
	10	25.16	25.50	40.33	30.33
	12	17.00	18.66	22.83	19.50
Pongamia extract	8	4.16	9.33	3.50	5.66
	10	4.00	4.33	3.50	3.95

	12	1.66	2.17	0.66	1.50
Ginger extract	10	8.00	11.00	6.50	8.50
	20	12.00	8.00	4.66	8.22
	30	8.50	6.33	2.66	5.83
Garlic extract	10	7.16	6.16	6.16	6.50
	20	2.83	4.16	3.33	3.44
	30	0.50	2.00	2.83	1.78
Pepper extract	10	9.33	6.50	5.66	7.16
	20	7.33	6.00	3.33	5.55
	30	4.83	5.33	3.00	4.39
Water spray	-	14.66	16.16	14.83	15.22
Control	-	13.50	15.33	14.00	14.27
Oberon (Spiromesifen) 22.9SC	1.5/l	1.12	0.54	1.00	0.88

DAS-days after spray

3.3 Phytotoxicity
All the plots were observed for phytotoxicity symptoms in the form of yellowing, bronzing, wilting, if any. No phytotoxicity was observed in any treatment.

4. Discussion
In this study we investigated the efficacy of various natural products and biorationals or plant products and safer molecule which can be incorporated into an integrated mite management programme against active stages of *Tetranychus* spp infesting okra under open field conditions. The present findings are in accordance with other studies [18, 14, 22] wherein the evaluation of acaricides including spiromesifen and propargite was done and it was observed that spiromesifen and propargite significantly reduced the *T. urticae* population with higher mortality in spiromesifen after fourteen days of spray in cucumber, rose and okra respectively. In similarity to the present work, 100 per cent reduction of mites per leaf was observed in spiromesifen and 50-75 per cent mortality in neem products at seven days after spraying under polyhouse [13]. Similarly [19, 22] neem oil @ 4 per cent caused 58 per cent reduction in mite population three days after spray but mortality decreased to 46 per cent after seven days of spray, similar trend has been found in our study also. Neem, *Melia azedarach*, is constituted of different compounds which are mainly categorized under limonoids, triterpinoids and steroids [7]. The main active ingredient azadirachtin is a chemically complex compound synthesized as a secondary metabolite having wide array of acaricidal activity such as antifeedance, fecundity deterrence, oviposition deterrence, growth inhibition and detrimental to physiological processes [3]. Azadirachtin exhibiting high levels of acaricidal activity derives support from the findings [21]. From the above observations, it became clear that home made aqueous extract of neem fruit requires a higher concentration for pest management as compared to the commercial formulations. The categorization of *dherek* extract being moderately effective finds support from other observations [21], wherein they observed that *Melia azedarach* possess insecticidal, antifeedant, growth regulating and development modifying properties in a wide array of insect and mite pests. The high acaricidal activity of *neemastra* and *agniastra* can be attributed to the added cow byproducts which as sole component offer high level of lethal toxicity to *T. urticae* adults [12]. So these biorationals can be used in combination for effective management. Therefore from the present studies, it can be concluded that all the biorationals tested were effective in reducing the tetranychid mite population and can form an integral part of integrated mite management programmes.

5. Conclusion
In conclusion, according to our findings of the present study, amongst the biorationals, botanicals i.e. ginger, pepper, homemade neem extracts showed promising results against *Tetranychus* spp on okra under field conditions However, maximum reduction of mites was observed in case of acaricides. So, the biorationals could be suggested for the integrated management of *T. urticae* on okra.

6. Competing interests: The authors declare that they have no competing interests.

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