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Comparative infestation of red spider mite, *Tetranychus macfarlanei* and abundance of phytoseiid predator, *Neoseiulus longispinosus* on okra germplasms across growing seasons under Bangalore conditions

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Abstract
Field screening of 36 okra (*Abelmoschus esculentus*) germplasm entries including a wild type okra, *Abelmoschus manihot tetraphyllus* for infestation by red spider mite, *Tetranychus macfarlanei* Baker and Pritchard was carried out during early summer (March to June 2014) and late kharif (Sept. to Dec. 2014) seasons under Bangalore conditions. Comparatively, red spider mite incidence on okra entries was more during kharif season compared to the summer season. Variety Aruna recorded the lowest mite load of 1 and 19.11 mites/4cm^2 leaf area during summer and kharif seasons, respectively. The highest mite population on individual okra entries during summer was 44.73 mites on Varsha Uphar and during kharif season, it was 106.17 mites on VRO-5, closely followed by Varsha Uphar with 104.18 mites. During the summer season, greater activity of phytoseiid predator, *Neoseiulus longispinosus* (Evans) observed was refractive and significant in terms of lower incidence of the spider mite, *T. macfarlanei*, on almost all okra entries.

Keywords: okra, early summer, late kharif, *T. macfarlanei* and *N. longispinosus*

1. Introduction
Spider mites are serious pests of many vegetable crops including okra. Among the spider mite species damaging this crop, *Tetranychus urticae* Koch, *Tetranychus macfarlanei* Baker and Pritchard, *Tetranychus ludeni* Zacher and *Tetranychus neocaledonicus* Andre are important. Recently, red spider mite, *T. macfarlanei*, a little known species [1, 2] so far, is causing severe damage on okra crop in parts of Karnataka, Kerala, Gujarat, Punjab and West Bengal [3]. Use of synthetic chemicals has been a more convenient method to reduce losses due to spider mites, which resulted in adverse side effects like pest resurgence, secondary pest outbreak, pesticide resistance, elimination of beneficial natural enemies and hazardous residues [4, 5]. This awareness has led to a change in the plant protection research, for using non-chemical methods like resistant crop varieties, augmentation of potential natural enemies *etc.*
Crop plants use their own means to protect themselves from damage by the pests, of which, three principle mechanisms of anti-xenosis, antibiosis and tolerance adversely affect the pests by altering growth, development and multiplication of the pest species [6, 7]. Host-plant resistance is a component compatible with all other control methods in the integrated pest management system. Knowledge of plant susceptibility/resistance and the underlying mechanisms are fundamental in host plant resistance study and such information will help in improving the advantageous reaction of cultivars against pests. In view of the significance of spider mites as the serious pest of okra crop, there is an urgent need to identify resistant source(s) for use in the development of mite tolerant varieties and to reduce the use of hazardous synthetic acaricides. Keeping this in view, investigations on the reaction of available okra germplasms to spider mite infestation were carried out.

2. Material and Methods
Thirty-six okra [*Abelmoschus esculentus* (L.) Moench] entries (including breeding lines, varieties and wild type, *Abelmoschus manihot* sub-species *tetraphyllus*) were field screened for infestation by spider mites during early *summer* (March to June 2014) and late *kharif*

(Sept. to Dec. 2014) seasons at the Zonal Agricultural Research Station farm, University of Agricultural Sciences, GKVK, Bangalore. Okra entries obtained from different sources, Indian Institute of Horticultural Research, Bangalore; Kerala Agricultural University, Thrissur and Navsari Agricultural University, Navsari were evaluated. Each of these entries was raised in 5 m rows in two replications with the plant spacing of 60cm x 30cm. The entries were raised in the field following recommended cultivation practices except for the plant protection measures against spider mites and entries were exposed to natural infestation by spider mites.

Observations on the incidence of spider mites were recorded on all the entries separately from 3 randomly selected plants. From each plant, leaves were sampled from 2 to 3 canopy levels (top, middle and bottom) and were observed under a stereo-binocular microscope in the laboratory to record the number of different stages of the mite *i.e.*, eggs and active stages (larvae, nymphs and adults) from 3 random spots of 2cm x 2cm from each leaf. Mite population was expressed as the number/4cm^2 leaf area. Mite counts were recorded at 10 to 15 days interval from 50 days after sowing untill maturity. Mite population data recorded were pooled interval-wise & season-wise and analysed statistically to compare mite infestation across entries and across the growing seasons. Similarly, observations on associated predominant predatory phytoseiid mite, *Neoseiulus longispinosus* were recorded (as number of eggs+ active stages/leaf) on all okra entries.

Statistical analysis

Season-wise mite population data recorded at different intervals within a season were subjected to statistical analysis following ANOVA technique for Factorial Randomized Complete Block Design considering intervals as Factor I (4 intervals) and okra entries as Factor II (36 entries). Mite population data pooled over seasons on different entries were analysed using AGRES statistical package considering different okra lines as treatments. Differences in spider mite abundance were studied across cropping seasons as well as okra lines. Predatory mites, predominantly more active during summer season were compared across different okra lines.

3. Results and Discussion

Early Summer Season (March to June 2014)

Spider mite infestation started from 50 days onwards on all the okra entries and it continued till the end of the crop. Similarly, [8] also reported *T. macfarlanei* infestation on different okra varieties from 50 days after sowing, as in the present study and further observed peak mite incidence between 70 and 80 days. [11] Recorded peak infestation of two spotted spider mite, *T. urticae* on okra crop during last week of May (18 mites/leaf) and during I week of October (7.56 mites/leaf) in Cooch Behar region of West Bengal. But peak mite records in the present study at Bangalore were during II week of May (3 mites), attributed to differences in geographical location and the climatic conditions.

During the summer season, the lowest mean mite population of 0.25 mites/4 cm^2 leaf area recorded on Aruna was significantly different from higher mite population recorded on at least 13 entries. Of these 13 entries, Varsha Uphar harboured a maximum of 11.18 mites/4 cm^2 leaf area, followed by Parbhani Kranti and VRO-5 with 5.51 and 5.22 mites, respectively (Table 1).

Population of *T. macfarlanei* recorded at different intervals were added entry-wise to determine the mite load (number) for the entire season and presented in Table 2. Mite load in terms of eggs or active stages varied significantly across okra entries, so also in respect of total of eggs and the active stages. Of all the entries, variety Aruna recorded the least mite load of 1 mite/4 cm^2 leaf area in the entire season and the highest mite population was 44.73 mites on variety Varsha Uphar. About 23 entries recorded mite load of <10 mites, 10 entries with 10-20 mites and on the remaining 3 entries mite load was >20 mites/4 cm^2 leaf area during the season.

Late Kharif season (Sept. to Dec. 2014)

During the season, mean mite incidence over okra entries started from 2.13 mites/4 cm^2 leaf area at 50 DAS, which further increased gradually to 10.16, 18.21 and 33.24 mites at 65, 75 and 85 days, respectively (Table 1). The lowest mean mite population of 4.78 mites recorded on Aruna was significantly different from higher mite population recorded on other 31 entries. Of these 31 entries, Varsha Uphar and VRO-5 harboured the maximum number of mites.

Mite abundance recorded at different intervals were added entry-wise to arrive at the mite load (number) for the entire kharif season. Total mite load (eggs + active stages) varied significantly across okra entries (Table 2). Variety Aruna harboured the least number of 19.11 mites, while the highest mite load was 106.17 mites on variety VRO-5. Seven entries which recorded number of mites up to 50 mites/4 cm^2 leaf area were; Aruna (19.11 mites), Azad bhendi-2 (48.06 mites), Line-199 (43.09 mites), SB-2 (43.14 mites), Susthira (33.87 mites), Suvarna (50.51 mites), VROR-159 (48.04 mites) and *Abelmoschus manihot tetraphyllus* (46.62 mites). 27 entries had mite population of 51-100 mites and 2 varieties, which recorded the maximum number of mites (>100 mites/4 cm^2 leaf area) were Varsha Uphar (104.18 mites) and VRO-5 (106.17 mites).

Abundance of phytoseiid predator *Neoseiulus longispinosus* on okra

The major phytoseiid predator *N. longispinosus* was also recorded by counting their number on the entire leaf. These predatory mites were predominantly active only during the summer season and their activity was negligible or insignificant during the kharif season.

Predator activity, which was evident from 65 DAS, continued up to 85 DAS on almost all okra entries. Maximum mean predator activity (6.88/leaf) was on VROR-159 at 65 DAS, while, at 75 DAS maximum number of predators (5.75/leaf) was on Kashi Kranti and at 85 DAS, the number was maximum (22.63/leaf) on Varsha Uphar. The total number of predators from different intervals *i.e.*, 65 to 85 days was highest, 23.38 predators/leaf on Varsha Uphar and the lowest was 'nil' on variety Salkeerthi. Predator abundance across different varieties was also found statistically significant. Some of the entries like Aruna, Line-199, Suvarna and wild type okra harboured <1 predator/leaf in the entire season. Azad bhendi-2 (9.63 predators/leaf), KS-410 (9.5), No. 315 (9.13), Punjab-7 (9.0), Pusa Sawani (11.5), SB-2 (9.44) and VROB-178 (10.06) recorded good activity of predators during the cropping period and most of these entries also had good number of spider mites (as prey) to support the activity of predatory mites (Table 2). [9] also reported more prominent activity of same species of phytoseiid predator *Amblyseius (=Neoseiulus) longispinosus* (Evans) associated with a different species of red spider mite *T. neocaledonicus* on okra crop during summer season in the Shimoga region of Karnataka.

Lower mean incidence of spider mites during summer season across entries (9.45 mites in summer and 67.48 mites/4 cm^2

leaf area in kharif) may be attributed to greater mean activity (5.99/leaf) of phytoseiid predator *N. longispinosus* (Table 2).

Lower activity of predators (1/leaf) on entries like Salkeerthi, Aruna, Line-199, Suvarna and wild okra *Abelmoschus manihot tetraphyllus* is attributed to corresponding low population of spider mites (prey mites) on these entries. Varieties Varsha Uphar, Parbhani Kranti and VRO-5 with more number of spider mites (44.73, 22.06 and 20.87 mites/4 cm^2 leaf area, respectively) supported the activity of predators by harbouring 23.38, 5.75 and 7.13 predators/leaf, respectively. Population of spider mites (prey mites) and predatory mites across different entries revealed highly significant positive correlation (r= +0.797**), which accounted for 64% variation in spider mite population to the activity of associated phytoseiid predators. The linear regression equation, Y= 1.45+0.43X (where, Y=number of *N. longispinosus* and X=number of *T. macfarlanei*) explained their more relative activity or abundance.

Severe damage by *T. macfarlanei* on summer okra crop was reported from Navsari area of Gujarat [10], who recorded peak mite population in the middle of May due to insignificant activity of predatory mites. But significant predator activity during summer season under Bangalore conditions in the present study resulted in lower spider mite incidence in the entire season. Comparatively, higher abundance of spider mites during kharif season in the present study was due to negligible activity of predatory phytoseiid mites.

No record of natural enemies on summer okra in Dharwad region of Karnataka but recorded peak incidence of *Tetranychus* spp. during the month of May (26.12 mites/4 cm^2 leaf area) [12]. But in the present study, mean incidence of 3 spider mites/4 cm^2 leaf area (mean over 36 okra entries) was associated with more number of predators (2.5 predatory mites/leaf) during II week of May, on 65 days old okra crop.

Table 1: Incidence of red spider mite, *Tetranychus macfarlanei* on okra entries during summer (March to June 2014) and kharif (Sept. to Dec. 2014) seasons

Entries	Number of mites (eggs + active stages)/4 cm^2 leaf area									
	50 DAS		65 DAS		75 DAS		85 DAS		Mean	
	Summer	*Kharif*	*Summer*	*Kharif*	*Summer*	*Kharif*	*Summer*	*Kharif*	*Summer*	*Kharif*
Anarva	1.88	0.85	0.25	7.56	0.00	17.67	0.00	57.58	0.53	20.91
Anoop	5.50	1.25	0.12	12.37	0.25	20.14	0.00	43.94	1.47	19.42
Arka Abhay	1.75	1.35	1.87	12.25	0.99	12.46	0.00	29.74	1.15	13.95
Arka Anamika	3.13	1.70	0.74	13.75	0.13	30.22	0.06	32.06	1.01	19.43
Aruna	0.00	1.30	0.00	1.56	0.00	4.40	1.00	11.85	0.25	4.78
Azad bhendi-1	4.75	2.40	0.00	12.87	0.00	16.99	0.00	40.93	1.19	18.30
Azad bhendi-2	2.50	1.30	8.25	5.31	0.56	6.20	0.25	35.25	2.89	12.01
BO-13	1.00	1.15	0.87	11.94	0.12	12.76	0.49	52.41	0.62	19.56
BO-2	1.75	1.30	4.81	14.31	0.06	18.87	0.00	27.24	1.66	15.43
CO-3	4.93	1.00	4.44	6.31	0.13	9.17	0.13	35.31	2.40	13.02
D-1-87-5	3.38	5.65	12.71	7.99	3.31	19.77	0.37	31.87	4.94	16.32
GOH-1	0.00	0.00	0.00	10.49	2.69	12.27	5.31	35.52	1.99	14.57
HRB-231	5.00	2.50	0.69	5.38	1.38	20.87	0.06	43.31	1.78	18.01
HRB-55	4.13	2.20	3.69	12.75	0.31	22.96	0.06	31.56	2.05	17.37
JBS-2	1.13	3.75	2.69	8.75	3.06	16.10	0.43	32.23	1.83	15.21
Kashi Kranti	0.88	5.60	6.56	12.92	2.12	30.23	0.25	33.70	2.45	20.63
Kashi Leela	4.38	3.65	7.81	8.18	0.13	12.86	0.06	25.78	3.09	12.61
KS-410	0.19	1.80	2.94	7.68	2.87	19.86	12.44	23.27	4.60	13.15
Line-199	0.00	2.25	0.75	5.56	1.49	13.25	0.62	32.03	0.72	10.77
No.315	2.75	3.05	11.06	20.27	2.37	28.77	0.69	27.41	4.22	19.88
Par. Kranti	0.00	1.90	1.06	10.44	2.06	23.17	18.94	31.60	5.51	16.76
Punjab-7	4.25	2.03	2.00	8.31	2.00	16.17	0.00	44.65	2.06	17.79
Punjab-8	5.13	2.95	4.25	14.55	1.62	32.99	0.25	29.45	2.80	19.98
Pusa A-4	4.50	2.85	6.62	7.49	0.62	17.77	0.49	32.55	3.05	15.17
Pusa Sawani	0.00	3.70	0.00	12.62	5.50	25.90	10.31	47.58	3.95	22.45
Salkeerthi	0.00	1.23	0.00	10.37	0.00	19.98	3.81	23.99	0.95	13.89
SB-2	7.63	0.80	1.25	9.06	1.93	12.66	0.56	20.62	2.84	10.78
Susthira	0.00	1.35	2.31	5.06	1.12	5.98	2.00	22.16	1.36	8.47
Suvarna	0.88	1.85	0.12	10.89	0.00	19.90	0.19	17.87	0.30	12.62
Varsha Uphar	2.00	1.00	6.56	15.75	10.94	25.69	25.25	45.62	11.18	26.04
VRO-5	9.00	4.50	1.50	15.31	8.37	36.24	2.00	50.12	5.22	26.54
VROB-178	3.75	1.50	0.62	13.56	0.06	14.68	0.19	24.34	1.15	13.52
VROR-159	3.83	0.85	1.62	6.68	0.75	13.98	0.38	26.53	1.64	12.01
136-THIN	2.00	2.35	0.25	7.68	0.00	14.26	0.19	32.19	0.61	14.12
307-10-1	4.00	2.10	8.75	18.37	0.00	28.52	0.19	16.93	3.23	16.48
Wild okra - *A. manihot tetraphyllus*	2.88	1.63	0.00	1.62	0.13	2.09	0.00	41.29	0.75	11.66
Mean	2.75	2.13	3.00	10.16	1.59	18.21	2.41	33.24		

	Summer		*Kharif*	
F-test	Sig.		Sig.	
Treatments	SEM±	CD @ P=0.05	SEM±	CD @ P=0.05
Entries	0.79	2.20	2.57	7.15
DAS	0.26	0.74	0.86	2.38
Entries×DAS	1.58	4.41	5.13	14.31

DAS: Days After Sowing

Table 2: Incidence of red spider mite, *Tetranychus macfarlanei* and abundance of phytoseiid predator, *Neoseiulus longispinosus* on okra entries during summer (March to June 2014) and kharif (Sept. to Dec. 2014) seasons

Entries	*Number of spider mites (eggs+active stages)/4 cm^2 leaf area		*Number of predators (eggs+active stages)/leaf
	Summer	***Kharif***	***Summer***
Anarva	2.13	83.66	2.38
Anoop	5.87	77.69	3.50
Arka Abhay	4.61	55.79	6.75
Arka Anamika	4.05	77.72	1.88
Aruna	1.00	19.11	0.13
Azad bhendi-1	4.76	73.19	1.50
Azad bhendi-2	11.56	48.06	9.63
BO-13	2.48	78.26	1.00
BO-2	6.63	61.71	6.13
CO-3	9.61	52.07	2.63
D-1-87-5	19.76	65.27	5.88
GOH-1	8.00	58.28	4.13
HRB-231	7.12	72.06	7.38
HRB-55	8.18	69.46	3.00
JBS-2	7.30	60.83	7.75
Kashi Kranti	9.80	82.52	7.63
Kashi Leela	12.37	50.47	5.88
KS-410	18.42	52.61	9.50
Line-199	2.86	43.09	0.63
No.315	16.86	79.50	9.13
Parbhani Kranti	22.06	67.10	5.75
Punjab-7	8.25	71.14	9.00
Punjab-8	11.24	79.93	7.88
Pusa A-4	12.23	60.67	5.75
Pusa Sawani	15.80	89.81	11.50
Salkeerthi	3.81	55.57	0.00
SB-2	11.36	43.14	9.44
Susthira	5.43	33.87	1.50
Suvarna	1.18	50.51	0.38
Varsha Uphar	44.73	104.18	23.38
VRO-5	20.88	106.17	7.13
VROB-178	4.62	54.07	10.06
VROR-159	6.57	48.04	7.75
136-THIN	2.43	56.48	2.63
307-10-1	12.94	65.93	4.50
Wild okra - *A. manihot tetraphyllus*	3.01	46.62	0.63
Mean	9.45	67.48	5.99
F test	Sig.	Sig.	Sig.
SEM±	2.50	11.05	1.97
CD at P=0.05	7.18	31.72	5.66

* Total of four intervals

4. Conclusion

Under Bangalore conditions, an overall incidence of red spider mites on okra crop was more (67.48 mites) during late kharif season (Sept. to Dec.) compared to early summer season (Mar. – June) (9.45 mites). During the kharif season, of 36 okra entries screened, variety Aruna harboured less number of 19.11 mites, while the maximum number of mites recorded was 104.18 to 106.17 mites on varieties, Varsha Uphar and VRO-5. During the summer season, variety Aruna recorded the lowest mite load (1 mite) in the entire season, while the highest mite population was on variety Varsha Uphar (44.73 mites). Lower incidence of spider mites during summer season was due to the significant activity of predominant phytoseiid predator, *N. longispinosus*, noticed on almost all the okra entries. But activity of these predators was insignificant on late kharif crop of okra from September to December.

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