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Diversity of phytoseiid mites (Acari: Mesostigmata: Phytoseiidae) in the agro-ecosystems of South Gujarat, India

Sanchit S Mandape and Abhishek Shukla

Abstract
The present study was conducted during 2014–15 and 2015-16 with the objective to explore the fauna of phytoseiid mites from different agri-horticultural crops, ornamentals, weeds, wild vegetation and leaf litter at Navsari, South Gujarat, India. Overall 357 specimens of phytoseiid mites were collected from different agro-ecosystems. From these specimens, 37 known species belonging to 3 subfamilies were identified. Out of all 37 species proportion of *Amblyseius longispinosus* (Evans) specimens was the highest (18.8%) followed by *Amblyseius alstoniae* Gupta (14.8%) and *Amblyseius finlandicus* (Oudemans) (13.2%). Among different agro-ecosystems, fruit crops supported maximum numbers of species (22 species) as compared to field crops (11 species), vegetable crops (9 species), ornamental crops (9 species), narrow and broad leaf weeds (8 species) while, no phytoseiid species were recorded on wild vegetations and in leaf litter. Total 11 species were recorded from field crops, 9 species from vegetable crops, 22 species from fruit crops, 3 species from weeds and 6 species from ornamentals. Maximum numbers of species were recorded during February-March and May-June months during the survey period. The value of Shannon index of diversity for phytoseiid mites at Navsari Agricultural University campus was 0.3657 and value of Simpson's index was 0.0879, evenness of phytoseiid mite species was 0.3074 while species richness is 37.

Keywords: Predatory mite, phytoseiidae, biodiversity, South Gujarat

1. Introduction
The mites of the family Phytoseiidae have received worldwide attention because of their importance in biological control of plant mites and some of the soft-bodied insect pests of various crops. This is probably the most explored and exploited among all the predatory mites. In view of their importance, these mites have also been explored in India, from where many new species have been described since 1960. Apart from these, work has also been carried out in India on their bio-ecology, predator–prey interactions and the effects of pesticides on these mites [1]. A comprehensive account on Indian phytoseiidae dealing with 139 species of this family while in another review of Oriental Phytoseiidae included 142 species [2]. Since then, several workers have explored the phytoseiid fauna of India from different parts of the country and raised the total to 207 species. Despite those, many other species have been added to the Indian phytoseiid fauna and present exercise is to collate the available information which indicates 207 species under 21 genera of eight tribes and three subfamilies arranged as per the classificatory scheme [3]. In addition, another 4 species two under Euseius and one each under Neoseiulus and Amblyseius are described separately [4] and hence the total now comes to 211 species described/ reported till date from India. Considering the importance of this group in biological control, the present study was carried out to understand the diversity of these important predatory mites under the South Gujarat agro-climatic conditions.

2. Material and Methods
Different orchards and crop fields of Navsari Agricultural University, Navsari and nearby area was comprehensively surveyed for the collection of phytoseiid mites from different habitats like crops, vegetables, orchards, ornamental, wild plants and leaf litter during 2014-15 and 2015-16.Collection of phytoseiid mites was made three times in a year at monthly interval. Collection schedule followed for the present study was as under:

I	February-March-2014	II	May-June-2014	III	August-September-2014
IV	February-March-2015	V	May June-2015	VI	August-September-2015

Comprehensive sampling was carried out from different sources during the course of survey. Following sources were selected for the collection of phytoseiid mite specimens.

I	Crops (Cotton, Sugarcane, Rice and Sorghum)	II	Vegetables (Brinjal, Tomato, Okra and Beans)
III	Fruits (Mango, Sapota, Banana and Coconut)	IV	Broad and narrow leaf weeds
V	Ornamental and wild vegetations	VI	Leaf litter

Samples of leaves from field crops, vegetables, fruits and ornamentals were collected form ten selected plants. About 3 to 5 leaves sampled form each of ten selected plants, leaves were brought to the laboratory in individual labeled polythene bags tied with rubber band. Mites were collected with the help of a needle and brush and preserved in 90% alcohol with a few drops of glycerin. These samples were properly labeled and kept in plastic vials with tightly closed caps for further studies. The mites thus collected, were mounted on glass slides by using Hoyer's medium. These slides were studied under high power phase contrast microscope. The specimens were identified by using keys [1, 2]. Photographs and measurements of specimens were taken with the help of Stereo trinocular microscope Olympus-SZ (16) fitted with Brand Catcam-130 camera having software power Scopephoto.

Biodiversity analysis: For making biodiversity analysis, the data regarding collected specimens of phytoseiid mites were arranged according to source during each season of collection. The biodiversity count was made by using Shannon diversity index [5] to estimate species richness, evenness and species diversity by using Shannon Weiner Diversity Index [6, 7]. The per cent proportion of different phytoseiid mite species was determined and percentage of each species was calculated. This analysis was made to determine the most abundant and prevalent phytoseiid mite species in the region during course of survey.

3. Results and Discussion

An investigation was undertaken to know the biodiversity of phytoseiid mites at Navsari Agricultural University campus and the findings are presented as under:

Biodiversity of phytoseiid mites

Overall 357 phytoseiid specimens were collected from different vegetations. Out of these specimens, 37 known species belonging to 3 subfamilies of family phytoseiidae were identified. Among 3 subfamilies Amblyseiinae contributed 87 per cent of total species recorded in Navsari Agricultural University campus. Total 32 species of the subfamily Amblyseiinae were recorded on different crop plants and weeds. These 32 species were belonging to 8 different genera *viz*., *Amblyseius* (6 species), *Euseius* (8 species), *Neoseiulus* (8 species), *Paraphytoseius* (1 species), *Typhlodromalus* (5 species), *Typhlodromi* (1 species), *Typhlodromips* (1 species) and *Indoseiulus* (2 species). One genus belonging to sub family Phytoseiinae (5%) and Typhlodrominae (8%) *viz*., *Phytoseius* (2 species) and *Typhlodromus* (3 species), respectively were also recorded during the survey (Table 1 and Fig. 1). Gupta and Karmakar [5] from Gangatic plains of India also reported the similar results and recorded phytoseiid mites as major group among the samples collected.

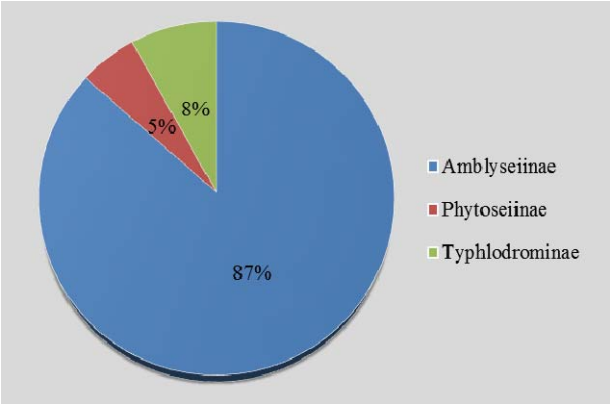

Fig 1: Different subfamilies of family phytoseiidae recorded

Table 1: Phytoseiid mites collected during 2014-15 and 2015-16

Family	Subfamily	Genera	Species numbers
Phytoseiidae	Amblyseiinae	*Amblyseius*	6
		Euseius	8
		Neoseiulus	8
		Paraphytoseius	1
		Typhlodromalus	5
		Typhlodromi	1
		Typhlodromips	1
		Indoseiulus	2
	Phytoseiinae	*Phytoseius*	2
	Typhlodrominae	*Typhlodromus*	3
Total			37

Proportion of different species in total specimens collected during survey is summarized in Table 2 and Fig. 2. Out of all 37 species proportion of *Amblyseius longispinosus* (Evans) was highest (18.8%) followed by *Amblyseius alstoniae* Gupta (14.8%) and *Amblyseius finlandicus* (Oudemans) (13.2%). The proportions of specimens of other species were very less as they occurred less frequently during the survey. The *N. longispinosus* was also reported as most frequent phytoseiid species from Gangatic plains of West Bengal, India by Gupta and Karmakar [5]. Further, most of the predatory mites belonging to three phytoseiid subfamilies and almost 93 per cent specimens and 91 per cent species belong to sub family Amblyseiinae as collected from Atlantic Forest of Sao Paulo State, Brazil reported by DeCastro and DeMoraes [8]. Thus the present findings are more or less very much close to the earlier work.

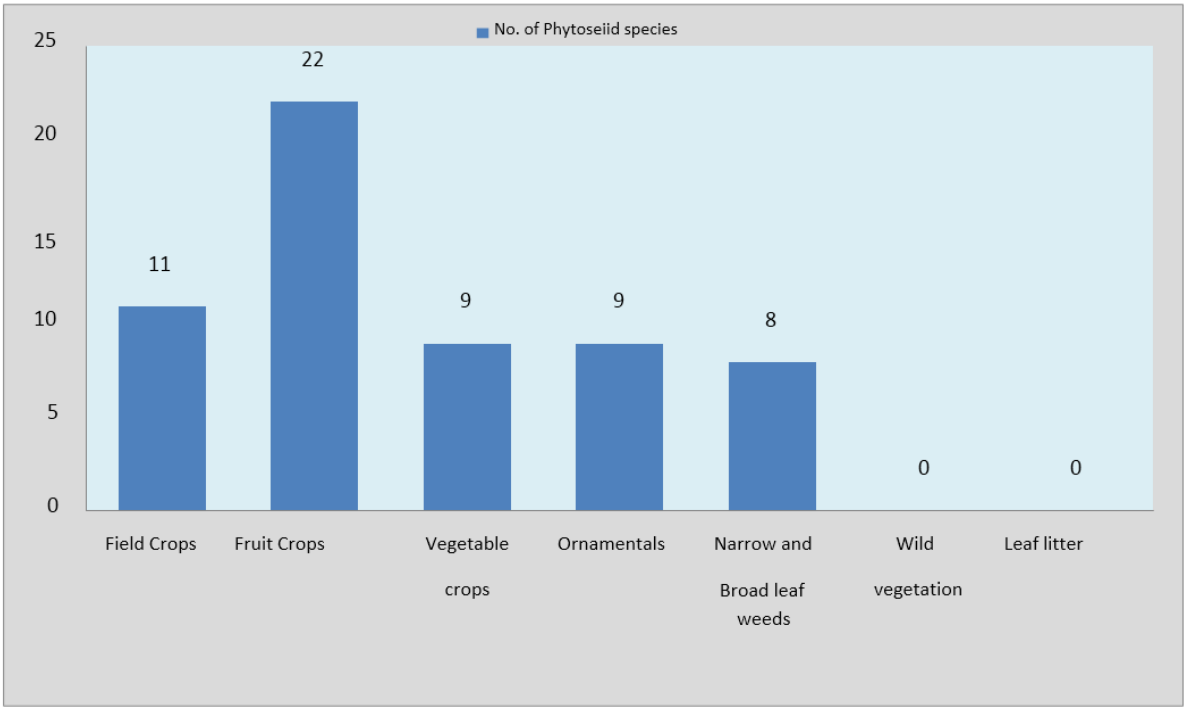

Fig 2: Phytoseiid fauna in different crop ecosystems

Table 2: Proportion of different phytoseiid species in total specimens collected during survey at NAU campus

	Phytoseiid Mite Species	Number of samples collected	Percentage (%)
1	*Amblyseius cucurbitae* Rather	10	2.80
2	*Amblyseius herbicolus* (Chant)	4	1.12
3	*Amblyseius largoensis* (Muma)	3	0.84
4	*Amblyseius orientalis* Ehara	7	1.96
5	*Amblyseius raoiellus* Denmark and Muma	1	0.28
6	*Amblyseius nucifera* (Gupta)	3	0.84
7	*Amblyseius (Euseius) alstoniae* Gupta	53	14.85
8	*Amblyseius (Euseius) bambusae* Ghai and Menon	2	0.56
9	*Amblyseius (Euseius) coccineae* Gupta	3	0.84
10	*Amblyseius (Euseius) coccosocius* Ghai and Menon	2	0.56
11	*Amblyseius (Euseius) eucalypti* Ghai and Menon	3	0.84
12	*Amblyseius (Euseius) finlandicus* (Oudemans)	47	13.17
13	*Amblyseius (Euseius) ovalis* (Evans)	7	1.96
14	*Amblyseius (Euseius) sacchari* Ghai and Menon	3	0.84
15	*Amblyseius (Neoseiulus) aceriae* Gupta	4	1.12
16	*Amblyseius (Neoseiulus) baraki* Athias-Henriot	18	5.04
17	*Amblyseius (Neoseiulus) cucumeris* (Oudemans)	13	3.64
18	*Amblyseius (Neoseiulus) cynodonae* Gupta	4	1.12
19	*Amblyseius (Neoseiulus) fallacies* (German)	9	2.52
20	*Amblyseius (Neoseiulus) indicus* (Narayanan and Kaur)	4	1.12
21	*Amblyseius (Neoseiulus) longispinosus* (Evans)	67	18.77
22	*Amblyseius (Neoseiulus) paspalvorus* (De Leon)	2	0.56
23	*Amblyseius (Paraphytoseius) multidentatus* (Swirski and Shechter)	17	4.76
24	*Amblyseius (Typhlodromalus) eucalypticus* (Gupta)	4	1.12
25	*Amblyseius (Typhlodromalus) ficusi* Gupta	4	1.12
26	*Amblyseius (Typhlodromalus) mangiferae* Chatterjee and Gupta	9	2.52
27	*Amblyseius(Typhlodromalus) sorghumae* Gupta	2	0.56
28	*Amblyseius(Typhlodromalus) arecae* Gupta	2	0.56
29	*Amblyseius (Typhlodromi) guajavae* Gupta	2	0.56
30	*Amblyseius (Typhlodromips) tetranychivorus* (Gupta)	11	3.08
31	*Indoseiuluseharai* Gupta	4	1.12
32	*Indoseiulusricini* (Ghai and Menon)	2	0.56
33	*Phytoseius (Phytoseius) jujube* Gupta	6	1.68
34	*Phytoseius (Phytoseius) swirskii* Gupta	12	3.36
35	*Typhlodromus (Amblydromella) chrysanthemi* Gupta	4	1.12
36	*Typhlodromus (Amblydromella) mori* Gupta	7	1.96
37	*Typhlodromus (Amblydromella) divergentis* (Chaudhri, Akbar and Rasool)	2	0.56
Total		357	

The phytoseiid mites were collected from different crop ecosystems. Among different crop ecosystems, fruit crops supported maximum numbers of species (22 species) as compared to field crops (11 species), vegetable crops (9 species), ornamental crops (9 species), narrow and broad leaf weeds (8 species) while, no species were recorded on wild vegetations and in leaf litter (Table 3 and Fig. 3). The present findings are more or less similar to the reports of Gupta and Karmakar [5].

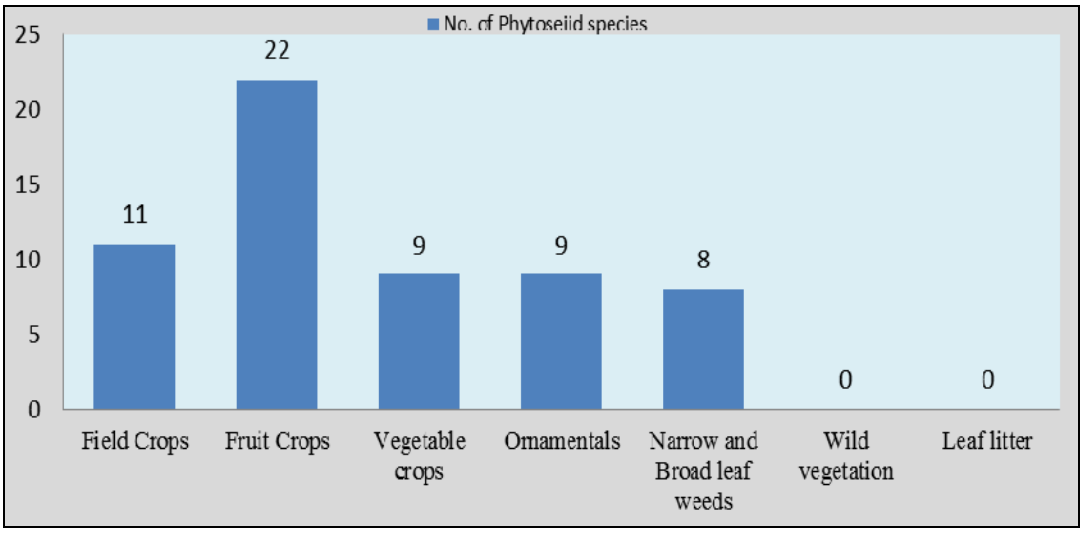

Fig 3: Phytoseiid fauna in different crop ecosystems

Table 3: Phytoseiid mites in field crops at Navsari Agricultural University campus

	Phytoseiid Mite Species	Cotton	Sugarcane	Rice	Sorghum
1	*A. cucurbitae*	-	-	-	-
2	*A. herbicolus*	-	-	-	-
3	*A. largoensis*	-	+	-	-
4	*A. orientalis*	+	-	-	-
5	*A. raoiellus*	-	-	-	-
6	*A. nucifera*	-	-	-	-
7	*A. alstoniae*	+	-	-	+
8	*A. bambusae*	-	-	-	-
9	*A. coccineae*	-	-	-	-
10	*A. coccosocius*	-	-	-	-
11	*A. eucalypti*	-	-	-	-
12	*A. finlandicus*	+	-	+	+
13	*A. ovalis*	-	-	-	-
14	*A. sacchari*	+	+	-	+
15	*A. aceriae*	-		-	-
16	*A. baraki*	-	+	-	-
17	*A.cucumeris*	-	-	-	-
18	*A.cynodonae*	-	-	-	-
19	*A. fallacies*	-	-	+	-
20	*A.indicus*	-	-	-	+
21	*A.longispinosus*	+	+	+	-
22	*A.paspalvorus*	-	-	-	-
23	*A. multidentatus*	-	-	+	-
24	*A. eucalypticus*	-	-	-	-
25	*A. (Typhlodromalus) ficusi*	-	-	-	-
26	*A. mangiferae*	-	-	-	-
27	*A. sorghumae*	-	-	-	+
28	*A. arecae*	-	-	-	-
29	*A. guajavae*	-	-	-	-
30	*A. tetranychivorus*	-	-	-	-
31	*I. eharai*	-	-	-	-
32	*I. ricini*	-	-	-	-
33	*P. jujube*	-	-	-	-
34	*P. swirskii*	-	-	-	-
35	*T. chrysanthemi*	-	-	-	-
36	*T. mori*	-	-	-	-
37	*T. divergentis*	-	-	-	-

+ Present, - Absent

Out of 11 species recorded in field crops 5 species viz., *Amblyseius orientalis, A. alstoniae, A. finlandicus, A. (Euseius) sacchari* and *A. longispinosus* were recorded on cotton, 4 species *viz., A. largoensis, A. sacchari, A. (Neoseiulus) baraki* and *A. longispinosus* on sugarcane, 4 species *viz., A. finlandicus, A. (Neoseiulus) fallacies, A. (Paraphytoseius) multidentatus* and *A. longispinosus* in rice and 5 species viz., *A. alstoniae, A. finlandicus, A. sacchari, A. (Neoseiulus) indicus* and *A. (Typhlodromalus) sorghumae* were recorded on sorghum (Table 3 and Fig. 4). According to Gupta and Karmakar [5] phytoseiid mites constitute a major mite fauna on field crops and play vital role in regulating the plant mite population.

Total 9 species were recorded from vegetable crops. Four species *viz., A. finlandicus, A. longispinosus, A. multidentatus* and *A. tetranychivorus* recorded on brinjal, *A. orientalis* and *A. longispinosus* were recorded on tomato, *A. raoiellus* on okra, *A. finlandicus, A. ovalis*, *A. longispinosus* and *Indoseiulusricini* on beans, *A. finlandicus* and *A. longispinosus* on cucurbits and *A. largoensis* and *A. finlandicus* were found on chilli (Table 4 and Fig. 5). The present findings are more or less similar to the survey carried out by Gupta and Karmakar [5].

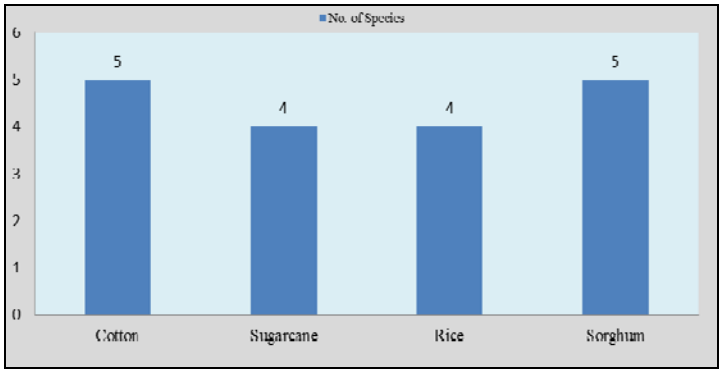

Fig 4: Phytoseiid mite species in field crops

Table 4: Phytoseiid mites in vegetable crops at Navsari Agricultural University campus

	Phytoseiid Mite Species	Brinjal	Tomato	Okra	Beans	Cucurbits	Chilli
1	*A. cucurbitae*	-	-	-	-	-	-
2	*A. herbicolus*	-	-	-	-	-	-
3	*A. largoensis*	-	-	-	-	-	+
4	*A. orientalis*	-	+	-	-	-	-
5	*A. raoiellus*	-	-	+	-	-	-
6	*A. nucifera*	-	-	-	-	-	-
7	*A. alstoniae*	-	-	-	-	-	-
8	*A. bambusae*	-	-	-	-	-	-
9	*A. coccineae*	-	-	-	-	-	-
10	*A. coccosocius*	-	-	-	-	-	-
11	*A. eucalypti*	-	-	-	-	-	-
12	*A. finlandicus*	+	-	-	+	+	+
13	*A. ovalis*	-	-	-	+	-	-
14	*A. sacchari*	-	-	-	-	-	-
15	*A. aceriae*	-	-	-	-	-	-
16	*A. baraki*	-	-	-	-	-	-
17	*A.cucumeris*	-	-	-	-	-	-
18	*A. cynodonae*	-	-	-	-	-	-
19	*A. fallacies*	-	-	-	-	-	-
20	*A.indicus*	-	-	-	-	-	-
21	*A.longispinosus*	+	+	-	+	+	-
22	*A.paspalvorus*	-	-	-	-	-	-
23	*A. multidentatus*	+	-	-	-	-	-
24	*A. eucalypticus*	-	-	-	-	-	-
25	*A.ficusi*	-	-	-	-	-	-
26	*A. mangiferae*	-	-	-	-	-	-
27	*A. sorghumae*	-	-	-	-	-	-
28	*A. arecae*	-	-	-	-	-	-
29	*A. guajavae*	-	-	-	-	-	-
30	*A. tetranychivorus*	+	-	-	-	-	-
31	*I. eharai*	-	-	-	-	-	-
32	*I. ricini*	-	-	-	+	-	-
33	*P. jujube*	-	-	-	-	-	-
34	*P. swirskii*	-	-	-	-	-	-
35	*T. chrysanthemi*	-	-	-	-	-	-
36	*T. mori*	-	-	-	-	-	-
37	*T. divergentis*	-	-	-	-	-	-

+=Present, - =Absent

Of all 22 species recorded from fruit crops 9 species viz., *A. herbicolus, A. largoensis,Amblyseius (Euseius) coccosocius, A. finlandicus, A. ovalis, A. cucumeris, A. longispinosus, A. paspalvorus* and *A. mangiferae* were recorded on mango alone followed by coconut (6 species viz., *A. nucifera, A. (Euseius) coccineae, Amblyseius (Euseius) coccosocius, A. finlandicus, A. ovalis and A. fallacies)*, mulberry (5 species viz., *A. herbicolus, A. alstoniae, A. finlandicus and A. longispinosus*), papaya (4 species viz., *A. longispinosus, I. eharai, P. jujube and P. swirskii*), banana (4 species viz., *Amblyseius (Euseius) bambusae, Amblyseius (Typhlodromalus) ficusi, A. (Typhlodromalus) arecae* and *P. swirskii*) and sapota (2 species viz., *A. alstoniae* and *A. fallacies*) (Table 5 and Fig. 6). The phytoseiid predators were found on various fruit crops from all over the world as reported by various workers in their comprehensive survey like Duso *et al.* [9] from vineyard, Kongchuensin *et al.* [10] from Mandarin citrus, Kim *et al.* [11] from apple and Raga *et al.* [12] from different nectarine cultivar. In the present study phytoseiid mites were found predominant in various crops ecosystems, thus the findings are in line with the work carried out by these workers.

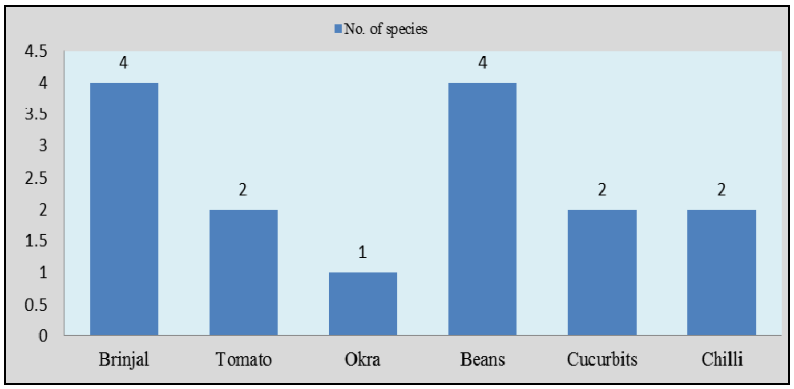

Fig 5: Phytoseiid mite species in vegetable crops

Table 5: Phytoseiid mites in fruit crops at Navsari Agricultural University campus

	Phytoseiid Mite Species	Mango	Sapota	Banana	Coconut	Mulberry	Papaya
1	*A. cucurbitae*	-	-	-	-	-	-
2	*A. herbicolus*	+	-	-	-	+	-
3	*A. largoensis*	+	-	-	-	-	-
4	*A. orientalis*	-	-	-	-	-	-
5	*A. raoiellus*	-	-	-	-	-	-
6	*A. nucifera*	-	-	-	+	-	-
7	*A. alstoniae*	-	+	-	-	+	-
8	*A. bambusae*	-	-	+	-	-	-
9	*A. coccineae*	-	-	-	+	-	-
10	*A. coccosocius*	+	-	-	+	-	-
11	*A. eucalypti*	-	-	-	-	-	-
12	*A. finlandicus*	+	-	-	+	+	-
13	*A. ovalis*	+	-	-	+	-	-
14	*A. sacchari*	-	-	-	-	-	-
15	*A. aceriae*	-	-	-	-	-	-
16	*A. baraki*	-	-	-	-	-	-
17	*A.cucumeris*	+	-	-	-	-	-
18	*A. cynodonae*	-	-	-	-	-	-
19	*A. fallacies*	-	+	-	+	-	-
20	*A.indicus*	-	-	-	-	-	-
21	*A.longispinosus*	+	-	-	-	+	+
22	*A.paspalvorus*	+	-	-	-	-	-
23	*A. multidentatus*	-	-	-	-	-	-
24	*A. eucalypticus*	-	-	-	-	-	-
25	*A.ficusi*	-	-	+	-	-	-
26	*A. mangiferae*	+	-	-	-	-	-
27	*A. sorghumae*		-	-	-	-	-
28	*A. arecae*	-	-	+	-	-	-
29	*A. guajavae*	-	-	-	-	-	-
30	*A. tetranychivorus*	-	-	-	-	-	-
31	*I. eharai*	-	-	-	-	-	+
32	*I. ricini*	-	-	-	-	-	-
33	*P. jujube*	-	-	-	-	-	+
34	*P. swirskii*	-	-	+	-	-	+
35	*T. chrysanthemi*	-	-	-	-	-	-
36	*T. mori*	-	-	-	-	+	-
37	*T. divergentis*	-	-	-	-	-	-

+=Present, - =Absent

Three species were recorded on *Cynodondactylon* (A. (*Euseius) ovalis, A. (Neoseiulus) cynodonae* and *A. (Typhlodromips) tetranychivorus*), three species on *Phalaris minor* (*A. (Euseius) eucalypti, A. (Euseius) sacchari* and *A. (Typhlodromalus) sorghumae*) two species were recorded on *Ipomoea indica* (*A.herbicolus* and *A. (Paraphytoseius) multidentatus*). Total 8 species were recorded on these three weed species (Table 6 and Fig. 7). The present findings are more or less in accordance with the earlier work carried out by Gupta and Karmakar [5].

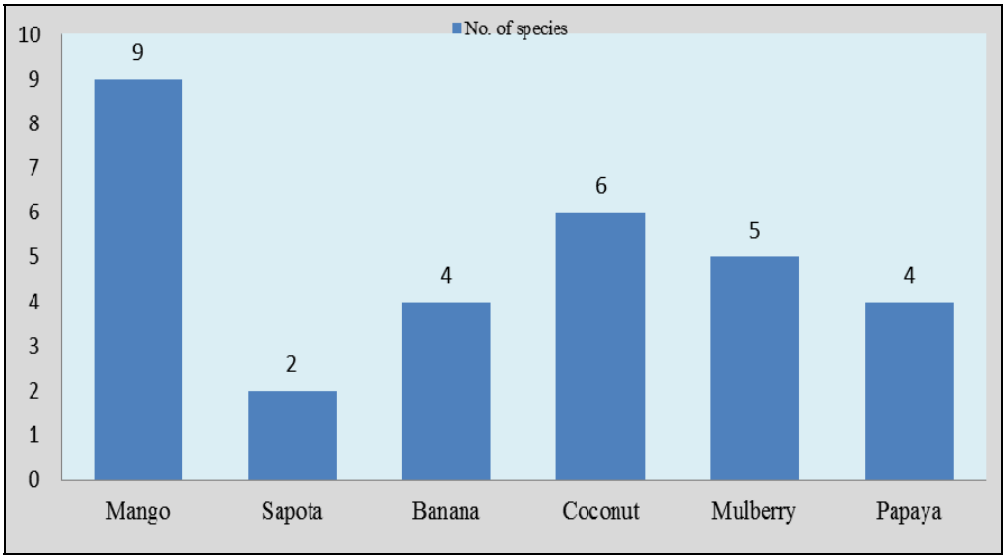

Fig 6: Phytoseiid mite species in fruit crops

Table 6: Phytoseiid mites on broad and narrow leaf weeds at Navsari Agricultural University campus

	Phytoseiid Mite Species	*Cynodondactylon*	*Phalaris sp.*	*Ipomoea sp.*
1	*A. cucurbitae*	-	-	-
2	*A. herbicolus*	-	-	+
3	*A. largoensis*	-	-	-
4	*A. orientalis*	-	-	-
5	*A. raoiellus*	-	-	-
6	*A. nucifera*	-	-	-
7	*A. alstoniae*	-	-	-
8	*A. bambusae*	-	-	-
9	*A. coccineae*	-	-	-
10	*A. coccosocius*	-	-	-
11	*A. eucalypti*	-	+	-
12	*A. finlandicus*	-	-	-
13	*A. ovalis*	+	-	-
14	*A. sacchari*	-	+	-
15	*A. aceriae*	-	-	-
16	*A. baraki*	-	-	-
17	*A.cucumeris*	-	-	-
18	*A. cynodonae*	+	-	-
19	*A. fallacies*	-	-	-
20	*A.indicus*	-	-	-
21	*A.longispinosus*	-	-	-
22	*A.paspalvorus*	-	-	-
23	*A. multidentatus*	-	-	+
24	*A. eucalypticus*	-	-	-
25	*A. ficusi*	-	-	-
26	*A. mangiferae*	-	-	-
27	*A. sorghumae*	-	+	-
28	*A. arecae*	-	-	-
29	*A. guajavae*	-	-	-
30	*A. tetranychivorus*	+	-	-
31	*I. eharai*	-	-	-
32	*I. ricini*	-	-	-
33	*P. jujube*	-	-	-
34	*P. swirskii*	-	-	-
35	*T. chrysanthemi*	-	-	-
36	*T. mori*	-	-	-
37	*T. divergentis*	-	-	-

+Present, - Absent

Among different ornamentals out of 6 species 3 species *viz*., *A. (Euseius) bambusae, Typhlodromus (Amblydromella) chrysanthemi* and *Typhlodromus (Amblydromella) divergentis* were recorded on chrysanthemum, 2 species *viz*., *A. coccineae* and *A. cucumeris* china rose, 2 species *viz*., *A. alstoniae* and *A. longispinosus* on rose and *A. (Euseius) eucalypti* and *A. (Typhlodromalus) eucalypticus* were recorded on eucalyptus. Wild vegetations and leaf litters were also surveyed for collection of phytoseiid mites, but no phytoseiid mites were recorded from there (Table 7 and Fig. 8). The phytoseiid predators were found on various floricultural crops as reported by Gupta [13]. In the present study phytoseiid mites were found predominant in various crops ecosystems, thus the findings are in line with the work carried out by these workers.

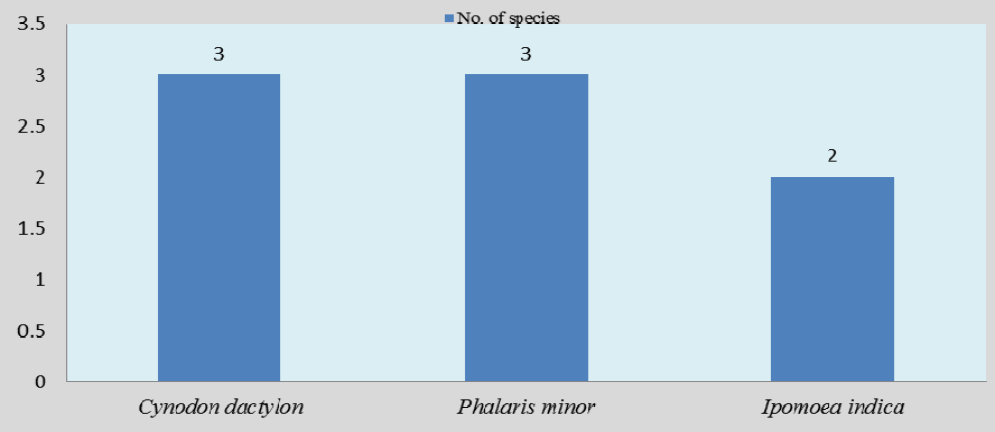

Fig 7: Phytoseiid mite species in weeds

Table 7: Phytoseiid mites on ornamentals, wild vegetation and leaf litter at Navsari Agricultural University campus

	Phytoseiid Mite Species	Ornamentals				Wild vegetation	Leaf litter
		China rose	Rose	Eucalyptus	chrysanthemum		
1	*A. cucurbitae*	-	-	-	-	-	-
2	*A. herbicolus*	-	-	-	-	-	-
3	*A. largoensis*	-	-	-	-	-	-
4	*A. orientalis*	-	-	-	-	-	-
5	*A. raoiellus*	-	-	-	-	-	-
6	*A. nucifera*	-	-	-	-	-	-
7	*A. alstoniae*	-	+	-	-	-	-
8	*A. bambusae*	-	-	-	+	-	-
9	*A. coccineae*	+	-	-	-	-	-
10	*A. coccosocius*	-	-	-	-	-	-
11	*A. eucalypti*	-	-	+	-	-	-
12	*A. finlandicus*	-	-	-	-	-	-
13	*A. ovalis*	-	-	-	-	-	-
14	*A. sacchari*	-	-	-	-	-	-
15	*A.aceriae*	-	-	-	-	-	-
16	*A.baraki*	-	-	-	-	-	-
17	*A.cucumeris*	+	-	-	-	-	-
18	*A.cynodonae*	-	-	-	-	-	-
19	*A.fallacies*	-	-	-	-	-	-
20	*A.indicus*	-	-	-	-	-	-
21	*A.longispinosus*	-	+	-	-	-	-
22	*A.paspalvorus*	-	-	-	-	-	-
23	*A. multidentatus*	-	-	-	-	-	-
24	*A. eucalypticus*	-	-	+	-	-	-
25	*A. ficusi*	-	-	-	-	-	-
26	*A. mangiferae*	-	-	-	-	-	-
27	*A. sorghumae*	-	-	-	-	-	-
28	*A. arecae*	-	-	-	-	-	-
29	*A. guajavae*	-	-	-	-	-	-
30	*A. tetranychivorus*	-	-	-	-	-	-
31	*I. eharai*	-	-	-	-	-	-
32	*I. ricini*	-	-	-	-	-	-
33	*P.jujube*	-	-	-	-	-	-
34	*P. swirskii*	-	-	-	-	-	-
35	*T. chrysanthemi*	-	-	-	+	-	-
36	*T. mori*		-	-	-	-	-
37	*T. divergentis*	-	-	-	+	-	-

+=Present, - =Absent

Maximum numbers of phytoseiid species were recorded during February-March and May-June months during the survey period. *A. alstoniae, A. finlandicus, A. baraki, A. fallacies, A. longispinosus, A. multidentatus* and *A. mangiferae* were most frequent during survey and found throughout survey period on different host plants. Due to rains phytoseiid species were less common in the months of August-September as compared to February-March and May-June (Table 8). The moderate summer and winter season was found quite good for the prey and predatory mites as reported by Gupta [13], thus closely support the present findings as the phytoseiid mites are more active in the months of February-March and May-June.

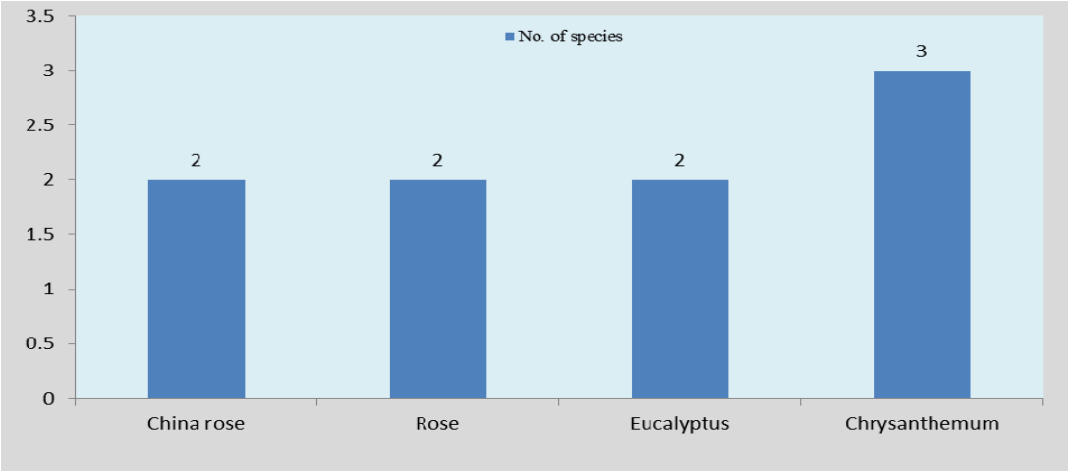

Fig 8: Phytoseiid mite species in ornamentals

Table 8: Monthly collection of different phytoseiid predatory mites at Navsari Agricultural University campus.

	Phytoseiid Mite Species	2014			2015		
		Feb- March	May- June	Aug- Sept	Feb- March	May- June	Aug- Sept
1	*A. cucurbitae*	+	+	-	+	+	-
2	*A. herbicolus*	-	-	+	-	-	-
3	*A. largoensis*	-	-	+	-	-	-
4	*A. orientalis*	-	+	-	-	+	-
5	*A. raoiellus*	+	-	-	+	-	-
6	*A. nucifera*	+	-	-	-	-	-
7	*A. alstoniae*	+	+	+	+	+	+
8	*A. bambusae*	+	-	-	+		-
9	*A. coccineae*	-	-	-	-	+	-
10	*A. coccosocius*	-	+	-	-	-	-
11	*A. eucalypti*	-	-	-	+	-	-
12	*A. finlandicus*	+	+	+	+	+	+
13	*A. ovalis*	-	-	-	-	+	+
14	*A. sacchari*	+	-	-	-	-	-
15	*A. aceriae*	-	+	-	-	+	-
16	*A. baraki*	+	+	+	+	+	+
17	*A.cucumeris*	+	+	-	+	+	-
18	*A. cynodonae*	-	+	-	-	+	-
19	*A. fallacies*	+	+	+	+	+	+
20	*A.indicus*	-	+	-	-	+	-
21	*A.longispinosus*	+	+	+	+	+	+
22	*A.paspalvorus*	-	-	+	-	-	-
23	*A. multidentatus*	+	+	+	+	+	+
24	*A. eucalypticus*	-	+	-	-	+	-
25	*A. ficusi*	-	+	-	-	+	-
26	*A. mangiferae*	+	+	+	+	+	+
27	*A. sorghumae*	+	-	-	+	-	-
28	*A. arecae*	-	+	-	-	-	-
29	*A. guajavae*	-	-	-	-	+	-
30	*A. tetranychivorus*	+	-	+	+	-	+
31	*I. eharai*	-	+	-	-	+	-
32	*I. ricini*	+	-	-	+	-	-
33	*P. jujube*	+	-	-	+	-	-
34	*P. swirskii*	+	+	-	+	+	-
35	*T. chrysanthemi*	+	-	-	+	-	-
36	*T. mori*	+	-	-	+	+	-
37	*T. divergentis*	-	+	-	-	-	-

+=Present, - =Absent

Biodiversity of phytoseiid mites

Biodiversity is the number and variety of species and other taxa in any locality, ecosystem, region or the biosphere. A diversity index is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types. The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of a diversity index is maximized when all types are equally abundant. The value of Shannon index of diversity for phytoseiid mites at Navsari Agricultural University campus is 0.3657, while, the value of Simpson's index of diversity for phytoseiid mites of Navsari Agricultural University campus is 0.0879 (Table 9)

$$\text{Shannon index } (H') = -\sum_{i=1}^{R} PilnPi = 0.3657$$

$$\text{Simpson index } (D) = \sum_{i=1}^{R} Pi^2 = 0.0879$$

Where, *Pi* is the proportion of characters belonging to the i^{th}type of letter in the string of interest (Table 9) The value of D ranges between 0 to 1, zero represent infinite diversity and 1, no diversity. This value is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give Simpson's index of diversity (1-D). The value of this also ranges between 0 and 1. The value of Simpson's index of diversity for phytoseiid mites of Navsari Agricultural University campus is 0.9121. Greater is the value, the greater the species diversity. So from this it can be stated that there is a greater diversity of predatory mites.

Evenness is a measure of the relative abundance of the different species making up the richness of an area. Evenness of phytoseiid mite species at Navsari Agricultural University campus is 0.3074.

$$E_{1/D} = \frac{1/D}{S} = 0.3074$$

Where, $E_{1/D}$ = Simpson's measure of evenness, D = Simpson's index, S = number of species in the sample.

Species richness is a measure of the number of different kinds of species present in a particular area. One would presume that more species equals more diversity. Phytoseiid species richness of Navsari Agricultural University campus is 37.

Relative abundance is a component of biodiversity and refers to how common or rare a species is relative to other species in a defined location. Among 37 phytoseiid species of Navsari Agricultural University campus *A. longispinosus* was most abundant (18.8%) followed by *A. alstoniae* (14.8%) and *A. finlandicus* (13.2%) as they found most commonly on various crop plants during survey. Other species occurred very rarely during survey and have low abundance. In past, Kongchuensin *et al*. [10] reported that *N. longispinosus* as most commonly found species while Toyoshima and Amano [14] reported that *E. finlandicus* as most dominant species whereas no such reference is available in case of *A. alstoniae*. However, all these three phytoseiid species were found most frequently from Navsari and are more or less in accordance with the earlier findings.

Table 9: Biodiversity indices of Phytoseiid mites at NAU campus

Phytoseiid species	n	N	n/N=*Pi*	Pi^2	ln *Pi*	*Pi* ln *Pi*
Amblyseius cucurbitae	10	357	0.03	0.0008	-7.1503	-0.00561
Amblyseius herbicolus	4	357	0.01	0.0001	-8.98288	-0.00113
Amblyseius largoensis	3	357	0.01	0.0001	-9.55825	-0.00067
Amblyseius orientalis	7	357	0.02	0.0004	-7.86365	-0.00302
Amblyseius raoiella	1	357	0.00	0.0000	-11.7555	-9.2236
Amblyseius nucifera	3	357	0.01	0.0001	-9.55825	-0.00067
Amblyseius(Euseius)alstoniae	53	357	0.15	0.0220	-3.81489	-0.08408
Amblyseius(Euseius)bambusae	2	357	0.01	0.0000	-10.3692	-0.00033
Amblyseius (Euseius) coccineae	3	357	0.01	0.0001	-9.55825	-0.00067
Amblyseius (Euseius) coccosocius	2	357	0.01	0.0000	-10.3692	-0.00033
Amblyseius (Euseius) eucalypti	3	357	0.01	0.0001	-9.55825	-0.00067
Amblyseius (Euseius) finlandicus	47	357	0.13	0.0173	-4.05518	-0.07029
Amblyseius (Euseius) ovalis	7	357	0.02	0.0004	-7.86365	-0.00302
Amblyseius (Euseius) sacchari	3	357	0.01	0.0001	-9.55825	-0.00067
Amblyseius (Neoseiulus) aceriae	4	357	0.01	0.0001	-8.98288	-0.00113
Amblyseius (Neoseiulus) baraki	18	357	0.05	0.0025	-5.97473	-0.01519
Amblyseius (Neoseiulus) cucumeris	13	357	0.04	0.0013	-6.62557	-0.00879
Amblyseius (Neoseiulus) cynodonae	4	357	0.01	0.0001	-8.98288	-0.00113
Amblyseius (Neoseiulus) fallacies	9	357	0.03	0.0006	-7.36102	-0.00468
Amblyseius (Neoseiulus) indicus	4	357	0.01	0.0001	-8.98288	-0.00113
Amblyseius (Neoseiulus) longispinosus	67	357	0.19	0.0352	-3.34609	-0.11786
Amblyseius (Neoseiulus) paspalvorus	2	357	0.01	0.0000	-10.3692	-0.00033
Amblyseius (Paraphytoseius) multidentatus	17	357	0.05	0.0023	-6.08904	-0.01381
Amblyseius (Typhlodromalus) eucalypticus	4	357	0.01	0.0001	-8.98288	-0.00113
Amblyseius (Typhlodromalus) ficusi	4	357	0.01	0.0001	-8.98288	-0.00113
Amblyseius (Typhlodromalus) mangiferae	9	357	0.03	0.0006	-7.36102	-0.00468
Amblyseius(Typhlodromalus) sorghumae	2	357	0.01	0.0000	-10.3692	-0.00033
Amblyseius(Typhlodromalus) arecae	2	357	0.01	0.0000	-10.3692	-0.00033
Amblyseius (Typhlodromi) guajavae	2	357	0.01	0.0000	-10.3692	-0.00033
Amblyseius (Typhlodromips) tetranychivorus	11	357	0.03	0.0009	-6.95968	-0.00661
Indoseiulus eharai	4	357	0.01	0.0001	-8.98288	-0.00113
Indoseiulus ricini	2	357	0.01	0.0000	-10.3692	-0.00033
Phytoseius (Phytoseius) jujube	6	357	0.02	0.0003	-8.17195	-0.00231

Phytoseius (Phytoseius) swirskii	12	357	0.03	0.0011	-6.78566	-0.00767
Typhlodromus (Amblydromella) chrysanthemi	4	357	0.01	0.0001	-8.98288	-0.00113
Typhlodromus (Amblydromella) mori	7	357	0.02	0.0004	-7.86365	-0.00302
Typhlodromus (Amblydromella) divergentis	2	357	0.01	0.0000	-10.3692	-0.00033
				$\sum Pi^2$=0.0879		$\sum Pi \ln Pi$= -0.3657

n= number of specimens of species.
N= Total number of specimens of all species.
Pi = Proportion of S made up of the i^{th} species.

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