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Mass production of predatory mite, *Neoseiulus longispinosus* (Evans) on two spotted spider mite, *Tetranychus urticae* Koch, using pole bean (*Phaseolus vulgaris* L.)

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Abstract
Mass production of *N. longispinosus* on *T. urticae* was studied on pole bean as well as in French bean in polycarbonate house. When the predator mites were released @ 4 per leaflet on spider mites infested 50 days old pole bean plants, a maximum of 25,933.47 predatory mites were recorded from each pole bean plant after 30 days. As a result the total number of predatory mites produced from 27 pole bean plants raised in 9.72 m^2 ground area was 7,00,203. Comparatively, a maximum of 1295.35 predatory mites per French bean plant and a total of 1,86,530 predatory mites from 9.72 m^2 ground area could be produced from 50 days old French bean plants. It was evident that using pole bean plants 900.47 predatory mites could be produced per m^2 per day as against 383.81 predatory mites per m^2 per day on French bean. Also there was 2.4 folds increase in the production of predatory mites when pole bean plants were used vis-a-vis French bean plants.

Keywords: *Neoseiulus longispinosus, Tetranychus urticae,* pole bean, French bean

Introduction
Phytoseiid mites are very effective predators used mainly in biological control of spider mites, *Tetranychus urticae* (Koch); however, phytoseiids are known to provide effective control of other mite species and some insects like thrips and white flies (Bolckmans, 2007) [1]. *Phytoseiulus persimilis* is an effective biological control agent of spider mites on vegetables in glasshouses (Chant, 1961; French *et al.*, 1976) [2, 3] and growers around the world use *P. persimilis* to control *T. urticae* and other tetranychid mites on crops grown in greenhouses and in the field (Van Lenteren, 2003; Van Lenteren, 2012) [4, 5]. Other phytoseiid species produced commercially and used in augmentative biological control of greenhouse pests include *Neoseiulus cucumeris* (Oudemans), *N. barkeri* Hughes, *N. californicus* (McGregor), *N. fallacis* (German), *Iphiseius degenerans* (Berlese), and *Galendromus occidentalis* (Nesbitt) (Zang, 2003) [6]. Among the predatory mites, the members of the family Phytoseiidae are the most promising ones, since they have shorter life cycle and they can be mass produced fairly easily (Gerson *et al.*, 2003; McMurtry *et al.*, 2013) [7, 8]. More than 2700 phytoseiid mite species are known in the world (Demite *et al.*, 2016) [9] and about 189 species from India (Chinnamadegowda, 2009) [10]. Among phytoseiids, *Neoseiulus longispinosus* (Evans) is the most potential obligate predator of many tetranychid mites in India (Mallik and Channabasavanna, 1983) [11]. This has been reported on a wide range of fruit crops, field crops and ornamentals.

The most common method of control of *T. urticae* is by using chemicals. A major problem in the control of *T. urticae* by chemicals is the mite's ability to develop resistance rapidly after a few applications (Stumpf *et al*., 2001) [12]. In recent times climate change has influenced the spider mites to assume the status of major pests on many cultivated crops and with the indiscriminate use of broad spectrum pesticides they have great potential to develop resistance to acaricides too. Use of predatory mites for the management of spider mites is a better option.

For mass multiplication of *N. longispinosus* on spider mites different host plants like mulberry, French bean, brinjal *etc*., have been used for rearing the prey mites. Among them, cultivars of beans, *Phaseolus vulgaris* L., were found better (Anonymous, 2007) [13]. Several bean varieties have been used for rearing this predatory mite. *Phaseolus vulgaris* L. is known by different names such as French bean, rajma, rajmash, haricot bean, kindey bean, snap bean, navy bean,

Field bean, dry bean, pole bean *etc*., in different parts of the world.

French bean is an herbaceous annual plant, grown within protected structures and in open fields for its edible bean, popular both as green pods and beans. Bushy varieties of the bean form erect bushes of 20 - 60 cm height, while running varieties form vines of 2–3 m long. The colour and shape of pods and seeds vary tremendously among cultivars. Duration of vine type beans is longer than the bush type variety beans and being vine type, the plants utilize vertical space effectively to give more biomass, which supports higher population of spider mites and in turn would be useful in the production of large number of obligatory predatory mites compared to French bean (Anuradha *et al*., 2014) [14].

In the present investigation, vine type variety of bean, known as pole bean was evaluated as a host plant for the mass production of *N. longispinosus* on *T. urticae*. Pole bean was used as host plant for spider mites in view of its high biomass. The main focus was to determine the appropriate age of pole bean plant for the initial release of predatory mites and the rate of release of these predatory mites intended to produce maximum number of predators. With this background, the present investigations were carried out.

Material and methods

Mass production of predatory mite, *N. longispinosus* on pole bean

Raising pole bean plants in the polycarbonate house

Pole bean plants were raised on soil inside the polycarbonate house. Pole bean seeds of the variety Classic NZ were sown in 4 ft. wide rows and 4 ft. apart and thereby maintaining 4' x 4' spacing as against its normal spacing of 2' X 2'. The wider spacing was followed to maintain isolation between the plants to check the interplant movement of spider mites as well as predatory mites. Interplant movement of mites was also checked by smearing grease all along support threads. Initially 3-4 seeds were sown in each hill and after germination (10 days after sowing) the extra seedlings were removed to retain only one good vigorous seedling per hill. The FYM and fertilizer were applied as per package of practices and the plants were watered as and when required. These plants were used for mass production of predatory mites.

Artificial infestation of spider mites (prey mites) on pole bean

The pole bean plants raised in the polycarbonate house were artificially infested with spider mites. All the plants were infested with the spider mite *T. urticae* @ 30 mites per leaflet at 30 days after sowing. The spider mites were allowed to establish on pole bean plants, which served as prey for the development of predatory mites which were inoculated later.

Initial release of predatory mites on pole bean

N. longispinosus predatory mites were released on pole bean plants which were artificially infested with spider mites *T. urticae* (in the polycarbonate house). Two variables were tested in this study. The first variable included, initial release of predatory mites at different days after infesting with spider mites/at different age of pole bean (S) and the second variable included, rate of release of predatory mites/numbers released per leaflet of pole bean (R).

First variable treatments were as follows

S_1: Initial release of predatory mites 10 days after infesting the plants with prey mites (*i.e.,* on 40 days old pole bean plant)

S_2: Initial release of predatory mites 20 days after infesting the plants with prey mites (*i.e.,* on 50 days old pole bean plant)

S_3: Initial release of predatory mites 30 days after infesting the plants with prey mites (*i.e.,* on 60 days old pole bean plant)

Second variable treatments were as follows

D_1: Initial release of predatory mites @ 2 predators per leaflet of pole bean.

D_1: Initial release of predatory mites @ 4 predators per leaflet of pole bean.

D_1: Initial release of predatory mites @ 6 predators per leaflet of pole bean.

All together there were nine treatment combinations. The experiment was laid out in factorial RBD design with three replications. Individual pole bean plant or bush was considered as one replication and the whole experiment consisted of 27 plants or bushes of pole bean.

Observations

For studying the number of predatory mites produced per pole bean plant, three leaflets, one each from top, middle and upper canopy of the pole bean plant were collected from each plant (treatment), at 10 days interval, starting from 40 days after sowing, and number of predatory mites on each leaflet was counted on both upper and lower surfaces. The total number of predatory mites per plant of pole bean was computed by multiplying mean number of predatory mites per leaflet with the total number of leaflets on the plant. The data were statistically analysed by Factorial ANOVA. The treatment means *i.e*., the number of predatory mites developed at different plant ages and at each of the predatory mite release rates were compared.

Mass production of predatory mite, *N. longispinosus* on French bean

As a standard check the French bean plant was assessed separately for the multiplication of predatory mite and compared with mass production of predatory mites on pole bean. This study was conducted in polycarbonate house. French bean plants, variety Selection-9, were used for the study. The French bean seeds were sown in 12″ diameter earthen pots (72 nos.) kept over 9.72 m^2 ground area inside polycarbonate house. The pot mixture was prepared with red soil and farm yard manure (FYM) and initially 3-4 seeds were sown in each earthen pot and after germination (10 days after sowing), the seedlings were thinned to retain only two good healthy seedlings per pot. The plants were infested with spider mites @ 10 spider mites/leaf let 20 days after sowing and further the predatory mites were released @ 4 predatory mites/leaflet 30 days after sowing. The plants were monitored regularly for the development of predatory mites and the observations on the number of predatory mites on plants were recorded following the same procedure as with pole bean 40, 50, 60 and 70 days after sowing. The mean number of predatory mites produced per plant as well as for the potted area of 9.72 m^2 was computed and data were compared with the data of production of predatory mites on pole bean plants.

Results

The present study was conducted to determine the appropriate age of pole bean plant for the initial release of predatory mites and the rate of release of these predatory mites intended to produce maximum number of predators.

Age of pole bean plant versus development of predatory mite *N. longispinosus*

The data with respect to the mean number of predatory mites per pole bean plant in different plant ages across initial predatory mite release rates are given in Table 1. Fifty days after sowing the predatory mite population data was available for only one release stage *i.e.*, predators released 10 days after infestation with prey mites (on 40 days old pole bean plants). At this stage, 1499.58 predatory mites per plant were recorded across three predatory mite release rates. Sixty days after sowing the predatory mite population data was available for two release stages *i.e.*, predators released 10 and 20 days after infestation with prey mites (on 40 and 50 days old pole bean plants. At these intervals, 6907.99 and 4087.76 predatory mites per plant were recorded, respectively.

Seventy, eighty, and ninety days after sowing, the predatory mite population data was available for all the three predatory mite release stages *i.e.*, predators released 10, 20 & 30 days after infestation with prey mites (on 40, 50 and 60 days old pole bean plants). Seventy days after sowing, the mean number of predatory mites recorded was 18,835.86 per plant where the predatory mites were released 10 days after infestation with prey mites however it was on par with 18,776.00 predators per plant recorded when the predatory mites were released 20 days after infestation with prey mites and these two treatments were significantly superior over the mite population recorded following predator release 30 days after infestation with prey mites (10,151.28 predators/plant).

The peak predatory mite production was recorded on 80 days old pole bean plants irrespective of the age of the plant for initial release of predators. When the predatory mites were released after 10, 20 and 30 days after infestation with prey mites (on 40, 50 and 60 days old pole bean plants), the corresponding mean number of predatory mites recorded was 21,598.50, 22,337.20 and 20,515.00 per plant, respectively, and were on par with each other statistically (Table 1).

Further record of the predatory mites showed a declining trend when the plant age was 90 days. The corresponding mean number of predatory mites recorded at this age was 10,913.05 and 10,763.84 mites per plant, following predatory mites released 10 and 20 days after infestation with prey mites (on 40 and 50 days old pole bean plants) and were on par with each other statistically. Mean of 8010.28 predators were recorded when predatory mites were released 30 days after infestation with prey mites (on 60 days old pole bean plants) and the predator number recorded was the lowest (Table 1).

Table 1: Production of predatory mite *N. longispinosus* on spider mite infested pole bean plants as influenced by release of predatory mites on different aged plants across their release rates, in polycarbonate house

Growth stages of pole bean	Mean number of predatory mites produced per pole bean plant after				
	50 DAS (10 DAPR)	60 DAS (20, 10 DAPR)	70 DAS (30, 20, 10 DAPR)	80 DAS (40, 30, 20 DAPR)	90 DAS (50, 40, 30 DAPR)
S_1 (40 days old)	1499.58 (37.37)	6907.99 (80.30)	18835.86 (135.98)[a]	21598.50 (146.36)	10763.84 (103.13)[a]
S_2 (50 days old)	-	4087.76 (62.75)	18776.00 (135.88)[a]	22337.20 (148.69)	10913.05 (103.97)[a]
S_3 (60 days old)	-	-	10151.28 (99.73)[b]	20515.00 (142.99)	8010.28 (89.28)[b]
F test	-	-	**	NS	**
SEM ±	-	-	(3.48)	(3.24)	(2.80)
CD (P= 0.05)	-	-	(10.40)	-	(8.36)

Note: Figures in the parentheses are √X transformed values
NS= Non significant
** = Significant at (P=0.01)

DAS= Days after sowing
DAPR = Days after predator release
S_1= Initial release of predatory mites on 40 days old spider mite infested pole bean plants
S_2= Initial release of predatory mites on 50 days old spider mite infested pole bean plants
S_3=Initial release of predatory mites on 60 days old spider mite infested pole bean plants

Initial predatory mite release rates versus production of predatory mite

The data with regard to the mean number of predatory mites produced on pole bean plants with different initial release rates (*i.e.*, @ 2, 4 and 6 predatory mites/ leaflet) across predators release at three intervals (10, 20 & 30 days after infestation with prey mites) are presented in Table 2.

Fifty days after sowing *i.e.*, 10 days after release of predatory mites, the predatory mite population recorded was highest (665.58 predatory mites per plant) when 4 predatory mites/leaflet, this was on par with release of 6 predatory mites/leaflet which produced 611.87 predatory mites per plant, however both these two initial releases rates produced significantly more number of predators compared to release of 2 predatory mites/leaflet, which produced only 222.13 predatory mites per plant.

Sixty days after sowing *i.e.*, 20 days after initial release, the highest mean number of predatory mites were recorded when 4 predatory mites/leaflet *i.e.*, 4141.85 predatory mites per plant were recorded, the lowest number of predatory mites was recorded with release rate of 2 predatory mites/leaflet *i.e.*, 3202.17 predatory mites per plant. However, all the release rates were statistically on par with respect to number of predators produced after 20 days.

Seventy, eighty and ninety days after sowing, *i.e.*, 30 days after release the highest mean number of predatory mites was produced when the released rate was 4 predatory mites/leaflet *i.e.*, 18,692.77 predatory mites per plant, which was on par with 17,921.54 predatory mites per plant produced with release rate of 6 mites/leaflet. Release rate of 2 predatory mites/leaflet produced least number of 11,148.33 predatory mites per plant after 30 days. Predatory mite production attained peak on 80 days old pole bean plant at all the three release rates. Maximum mean number of predatory mites was recorded with release rate of 4 predatory mites/leaflet *i.e.*, 23,413.39 predatory mites per plant on par with the initial release of 6 predatory mites/leaflet *i.e.*, 22,270.67 predatory

mites per plant. Release rate of @ 2 predatory mites/leaflet produced/yielded least numb predators *i.e.*, 18,766.65 predatory mites per plant.

Ninety days after sowing, *i.e.*, 50 days after release there was general decline in the predatory mite at all the release rates. Highest mean number of predatory mites were recorded in the mite release rate of 4 predatory mites/leaflet *i.e.*, 11,275.04 predatory mites per plant, on par with mite release rate of 6 predatory mites/leaflet *i.e.*, 9733.94 predatory mites per plant. These two treatments were significantly superior over mite release rate of 2 predatory mites per leaflet, which produced relatively less number of 8678.18 predatory mites per plant.

Table 2: Production of predatory mite *N. longispinosus* on spider mite infested pole bean plants as influenced by their release rates across releasing them on different aged pole bean plants, in polycarbonate house

Predatory mite release rate	Mean number of predatory mite produced per pole bean plant after				
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
D_1(@ 2/leaflet)	222.13 (8.40)^b	3202.17 (43.71)^a	11148.83 (104.00)^b	18766.65 (136.48)^b	8678.18 (92.64)^b
D_2 (@ 4/leaflet)	665.58 (14.81)^a	4141.85 (50.22)^a	18692.77 (135.03)^a	23413.39 (152.69)^a	11275.04 (105.61)^a
D_3 (@ 6/leaflet)	611.87 (14.14)^a	3651.73 (49.11)^a	17921.54 (132.55)^a	22270.67 (148.88)^a	9733.94 (98.10)^{ab}
F test	*	**	**	**	*
SEM ±	(1.31)	(4.60)	(3.48)	(3.24)	(2.80)
CD (P= 0.05)	(3.91)	(13.75)	(10.40)	(9.68)	(8.36)

Note: Figures in the parentheses are √X transformed values

*= Significant at (P=0.05)

** = Significant at (P=0.01)

DAS= Days after sowing

D_1= Initial release of predatory mites on spider mite infested pole bean plants @ 2 predatory mites leaflet^{-1}

D_2= Initial release of predatory mites on spider mite infested pole bean plants @ 4 predatory mites leaflet^{-1}

D_3=Initial release of predatory mites on spider mite infested pole bean plants @ 6 predatory mites leaflet^{-1}

Combined effect of pole bean plant age and initial release rate of predators on the production of predatory mite, *N. longispinosus*

The data of mean number of predatory mites produced per pole bean plant as a combined effect of both release of predatory mites at three different time intervals (10, 20 & 30 days after infestation with prey mites, coinciding with 40, 50 & 60 days old pole bean plants, respectively) and three release rates (@ 2, 4 and 6 predatory mites/leaflet) are presented in Table 3.

Fifty days after sowing, the number of predatory mites recorded with initial release rates of 2, 4 and 6 predatory mites/leaflet was 666.39, 1996.74 and 1835.63 predators/plant, respectively. Sixty days after sowing (20 days after release) 5095.77 to 8677.76 predatory mites/plant were recorded across three release rates on 40 days after sowing, as against 2656.06 to 5859.43 predators released at 50 days after sowing.

Seventy, eighty & ninety days after sowing, (30, 40 & 50 days after release) the number of predatory mites produced was on an increasing trend and reached the peak at 80 days after sowing (*i.e.*, after 40 days) and then the predator number declined further in all the treatments. Seventy days after sowing the number of predatory mite ranged from 6546.40 to 23,348.20 predatory mites/plant, (but the interaction between all these treatments were non-significant). Eighty days after sowing the number of predatory mite ranged from 17,767.59 to 25,933.47 predatory mites/plant, and the interaction effects were non-significant. Ninety days after sowing there was a decline in the number of predators recorded per plant as the plant age advanced? The interaction between the mite release rate and plant ages was non-significant in respect of number of predatory mites produced per plant.

Table 3: Production of predatory mite *N. longispinosus* on spider mite infested pole bean plants as a combined effect of pole bean plant age and release rates of predatory mites, in polycarbonate house

Treatments	Mean number of predatory mites produced per pole bean plant after				
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
S_1D_1	666.39 (25.22)	6950.46 (80.08)	13745.57 (116.79)	19985.24 (140.72)	9402.06 (96.30)
S_1D_2	1996.74 (44.46)	8677.76 (89.49)	21010.20 (144.28)	22984.68 (151.04)	12155.62 (109.71)
S_1D_3	1835.63 (42.45)	5095.77 (71.32)	21751.82 (146.86)	21825.58 (147.34)	10733.85 (103.39)
S_2D_1	-	2656.06 (51.07)	13154.52 (114.52)	18547.13 (135.52)	9301.32 (96.04)
S_2D_2	-	3747.81 (61.18)	23348.20 (152.59)	25933.47 (161.01)	12457.84 (111.48)
S_2D_3	-	5859.43 (76.00)	19825.30 (140.53)	22531.02 (149.54)	10979.99 (104.41)
S_3D_1	-	-	6546.40 (80.70)	17767.59 (133.20)	7331.19 (85.59)
S_3D_2	-	-	11719.93 (108.22)	21322.02 (146.00)	9211.67 (95.65)
S_3D_3	-	-	12187.53 (110.28)	22455.41 (149.75)	7488.00 (86.52)
F test	-	-	NS	NS	NS
SEM ±	-	-	(6.03)	(5.61)	(4.84)

Note: Figures in the parentheses are √X transformed values

NS= Non significant

DAS= Days after sowing

S_1= Initial release of predatory mites on 40 days old spider mite infested pole bean plants

S_2= Initial release of predatory mites on 50 days old spider mite infested pole bean plants

S_3=Initial release of predatory mites on 60 days old spider mite infested pole bean plants

D_1= Initial release of predatory mites on spider mite infested pole bean plants @ 2 predatory mites leaflet^{-1}

D_2= Initial release of predatory mites on spider mite infested pole bean plants @ 4 predatory mites leaflet^{-1}

D_3= Initial release of predatory mites on spider mite infested pole bean plants @ 6 predatory mites leaflet^{-1}

Production of predatory mite *N. longispinosus* on pole bean

Among all the treatment combinations the maximum number of predatory mites produced was 25,933.47 per pole bean plant 80 days after sowing (*i.e.*,40 days after release) when the predatory mites were inoculated on spider mites infested pole bean plants @ 4 predatory mites per leaflet on 50 days old pole bean plants. 27 pole bean plants were used for the entire experimentation. The area that could be occupied by these 27 pole bean plants when they are planted in their normal spacing of 2' X 2' is 9.72 m^2. By calculation, the total number of predatory mites that could be recovered from these 27 plants (9.72 m^2) would be 7,00,203 predatory mites.

Relative production of predatory mite *N. longispinosus* on *T. urticae* on French bean in polycarbonate house

The predatory mite *N. longispinosus* was also multiplied on spider mite infested French bean plants in polycarbonate house, for comparing with production of predatory mites on pole bean. The French bean plants were raised in 72 earthen pots (occupying 9.72 m^2 area) and infested with spider mites 20 days after sowing @ 10 spider mites/leaf let, later 30 days after sowing (*i.e.*, after 10 days release) predatory mites were released @ 4 mites per leaflet. The mean number of predatory mites recorded on French bean plant 40, 50, 60 and 70 days after sowing, *i.e.*, 10, 20, 30 & 40 days after predator release was 449.51 ± 44.312, 1295.35 ± 92.78, 887.59 ± 49.54 and 398.17 ± 60.64 predatory mites per plant, respectively. There was a steady increase in the number of predatory mites from 40 days to 50 days after sowing (10-20 days after initial predator release) and further their number started declining due to senescence of plants and reduced availability of prey mites for feeding by the predatory mites. Maximum number of 1295.35 ± 92.78 predatory mites per plant was produced 50 days after sowing *i.e.,* 20 days after release and altogether 1,86,530 predatory mites per 9.72 m^2 area could be produced.

Discussion

Studies similar to present study were conducted by many earlier workers. Mallik *et al*. (1999) [15] studied the mass production of predatory mite *A.* (=*N.*) *longispinosus* on potted French bean plants in glass house. They suggested raising French bean plants in earthen pots, infesting them with spider mites at 9 leaflet stage (17 days after sowing), inoculating with predatory mites 9 days later and harvest of predatory mites after 12 days. They could harvest 4715 predatory mites in 38 days from sowing. The number is low compared to 1295.35 predatory mites obtained per plant in the present study. More number of predatory mites obtained in the present study is attributed to more number of predatory mites initially released and sufficient time was allowed for the multiplication of the predatory mites.

Jayasinghe (2008) [16] conducted a study on large scale production of the predatory mite, *N. longispinosus* on French bean plants in polycarbonate house. French bean plants were infested with prey mites *T. urticae* @ 10 per leaflet, on 20 days old French bean plants, followed by release of the predatory mites @ 2 or 4 per leaflet after 10 days. In this study he could record 10,83,420 to 20,00,700 predatory mites per 600 plants (40.5 m^2), when harvested 50 to 65 days after sowing. The predatory mite productivity in this study was slightly more than in the present study because of the good plant growth condition which contributed for higher prey mites as well as predatory mites yield.

Hoy *et al.* (1982) [17] mass produced the predatory mite *Typlodromus occidentalis* (Nesbitt) on *T. urticae* as prey on pinto bean plants in green house. They could produce over 1.5 million predators in 45.5 m^2 green house bench space area from June to September (120 days period), which would be equal to around 274.7 predatory mites per m^2 per day. This number is nearer to the production of predatory mites on French bean plants but much lower than that produced on pole bean plants in the present study. This difference may be because of change in the host plant as well as the predatory mite species. They also found that the suitable initial predatory: prey ratio to be released to harvest maximum number of predatory mites was 1:20 to 1:40.

Hegde and Patil (1994) [18] reported on the multiplication of the predatory mite *A.* (=*N.*) *longispinosus* on potted cotton (MCU-5) plant containing cotton red spider mite, *Tetranychus macfarlaeni* Baker and Pritchard. Gravid females of *A.* (=*N.*) *longispinosus* were released at densities of 1, 2, 3, 4 and 5 pairs per plant and obtained a total of 4, 7, 12,15 and 20 predators per plant in the respective treatments, 10 days after release of predatory mites. The low recovery of predatory mites in this study could be attributed to change in the host plant and least time allowed between initial release of predatory mites and the harvest.

Heikal (2003) [19] mass produced the predatory mite *Phytoseiulus macropilis* (Banks) in greenhouse condition. The predator was reared on *T. urticae* feeding on bean plants grown either in trays or on soil, in green house. From this study he could record more number of predators in both the conditions during spring and autumn seasons obtaining an yield of 10,80,600 and 15,28,800 predators per 4 m^2 area on bean plants in soil and 10,80,000 & 7,20,000 predators per 4 m^2 area on bean trays in spring and autumn seasons, respectively. The number of predatory mites harvested in this study was very high compared to the present study; this higher number may because of different species of predatory mite.

Morales-Ramos and Rojas (2014) [20] designed a stacked modular cage system for continuous production of the predatory mite *P. persimilis* on *T. urticae*. The spider mite infested red kidney bean (*Phaseolus vulgaris* L.) or lima bean (*Phaseolus lunatus* L.) leaves were provided to the predators inside the cage. During six months evaluation period, a weekly mean of 20,894.9 ± 10428.5 *P. persimilis* from 36.7 ± 17.0 cages were collected. This method describes the production of predatory mites by utilizing the prey mites established on host plants in the poly house, a deviation from the present study which involves the production of predatory mites on spider mite infested pole bean plants in the polycarbonate house.

Kongchuensin *et al.* (2006) [21] also conducted a study to determine the initial predator: prey ratio appropriate to harvest large number of the predatory mite, *N. longispinosus*. The results of the study showed that the optimum ratio for the best harvest of *N. longispinosus* on cowpea was 1:20 or 1:40. This study also revealed that the best harvesting time of *N. longispinosus* would be two weeks after initial release with predatory mites. Three weeks after release, the physiological condition of the bean plants was found deteriorated due to severe mite injury as a result, the prey mites abandoned such plants, followed by dispersal of predatory mites which resulted in fewer number of predators recorded on such plants.

The present results are in conformity with the above study. The initial predatory: prey ratio when worked out in the present study ranged from 1: 1.38 to 1:79.1 at 40, 50 and 60 days after sowing pole bean which resulted in the production of maximum number of predatory mites. When predatory mites were not harvested at appropriate time *i.e.*, at 80 days after sowing, there was deterioration in the quality of pole bean plants due to heavy mite injury and prey mite started leaving the plants thereby reducing the number of predatory mites after 80 days age.

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