# SPIDERS AS BIO-CONTROL AGENTS IN HORTICULTURAL ECO-SYSTEMS WITH SPECIAL REFERENCE TO THEIR ROLE IN MANGO ORCHARDS

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# SPIDERS AS BIO-CONTROL AGENTS IN HORTICULTURAL ECO-SYSTEMS WITH SPECIAL REFERENCE TO THEIR ROLE IN MANGO ORCHARDS

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## *CERTIFICATE*

This is to certify that the thesis entitled **"SPIDERS AS BIO-CONTROL AGENTS IN HORTICULTURAL ECO-SYSTEMS WITH SPECIAL REFERENCE TO THEIR ROLE IN MANGO ORCHARDS"** submitted by **Mr.H. GURUPRASAD,** in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL ENTOMOLOGY**, to the University of Agricultural Sciences, Bangalore is a record of research work carried out by him, under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or similar titles.

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# INTRODUCTION

# I INTRODUCTION

Mango (*Mangifera indica* L.), undoubtedly the king of fruits, is grown in more than 87 countries in the world. India ranks first, with an area of 1.13 million hectares with a production of 9.22 million tonnes (Chada, 1996), contributing more than 70 per cent to the world mango production. It is largely grown in U.P. (34%), A.P. (12.8%) and Bihar (3.2%) (Chada, 1989).

Mango is distributed throughout the length and breadth of the country except the hilly region up to an altitude of 915 meters from mean sea level. Being a rich source of vitamin A and C, it also possesses unique nutritional and medicinal values. The reports on the area under mango cultivation in India vary widely, because a large number of trees are grown on road sides or in isolation, on boundaries of fields. All the cultivated mango varieties in India, belong to a single species, *Mangifera indica* L., an important member of the family Anacardiaceae. A large number of insect-pests attack the crop causing considerable damage to all parts of the plants, those affecting flowers and fruits are the most serious and may result in total loss of crop. The major pests of mango are, mango hopper (*Idioscopus niveosparasus* L., *I. clypealis* L., *I. nagpurensis* L.), mango mealy bug (*Drosicha mangiferae* G.), mango leaf webber (*Orthaga euadrusalis* Walker), mango fruitfly (*Bactrocera dorsalis* H.), and stem borer (*Batocera* sp.).

In order to keep productivity with a study pace, several chemical molecules have been tested and used to combat the mango pest complex. As pesticides are not only hazardous for beneficial fauna, but also created pesticide resistance and resurgence problems in insects. In the present context, it was felt necessary to explore the possibility to use Eco-friendly management strategies using bio-control agents to tackle this problem. Of the several bio-control agents, spiders form one of the most ubiquitous groups of organisms in the animal kingdom. They play an important role in limiting the pest populations from reaching harmful levels. Yet little attention has been paid to their possible use in mango insect pest management.

Spider community of mango ecosystem can be conveniently divided into two groups, the canopy habitat type and the under part habitat type. Each type of community in turn is divided into snarer (webbing) and hunter sub communities. The spider injects poison through its bite and paralyses the prey, digests its internal organs with digestive enzymes and sucks out body fluid leaving only a compressed ball of virtually unrecognizable exoskeletal fragments. Spiders are amongst the most omnipresent and numerous predators in both agriculture and natural ecosystems, with an average of 50,000 individuals per acre in vegetated areas (Zahl, 1971). They are nature's master spinners of silken webs and highly proficient predators. The insect pest world run amok, creating havoc for our health and food resources in their absence. Unfortunately, spiders are also the most feared and maligned of nature's smaller animals due to the infamous poisonous species such as the black widow, *Latrodectus mactans* (Fabricius) with a more potent venom, drop for drop, than poisonous snakes (Gertsch, 1979).

Approximately 1,20,000 species of spiders occur world wide and only one fourth of the total fauna has been named (Levi and Levi, 1968 ; Dondale, 1979 ; Gertsch, 1979 ; Roberts, 1985). The potential of spiders as natural control agents of arthropod pests (Reichert and Lockley, 1984) has aroused interest in learning more about them, especially their abundance and species composition in different ecological systems (Whitcomb *et al.*, 1963; Turnbull, 1966; Altieri and Whitcomb, 1979, 1980; Doane and Dondale, 1979). Species of *Lyssomanid*, especially *Lyssomanes sikkimensis* (Tikadar) has been reported to be beneficial predator on mango leaf hopper, *Idioscopus clypealis* (Lethierry) (Sadana and Meena Kumari, 1991).

Spiders being carnivorous, feed potentially on insect pests. Their presence in the mango orchards may have direct and indirect influence on the population fluctuation of all insect pests. In order to understand the role of spiders on population dynamics of insects, the species composition and seasonal abundance of spiders, the present study was undertaken with the following objectives :

1. To conduct a survey for the collection of spiders in and around Bangalore
2. To study the biology and feeding potential of the spider (*Argiope pulchella* Thorell).
3. To study the webbing pattern of spiders.
4. To study the effect of interference behaviour of spider (*Argiope pulchella* Thorell) with the Reduviid (*Endochus inornatus* Stal.) under laboratory condition.

# REVIEW OF LITERATURES

# II REVIEW OF LITERATURE

Since the literature available on spiders of mango is scanty for comparison, the available literature on the other related ecosystems are also reviewed. The objective-wise review of literature included those pertaining to studies on various aspects on ecology, distribution and role of spiders in pest management in different agro-ecosystems and is presented here under.

## 2.1 Survey for spiders

### 2.1.1 Abundance of spider fauna in different agro-ecosystems

A survey conducted in Quebec during 1970-75 revealed that *Theridion murarium* Emerton, *Araneilla displicata* Hentz and *Philodromus rufus* Walk. were dominant species in the apple orchard (Dondale *et al*., 1979). Mansour *et al* . (1982) reported species of spiders(belonging to 22 families) in citrus grooves in Florida. Barrion and Talyo (1988) reported that a total of 993 spiders belonging to 16 different families, 44 genera and 70 species in citrus orchards in Batangas, Laguna and Davao city.The dominantly occurring species were *Erofurcata* sp. (Villers), *Neoscona* spp., *Metaphidippus galathea* Walckenaer), *Leucauge decorata* (Blackwall) and *Oxyopes javana* Thorell in Batangas ; *O. javanas*, *Argyrodes* sp., *M. galathea, Neoscona* spp. *Cheiracanthium* sp. in Laguna and *Oxyopes* in Dava city.

A Survey in wetland rice fields of Orissa showed the highest representatives,three species of Araneidae (7 species) followed by Salticidae, Clubionidae and Tetragnathidae each (Ghode *et al*., 1985). In Israel, a survey conducted for a year revealed that *Theridion* spp. represented 63 per cent and *Clubiona* sp. 20 per cent of all spiders collected on avocado foliage, while Lycosids represented 58 per cent and Linyphiids 19 per cent of the total captured in pitfall traps (Mansour *et al*., 1985). Gupta *et al*. (1986) surveyed rice fields in Andhra Pradesh and the relative abundance of families of spiders was Tetragnathidae (47 per cent of species), Araneidae (20 per cent), Lycosidae (16 per cent), Thomisidae (10 per cent), Clubionidae (4 per cent) and Oxyopidae (2 per cent).

In Northern Israel, a survey conducted during 1980-81 revealed that *Cheiracanthium mildei* L. Koch and *Theridion* sp. formed 52 and 43 per cent of the total, respectively. The families Gnaphosidae and Lycosidae accounted for 43 and 35 per cent respectively, of the total spiders captured in pitfall traps in the undercover (Mansour and Whitcomb, 1986). Meenakumari (1986) showed *L. sikkimiensis, Myrmarachne tikaderi* sp. nov. and *Marpissa tigrina* Tikader formed 43.2, 27.46 and 23.2 per cent respectively, and *Zygoballus pateli* sp. nov. *M. ludhianaensis* Sadana and Kaur and *Salticus scenicus* Clerck. 3.46, 2.3 and 0.75 per cent respectively, of the total spider population in mango. Sengonca *et al.* (1986) reported Araneidae and Therididae predominant in apple orchards in the Bonn-Meckenbein region. Lee and Geon (1987) reported *Pirataprocurms* sp., *Stermopsnipponicus* sp., *Clubiona rostrata* sp. and *Phrusolithus prennatus* sp. as dominant in latifolia tree.

Yan and Wang (1987) recorded 72 species in 19 families of spider. The dominant species were *Clubiona* sp., *Tetragnatha* sp., *Mymarachnegisti* sp., *Theridion octamaculatum* (Bosenberg), *Uloborus Walckenarius* (Latreille), *Eriginsdium graminicolum* (Sunderall) and *Araneus ejasmoidisi* (CL.) in citrus grooves. In Gujarath, a survey conducted during 1984-86 revealed that Theridiidae and Lycosidae as dominant spider and *Coleasoma blundan* Cambridge of Theridiidae and *Pardosa bimarica* Simon of Lycosidae were abundant spider species of tur (Patel *et al.*, 1988).

Dulia and Yadav (1994) recorded 13 species of predatory spiders on hybrid cotton eco-system in Anand (Gujarath). The observations showed that hunting species contributed a major proportion (63.15%). Easwaramoorthy *et al.* (1994) reported 57 species of spiders belonging to 13 families of Araneae in sugarcane ecosystem. Only two species, *viz., Hipposa greenalliae* Blackwall and *Cyrtophora cicatrosa* Stoliczka were abundant. Michel *et al.* (1995) observed hunting spiders (*C. inclusum* Hentz, *Trachelas pacificus* Chamberlin and Ivie, *Oxyopes* spp. and *M. vitis* Cockerell) to be dominant in grapevine yards.

Satish Kumar (1996) recorded 11 species of spiders in mango orchards. Population of Lycosid spiders was 41.54 per cent out of which, *Lycosa prolifera* (Pocock), *Lycosa mackenzei* (Gravely) and *Pardosa chambaersis* (Tikader and Malhotra) formed 12.46, 14.54 and14.54 per cent of the population, respectively. Salticids formed an abundant group with 38.17 per cent population. *Olios obesuls* (Pocock) and *Neoscona theisi* (Walck) formed 14.62 and 6.23 per cent, respectively of the total spider population. Venkateshalu (1995) reported 20 species of spiders belonging to 12 genera representing 9 families in paddy field in Mandya and Bangalore districts. The dominant occurring families were *Lycosidae*, *Salticidae* and *Theridae*, respectively.

### 2.1.2 Population dynamics of spiders in relation to season, pest density and weather parameters

#### 2.1.2.1 Season and weather parameters

Elliot (1930) made ecological studies of beech maple forest and found seasonal succession of spiders. Dondale (1958) observed that fluctuation in spider population occurred due to some general environmental influences in a study on apple orchards. There were two peaks in the number of active spiders in apple orchards, a small one in the spring and a large one in the late summer. The period of decline was found in the late June or early July and in the late September and October. Turnbull (1960) too observed two peaks in population of active spiders on Oak, one in the mid-summer and other in October. Chew (1961) studied spider fauna of southern desert shrub community and found that the density was lowest in February. The different species showed population peaks either before or after June when temperature was maximum and humidity was minimum.

Seasonal succession of spiders with some forms abundant, early in the season and others later and some even with two population peaks were observed by Whitcomb *et al.* (1963). Ecology of spiders of a Finnish forest was studied by Huhta (1965) and it was found that there were two maxima, the first one in the spring and second in the autumn. The abundance of insects and spiders in an ecosystem is influenced by seasonal fluctuations.

This has been observed by other workers like Nentwig (1985), Losalle and Aramando (1985).

Easwaramoorthy *et al.* (1994) reported that the population of *H. greenalliae* and all the 57 species had associated negatively with maximum temperature and positively with relative humidity. Schuster *et al.* (1994) made field observations on the population structure of three ctenid spiders and found that spider density in all three species was positively correlated with the number of retreats offered by their plants. Arora and Monga (1993a) found that there was only one peak population of spiders in October on pigeon pea which coincides with peak population of insect pests.

**2.1.2.2 Pest density**

Singh (1967) found positive correlation between population of sugarcane pest, *Pyrilla perpusilla* (Wlk) and the spider, *Clubiona drassodes* (Cambridge). Sadana and Kaur (1974) and Sadana and Sandhu (1977) studied the spider fauna of citrus and grapevine orchards respectively and found positive correlation between spiders and pest population.

Srivastava *et al.* (1979) studied on natural control of insect pests of mangoes and reported 12 species of spiders belonging to 8 families, prey up on mangohopper. Mansour *et al.* (1980c) also reported significant decrease in damage caused by larvae of apple pest, *Spodoptera littoralis* (Boisdoval) on trees occupied by spiders as compared to those from which spiders were removed.

Positive correlation was observed between the population of spiders and mangohoppers by Meenakumari (1986) and Venkateshan *et al.* (1992). Similarly, Satishkumar (1996) found that seven dominant spider species had significant correlation with population of insect pests on mango. Arora and Monga (1993a) found that there was a strong positive correlation between the spider population and population of insect pests.

#### 2.1.2.3 Diversity of spiders

Uetz (1975) observed that a seasonal peak in species diversity ($H^1$) and species richness in mid-summer was significantly correlated with prey abundance but not with temperature, relative humidity or rainfall. Hatley *et al.* (1980) reported spider species diversity and found that the number of species and guilds were positively correlated with indicators of shrub volume and shrub foliage diversity. Okuma and Yuzo (1982) reported that diversity of spiders was highest in the natural forest than the newly created area such as bare ground and lawns. Sinha and Biswas (1983) reported that abundance and diversity of spiders in three habitats at Totopora, West Bengal had a direct correlation with complexity of habitat in terms of diversity and density of vegetation types and cubic area occupied by it. Lee and Geon (1987) observed species diversity of spiders in latifoliate tree stand. Barrion and Taylo (1988) reported that spider diversity was highest in Batangas followed by Laguna while it was least in Dava city.

Dobel *et al.* (1990) reported vegetation structure and elevational factors in relation to influence the distribution, abundance and community structure of spiders in intertidal marshes. Niemala *et al.* (1994) found that the overall abundance and species richness was highest in early season, i.e. May and June.

## 2.2 Biology of spiders

Biology of *Misumenops celer* (Hentz) was studied in the laboratory. The number of egg sacs per female varied from 1 to 3 and the number of eggs per sac varied from 55 to 234. Males reached maturity after 4 or 5 instars, and females attained the adult stage after 7 instars. The I instar remained inside the egg sac. The period from egg to attainment of adult stage was 85-169 days for male and 118-311 days for females (Muniappan and Chada, 1970). Suzuki and Kiritani (1974) studied the reproduction of *Lycosa pseudoannulata* (Boeset.strand) using *Nephotettix cincticeps* (Uhler) as prey. They showed that malnourished females were less fecund, with a prolonged pre-oviposition period. When adult females consumed four prey per day, oviposition began nine days after emergence and the number of eggs/egg sac increased as the amount of food consumed daily by the adult increased. They also established a linear relationship that females produced about three eggs for every prey consumed. Biology of predatory wolf spider, *L. pseudoannulata* was studied in laboratory using *Nilaparvatha lugens* (Stal) as a prey. The longevity of the adult was on an average 147.6 days and incubation period of egg lasted for 59 days. Adults were able to survive for seven days without free water and over a month without food (Gavarra and Raros, 1975).

Charles *et al.* (1978) studied the life history of the orbweaving spider, *Tetragnatha laborisa* Hentz, under field and laboratory conditions. The development from the egg to adult stage required Ca 12 months. These were 9 instars including the adult stage. Males lived an average of 16 days, while females lived an average of 21 days.

Mansour *et al.*,(1980) studied the biology of *Chiracanthium mildei* L. (Koch) in laboratory using 1-6 day old *Spodoptera* larvae as prey. They reported that Males required a mean of 182 (137-207) days after hatching to reach maturity, became adults following 7-8 moults and lived for an average of 73 days as adults. Females required a mean of 231 (191-286) days after hatching to mature, reached adulthood after 9-10 moults, and lived for an average of 240 days as adults. Females oviposited from 1 to 5 times (average 1.8) at 30 day intervals. They produced a mean of 35 eggs in the Ist batch and 32 eggs in the 2nd batch. Samal and Misra (1985) studied the biology of *Lycosa chaperi* Simon. They observed that the total duration of spiderlings varied from 36 to 50 days. The copulation lasted for 30 to 60 minutes and the incubation period for 9-15 days. Three to five cocoons (consisting 80-120 eggs/sac) were produced by a female spider. The rate of consumption of nymph and adult brown planthopper by wolf spider was 10.4 and 12.5 respectively.

Biology of *Rhene indicus* (Tikader) and *Cheiracanthium* sp. was studied by Sathiamma *et al.* (1986) under laboratory conditions. The different life stages were reared using caterpillars of *Opisina arenosella* (Walcker) as prey. *R. indicus* males required a mean of 83 (range 67-104) days after hatching to maturity, reached adulthood after six moults and lived for an average of 51.25 (range 25-77) days. Females required a mean of 79.5 (range 59-105) days after hatching to maturity, reached adulthood after six moults and lived for an average of 139.83 (range 71-296) days. Females were found to oviposit for 6-31 days from mating, producing 7-10 broods and 9-37 spiderlings emerged from single egg mass. Males of *Cheiracanthium* sp. required a mean of 214.6 (range 162-261) days after hatching to maturity, reached adulthood after 12 moults, and lived for an average of 74.5 (range 35-122) days as adult. Females required a mean of 207 (range 169-248) days after hatching to maturity, reached adulthood after 12 moults and lived for an average of 85.7 (range 51-127) days as adult. Females oviposited in 8-30 days after mating, producing one to four broods and 9-86 spiderlings emerged from a single egg mass with an average of 49.

Meenakumari (1986) recorded the life history of *L. sikkimiensis* which moulted six times to reach adulthood. The total developmental duration occupied was 57-239 days. The number of eggs varied from 19 to 66 in different cocoons with an incubation period of 5-9 days after oviposition . Kim and Lee (1994) found that *P. subpiraticus* (Bosen berg and Strand) had laid 60.5 eggs/egg-sac and the period of maternal care of spiderlings lasted for 3 days.

Similarly Dhulia and Yadav (1994) studied the biology of *Oxyopes ratnae* Tikadar. The spiders laid on an average 2.8 egg masses during the life span. The average incubation period was 10.1 ± 0.74 days and the number of spiderlings emerging per egg mass varied from 30-42, with an average of 35.6 ± 3.82. Males and females passed through 10 and 11 instars, respectively to reach maturity. Male and female spiderlings took an average of 187.20 ± 4.87 and 259.50 ± 4.18 days, respectively to complete the development from egg to adult. The total average life span of adults in case of male and female was 305.80 and 358.80 days, respectively. The males and females mated readily under laboratory conditions and the mating period lasted for few seconds.

Rearing the wolf spider, *L. pseudoannulata* Boes. upto third instar on the nymphs of *N. lugens* and then with the grubs of *Tribolium castaneam* (Herbst) was the best for the spiders, taking minimum time to reach adulthood with high fecundity and high percentage of individuals reaching the adult stage compared to the other preys used. *Aphis craccivora* Koch. was found to be a poor prey for the multiplication of *L. pseudoannulata* (Ganesh Kumar and Velusamy, 1995). Easwaramoorthy *et al.* (1996) studied the life history of commonly occurring spiders in sugarcane ecosystem in the laboratory and field. In the laboratory, males and females of *Hipposa greenalliae* Blackwall passed through eight and nine instars, and the total life cycle lasted 263.3 and 371.6 days, respectively. In the field, females of *Cyrtophora cicatrosa* Stoliczka passed through nine instar and the total life cycle lasted for 195.2 days. Venkateshalu (1996) studied the biology of *Pardosa sumantrana* (Thorell) in laboratory using *N. lugens* as a prey. He reported an average number of 2.8 eggs-sac per female. The average incubation period was 19.2 days and the average pre-copulation, pre-oviposition, oviposition and post-oviposition periods lasted 4.6, 21.8, 78.8 and 33.6 days, respectively. Males lived on an average 105.90 days, while female lived for an average of 135.80 days.

### 2.2.1 Food and feeding behaviour

Harrison (1913) observed that there is less insect infestation in woods of pine trees in which population of spiders was more. Johnson (1913) observed that spiders of the family Theridiidae feed actively on larvae of spruce budworms *Tortix* sp. Further, Hustan (1917) observed salticid spiders feeding on sugarcane froghopper *Torriapsid* sp. Misra (1917) was the first Indian to observe spiders preying on nymphs of *Pyrilla* sp. and recorded a significant role in their control. Veitch (1919) also reported large jumping spiders feeding on sugarcane pests. Savory (1928) mentioned in his book entitled 'Biology of Spiders' that spiders can eat everything that comes in their way but his statement was criticized by Bristowe (1941) who observed that large number of insects were rejected by spiders. The findings reported by various authors regarding possibility of introducing spiders into crop fields, i.e. opinions regarding their importance for reduction of pests have been collected in papers elaborated by Bristowe (1941). Vite (1953) found that spiders prefer to feed on such insects which are abundant, so that biological balance is maintained.

Snetsinger (1955) studied the feeding behaviour and observed that *Phidippus audax* (Hentz) and *P. rimutor* (Walckenaer) mostly suck the juices of Orthopterous, dipterous, homopterous and heteropterous insects. Whitcomb *et al.* (1963) reported that *Latrodactus mactans* (Fab.) and *P. audax* preferred to feed upon boll weevil and a number of other spiders preferred feeding on *Heliothis* sp. and concluded that hunting spiders showed more prey preference than that of sedentary spiders. Kajak (1965) reported that *Araneus cornutus* (Clerck) and *A. quadratus* (Clerck) feed on all the insects occurring in the meadows. Harrison (1968) found that spiders also feed on lepidopterous pests on banana. Sadana and Kaur (1974) observed that out of 23 species of spiders in citrus orchards, two were voracious feeders on Citrus psylla and finally concluded that non-web spinners were more effective predators as compared to web spinners. Sadana and Sandhu (1977) observed the feeding intensity of *M. ludhianaensis* (Tikader) on *Brahmabole* sp. and observed that the adult spiders were voracious feeders, while the feeding intensity of 1st and 2nd instars was quite less as compared to 3rd to 7th instars. Temerak (1981) observed *Dactyna* sp. feeding on rove beetles and whiteflies.

Holmberg and Turnbull (1982) observed that *P. vancouveri* (Emerton) feed on male and female fruitflies, *Drosophila melanogaster* (Meig), small and large beetle larvae *Tenebrio* sp. and nymphal milk weed bugs, *Oncopeltus fasciatus* (Dalls). Female adult and sub adult spiders were used as predators. Spiders of both age classes showed similar selective tendencies. Reichert and Lockley (1984) while assessing the role of spiders as biological control agents have concluded that application of spiders as pest control agents should be actively perused in agro-ecosystems.

Sathiamma *et al.* (1986) observed that *R. indicus* started feeding on early instar caterpillars of *Opisina* from the second instar onwards and the prey consumption of adults ranged from 49-207 in case of females and 12-31 in the males. The first instar spiderling depended on the egg yolk for their food and were never observed to feed on the prey caterpillars. Further, they also noted that spider *Cheiracanthium*, except the first instar, all the eleven instar spiderlings consumed from 60-151 in case of females and 24-86 in the males. Nyffeler (1987) studied feeding ecology of orb weaving spiders, *Argiope aurantia* (Lucas) in a cotton agro-ecosystem and found that major food component of *A. aurantia* were aphids (30%), Diptera (26.8%), grasshoppers (17.9%) and Hymenoptera (12.6%). It was further found that adult female of *A. aurantia* have the potential to kill the prey upto 200% of their own size. Sathiamma *et al.* (1987) have revealed that spiders constitute an important group of bio-control agents in management of coconut leaf eating caterpillar, *O. arenosella* (Walk). Vandenberg *et al.* (1987) reported that spiders appear to be most important predators of Citrus psylla among its other predators.

Nyffeler and Benz (1988) observed spiders as generalist predators of small soft bodied arthropods of classes insecta and Arachinida in winter wheat fields and hay meadows. Parquet and Raymond (1990) reported the prey capture efficiency and prey selection by four orbweaving spiders, *Agalenatea* sp., *Aculepeira* sp., *Araneus marmoreus* (Clerck), *Argiope bruennichi* (Scop), *A. redii*. It was found that *Agalenatea* sp. and *Aculepeira* sp. had a better interception 0.97 and 0.57 prey intercepted/hour/100 cm$^2$ of trap respectively than *A. marmoreus* and *A. bruennichi* (0.15 and 0.12 respectively). *Agalenatea* sp. tried to catch each insect which touched its web independently of insect size while the other three tried to capture only large intercepted insects (72 mm). Tanaka (1991) estimated the food consumption and diet composition of web-building *Agelena* in woody and open habitats by a sight-count method and observed that the daily food consumption of adult spiders in the open habitat was about half of that in woody habitat and further it was also observed that *A. limbata* captured a great range of prey comprising ten orders of arthropods and ate chemically defended insects, e.g. stink bugs, lady beetles and ants which are rejected by many other species of spiders. Sadana and Kumari (1991) reported that *L. sikkimiensis* a beneficial predator on mango leaf hopper, *I. Clypealis*. Sterling *et al.* (1992) concluded studies on the economic benefits of spiders and insect predators of cotton flea-hoppers, showed that spiders were worth three times the value of insects as predators of the cotton flea-hopper.

Miyashita (1992) studied mean daily food consumption and total life time food consumption of the spider, *Nephila clavata* (L. Koch) and found that mean daily food consumption in the late adult stage was 27-150 mg wet weight which was nearly equivalent or slightly larger than in other large web-building spiders. Considerable variation in food consumption was found among habitats or years. Rehfeldt (1992) studied predation of orb-weaving spiders and crab spiders on the damselfly, *Calopteryx* sp. in southern France and observed that one species of orb-weaving spider, *Larinicides* sp. caught 76 per cent of damselflies which fell prey to spiders. It was also observed that predation rate correspond to orb-web density. Arora and Monga (1993b) studied the feeding intensity of four spiders, viz., *Hipposa* sp., *Pardosa tikaderi* (Tikader), *Lycosa* sp. and *Cheiracanthium* sp. under laboratory condition on insect pests of pigeon pea and it was found that all the four spider species feed voraciously on thrips and jassids, moderately on *Clavigralla* sp. and larvae of *Melanagromyza obtusa* (Malloch). None of the spider species consumed the larvae of *Helicoverpa armigera* (Hubner).

### 2.2.1.1. Functional response of spiders

Haynes and Sisojiri (1966) reported that individual fly activity increased with fly density and resulted in a functional response curve with an increasing slope. Most types of functional response curves of predators were obtained with varying prey density and hunger effect. Spiders were shown to have a high capture rate for highly motile prey (Nakamura, 1977). Cumulative number of WBPH nymphs killed by *L. pseudoannulata* was studied at different density of prey, viz., 50, 100, 150 and 200 for 5 days. The results showed that *Lycosa* reached a saturation level at 150 to 200 WBPH nymphs (Anonymous, 1984).

Mansour *et al.* (1980b) studied the functional response of *C. mildei* to increasing prey density of its prey, the larvae of *Spodoptera littoralis* (Boisdaval). A sigmoid curve was found to represent the preying rate. All the larvae were consumed by the spider at prey density of 10 or 50, but the number of larvae consumed appeared to reach a plateu (188.9) at the highest densities of 250 and 300 per spider.

Zhou and Chen (1986) suggested that ratio of attacking rate to handling time could be used to estimate the ability of natural enemies to control pests. The functional response of *P. subpiratius* was found to be positively correlated with prey density and negatively correlated with its own density (Yan and Wang, 1987). Ge and Chen (1989) concluded that functional response model of *T. octomaculatum* to *N. lugens* becomes a typical sigmoid III type when the space and complexity of experimental area were increased. Heong and Rubia (1989) fitted the functional responses of adult females of *L. pseudoannulata* exposed to adult hoppers to Holling's type II curve. *L. pseudoannulata* searched more efficiently for BPH than for GLH with attack rate of 0.39 and 0.22, respectively, thus suggesting that BPH was the preferred prey.

Functional response experiments of wolf spider on mirid bug, *Cyrtorhinus lividipennis* (Reuter) showed that both male and female spiders attacked all stages of mirid bugs equally from 3rd instar to adult stages. An adult spider could consume as many as 22 mirids per day. Both male and female spiders showed significant preference for BPH when exposed to different ratios of mirid bug and BPH adults (Heong, 1989). Heong and Rubia (1990) reported that one day old females of *L. pseudoannulata* showed Holling's type II functional response to the adult brown planthopper densities of 5, 10, 20, 30 and 60. They also calculated the handling time of 0.10 spent on prey, at an attack rate of 0.50. Predation of *L. pseudoannulata* to the YSB moth indicated that spiders searched more efficiently on 13 day old rice plants ($a^1$ = 3.14) compared to 35 day old ones with more than 10 tillers and dense foliage ($a^1$ = 1.04). Number of moths consumed was the lowest on rice stubbles (2/24 grs) but spiders consumed on an average four moths per 24 hrs in 13 and 35 day old plants (Rubia *et al.*, 1990). Somu and Biru (1993) reported that feeding behaviour of *Pardosa* sp. was studied in the laboratory under different prey densities. The amount of prey eaten in the different prey density treatments indicated a Holling type II functional response. Venkateshlu (1996) studied the functional response of *P. sumatrana* on *N. lugens* at a prey density of 10, 20, 30, 40 and 50.

## 2.3 Webbing pattern of spiders

### 2.3.1 Changes of webs with age

Wiehle *et al.* (1927) counted more radii in the webs of young spiders than in those of adults, while Koenig *et al.* (1951) found fewer radii in the smaller webs of young *A. diadematus* (Clerck) than in webs of full grown individuals. Savory (1952) observed a slight decrease in the number of radii during four summer months in outdoor *A. diadematus* webs, but points out that there was considerable variation.

Tilquin (1942) who counted radii in many webs of *A. bruennichi* which he kept indoors - related the number of radii to moulting. He recorded a slight increase in average number of radii (from 22 to 29) around the third moulting. For the rest of the spiders life the average number remained constant. His counts varied between 10 and 40 radii in the webs of young spiders as compared to between 19 and 41 in adult webs. Witt *et al.* (1968) studied the web features like number of radii, spirals, construction of the web and time required to make the web in *A. diadematus*. Webbing pattern of spiders were observed by Tikader (1987) and Vijayalakshmi and Ahimaz (1993). Biswas *et al.* (1995) recorded the orb-weaving behaviour, construction of the web, radii, time taken to make the webs in 4 species of spiders *Uloborus* sp., *Neoscona theisi* (Walckenaer) *Tetrangnatha mandibulata* (Walckenaer) and *P. sumantrana* in rice.

## 2.4 Effect of spider with other predators

Morse (1988) studied the interaction between the crab spider, *Misumea ratia* (Clerck) (Araneae) and its *ichneumonid* egg predator *Trychosis cuperia* Townes (Hymenoptera). Guillebeav and Ali (1989) found that inundation of fields with *Geocories* spp. is unlikely to reduce *O. salticus* populations, but predation by an increased *O. salticus* (Hentz) population could decrease geocoried populations.

Young (1989) reported the interaction between predators *P. audax* (Araneae: Salticidae) and *Hippodomia convergens* (Guerin-Meheville) (Coleoptera : Coccinellidae) in cotton fields and in the laboratory.

# MATERIAL AND METHODS

# III MATERIAL AND METHODS

The experimental site chosen for field studies was located at UAS, GKVK, Bangalore at an attitude of 913 m above mean sea level between latitude $13^0$ N and longitude $77^0$ $37^1$ E. The mango orchard had 250 plants which were spaced 10 m X 10 m with an age of 7-8 year old. The trees of Mallika variety were selected during the period of study from October 1998 to March 1999. The studies other than field observations were conducted at the Department of Entomology, College of Agriculture , UAS, GKVK. The materials used and methodology adopted during the course of investigation is presented objective wise in this chapter.

## 3.1 Survey for spiders

The mango orchards at GKVK Campus and Indian Institute of Horticulture Research, Hesarghatta, were surveyed for spiders at fortnightly intervals between October 1998 and March 1999.

### 3.1.1 Collection and preservation of spiders

The spiders were collected using an insect sweepnet and transferred to polyethlene bags (30 X 22 cm), with pin holes made for aeration, sealed using rubber bands and taken to the laboratory where different stages of the spiders and their numbers were recorded.

During initial stages odamens fluid (Barrion and Litsinger, 1980) was used for preservation of dead spider for identification purpose. However, as the specimens became brittle in it, they were later preserved in absolute alcohol as suggested by Biswas (1995). Each specimen was labelled giving information about locality, date of collection, collector's name, etc. The preserved spiders were got identified by Dr. Vijayalakshmi and Veena Kapoor, Centre for Indian Knowledge System, Chennai.

### 3.1.2 Sampling of spiders and insect pests in the main orchard

During survey in the main orchard, population of spiders and insect pests were recorded by selecting ten mango trees randomly and by following suitably modified techniques suggested by Venkateshan *et al.* (1992) and Satish Kumar (1996). The number of spiders and insect pests were counted at ground level and three different levels above the ground. The average height of the tree was determined by measuring the heights of the ten trees. The average height was divided into three equal parts, bottom one-third noted as $H_1$, middle one-third as $H_2$ and top one-third as $H_3$. The ground fauna were recorded as the species occurring at $H_0$ level. A wooden stick measuring four meters was used. Leaving the bottom 15 cm, the stick was marked with a rubber band, three corresponding heights of the bottom, middle and top one-third of the tree. The spiders present in each of the strata were recorded as the ones present in the bottom, middle and top portion of the tree. Data on spider population on the ground were recorded by visual counting method in an area of 2 X 3 m from ten randomly selected places. The mango leafhopper counts were made by sweep method using an insect net (64 cm handle length and 31 cm diameter ring). Totally eight random sweeps per tree were made on each of the four sides. The samples were transferred to insect killing bottle and the number of leafhoppers, spiders, and other predators and pests were collected and recorded separately.

### 3.1.3 Seasonal abundance of spider

Seasonal abundance of spiders was recorded between October 1998 and March 1999 at UAS, GKVK, Bangalore, both in the main orchard at fortnightly intervals. Attempts were made to correlate abiotic factors like rainfall, temperature, relative humidity, etc. with the abundance of spiders (Appendix I).

### 3.1.4 Population fluctuation of spiders

Observations were recorded on the population fluctuation of spiders in the main orchard at fortnightly intervals from October 1998 to March 1999 at GKVK, Bangalore.

### 3.1.5 Diversity index

The diversity of fauna was worked out following Simpson's index ($\lambda$) (Simpson, 1949) and Shanon's Weaver index ($H^1$) (Shanon and Weaver, 1949) formulae to know the seasonal abundance across the different sampling dates.

$$\lambda = \sum_{i=1}^{S} Pi^2$$

Where, Pi is the proportional abundance of the ith species given by

Pi = ni/N, I =1,2,3,.........s where, ni is the number of individuals of the ith species and N is the total number of individuals for all S species in the population.

$$H^1 = -\sum_{i=1}^{S} [Pi \ln Pi]$$

Where, $H^1$ is the average uncertainty per species in an infinite community made up of S species with known proportional abundance.

Pi = P1, P2, P3, .............Ps

### 3.1.6 Morisita similarity index

The similarity of fauna was worked out using Morisita index (cmhw) formula to know the similarity occurring in different taxa between the canopy and ground samples.

$$Cmhw = \frac{2\Sigma\,(ani \times bni)}{(da + db)\, aN \times bN}$$

Where, aN = is the number of individuals in sample A and bN is the number of individuals in sample B.

ani = is the number of individuals in sample of the ith taxon in sample A and bni is the number of individuals of the ith taxon in sample B.

$$da = \frac{\Sigma ani^2}{aN^2} \quad \text{and} \quad db = \frac{\Sigma bni^2}{bN^2}$$

### 3.2 Biology of the spider, *Argiope pulchella* Thorell under laboratory conditions

The biology of the spider *A. pulchella* on *Drosophila melanogaster* (Meign) was carried out in the laboratory and prevailing temperature and relative humidity were recorded daily (Appendix II).

#### 3.2.1 Standardization of mating period

The field collected sub-adult stage male and female spiders of *A. pulchella* (Thorell) were used for the purpose. The spiders were separated based on enlarged pedipalp tips in males and development of weak epigynum and enlarged abdomen in females and reared in the laboratory until they reached the adult stage by giving adult *D. melanogaster* as prey. After last moulting the adult stage was confirmed by examining the development of sclerotized tip of pedipalps in the males and sclerotized epigynal plate in the female spiders. The sexually starved males and females at intervals of 1, 3, 5, 10 and 20 days after attaining the adult stage were released into the cages (35 X 10 X 35 cm) and the rotten banana was kept in plastic bottle (9 cm diameter and 6 cm height) at the bottom and provided with sufficient number of adult *D. melanogaster* as prey. The success in mating was determined by looking into the viable eggs laid by the females. The treatments of sexual starvation were replicated six times. The females which were allowed to mate immediately after emergence were taken to compare the success and expressed as percentage. Observations were recorded on pre and post mating behaviour individually. After 24 hours the females were transferred to polyethlene bags (22 X 15 cm) with moist cotton at bottom. The mouth of the bags folded twice were tightly secured by paper clips. The folded bags were hung on a thread with the help of clips and spiders were reared with adults of *D. melanogaster* as food.

### 3.2.2 Laboratory rearing for spiderlings

The polyethlene bags of 13 X 9 cm size and 300 guage thickness were selected and pin holes were made with the help of a dissection needle (No.7). Opposite to the longitudinal fold lines, folds were made across at the opening so that the polyethlene bag remained constantly like a balloon. The opening was folded and secured with the help of paper clips.

Spiderlings just hatched form egg mass were collected from the laboratory reared parent spiders and placed individually in each polyethlene bag. Equal sized moist cotton bits were left inside each bag to maintain humidity and also to serve as a water source for the spiderling. A laboratory cultured *D. melanogaster* were fed to the spiderlings. The cotton wad was changed daily. A known number of flies were provided daily as food by using aspirator and the number of prey consumed by the spiderling was recorded daily. The folded bags were hung with the help of paper clips on a polyethlene thread at 1.5 metres above the ground (Plate 1). Daily observations were made on the duration of different instars, feeding potential, morphological characters of all stages, adult emergence, incubation period, pre-oviposition, oviposition pattern, post-oviposition period, fecundity and adult longevity. The mean and standard deviation was calculated for the duration of each of the instars and adults.

### 3.2.3 Feeding potential of adult spider *A. pulchella*

#### 3.2.3.1 Feeding potential

Based on observation on daily predation of *D. melanogaster* flies by spider, the feeding potential per day was computed separately for male and female spiders and mean and standard deviation were worked out.

Plate 1 : Polyethelene covers and nylon thread used for individual rearing

#### 3.2.3.2 Functional response of adult spiders to the prey

Thirtyfive adult spiders were starved for 4 days and then presented with different numbers of adult *D. melanogaster* (10, 50, 100, 150, 200, 250, 300) in five replicates. Each spider was kept in an individual bag. The number of flies consumed by each spider was recorded 24 hours from beginning of the experiment. Functional curves were drawn and data obtained were subjected to regression analysis.

### 3.2.4 Starvation studies of the spider *A. pulchella*

The newly emerged male and female of *A. pulchella* were used for the study in the laboratory. Starvation of the spiders for water, food and both was carried out by keeping individual spiders in polyethlene bags (22 X 15 cm). Treatments were replicated 10 times and mortality of spiders was recorded daily.

### 3.2.5 Measurements

The measurements of eggs, egg sacs, instars of spider and adult were made under a stereobinocular microscope containing calibrated occular micrometer.

### 3.2.6 Temperature in the laboratory

Daily minimum and maximum temperature that pre-valid during the entire period of investigation were recorded.

## 3.3 Webbing pattern of spiders in field

The webbing pattern of four species of spiders, *Gastrocantha germinata* (Fabricius). *Leucauge fastigata* (Simon), *Leucauge decorata* (Blackwall) and *A. pulchella* on mango trees were recorded. Observations were made by placing a black sheet as background and counting the number of radii and spirals in each of the four sides with the help of a hand lens. Nature of orb-weaving behaviour, construction of web and time required to make the webs were also recorded.

### 3.3.1 Webbing pattern in laboratory

The laboratory reared spiderlings and field collected adult female spiders *A. pulchella* were maintained on bamboo pyramid frames to know the webbing pattern from babyhood to adulthood and to know if the pattern changes are related to body growth of species. Different sizes of pyramids with 14, 26, 40 and 50 cm bamboo sticks were made and spiders were released into them for webbing. The webbing patterns in different pyramids were studied. From the preliminary studies, the pyramid with 40 cm bamboo stick was found to be appropriate and hence used for other studies (Plate 2).

Observations were recorded on number of radii and spirals in each of four sides with the help of hand lens. Nature of the orb weaver's behaviour, construction of the web and time required to make the webs were also recorded. The data obtained were pooled and statistically analysed.

## 3.4 Effect of interference behaviour of spider (*Argiope pulchella*) with the Reduviid (*Endochus inornatus* Stal.)

A laboratory experiment was conducted to know the effect of spider, *A. pulchella* and Reduviid, *Endochus inornatus* (Stal.). Spider and Reduviids collected from fields were starved for one day and then presented with different number of adult *D. melanogaster*. The experiment was done with four treatments, replicated six times using polyethlene bags (30 X 23 cm).

$T_1$ = Spider with 30 *D. melanogaster*

$T_2$ = Reduviid with 30 *D. melanogaster*

$T_3$ = Spider + Reduviid 60 *D. melanogaster*

$T_4$ = Control (prey only) 30 *D. melanogaster*

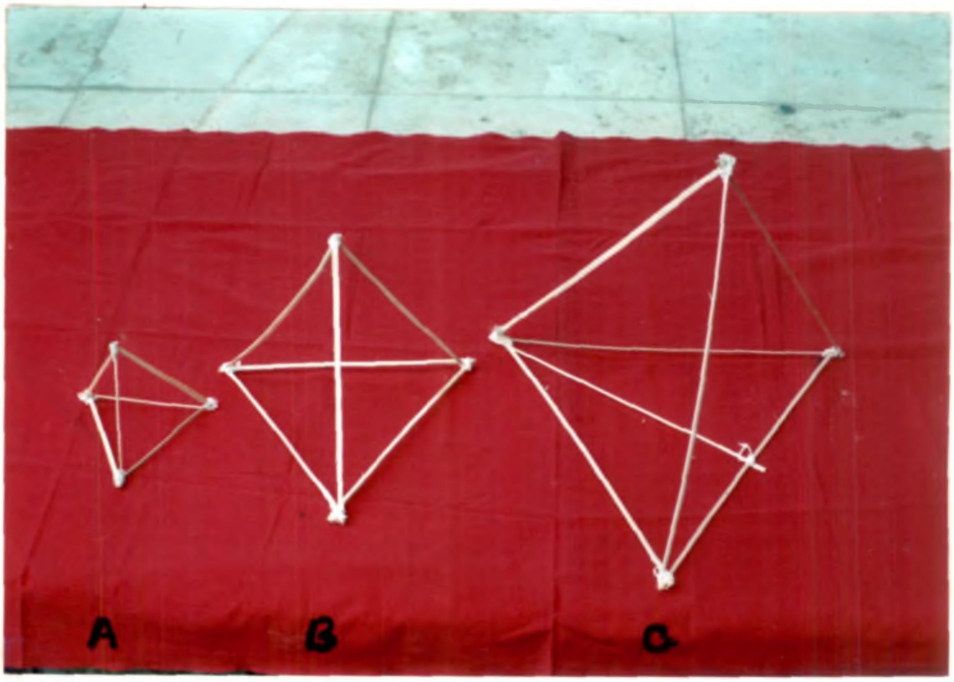


**Plate 2 : Different bamboo frames used for webbing pattern**

**A = 14 Cms   B = 26 Cms   C = 40 Cms**

Observations were recorded on the number of *D. melanogaster* consumed by spider and Reduviid and also whether the spider feeds on Reduviid or Reduviid feeds on spider in each replication at an interval of 24 hours for 7 days. The data obtained was pooled and statistically analysed.

# EXPERIMENTAL RESULTS

# IV EXPERIMENTAL RESULTS

Results of the experiments conducted during the course of investigation are presented objective wise hereunder.

## 4.1 Survey for spiders

### 4.1.1 Abundance of spider fauna in mango ecosystem

Survey conducted in two locations *viz.*, GKVK and IIHR, Bangalore between October 1998 and March 1999 yielded 15 species of spiders, belonging to 11 genera and 5 families (Table 1). The highest number of species was represented by Araneidae, Salticidae followed by Metidae and Oxyopidae, which included two species each and one species in Lycosidae (Plates 3-5).

In terms of abundance, Araneidae was the most dominant group in GKVK, accounting for 51.78 per cent of the total spider species in mango orchard at GKVK. Four families, *viz.*, Metidae, Salticidae, Lycosidae and Oxyopidae, respectively accounted for 30.97, 8.06, 6.73 and 3.18 per cent of the total spider species (Fig.1). Webbing and hunting spiders represented 88.48 and 11.24 per cent respectively. Among the webbing spiders, *G. germinata* was found in large numbers in the orchards followed by *L. fastigata*. They accounted for 29.7 and 23.08 per cent, respectively (Table 2). Among the hunting spiders, *Telamonia* sp. and *Oxyopes javana* accounted for 3.18 and 2.05 per cent, respectively.

### 4.1.2 Population dynamics of spiders in relation to season, pest density and weather parameters

#### 4.1.2.1 Season and weather parameters

The data on seasonal changes of spiders is given in Table 2. The total percentage population of Araneids was 51.78 per cent, out of which, *G. germinata, A. pulchella, C. cicatrosa, A. aemula, A. anasuja* and *Araneus* sp. formed 29.7, 7.15, 5.63, 5.19, 2.89 and 1.22 per cent respectively. The population of these spiders was maximum during first

Table 1 : Spider fauna in mango orchards at UAS, GKVK, Bangalore during October 1998-March 1999

| Sl. No. | Family | Representative species |
|---|---|---|
| 1 | Araneidae | *Gastrocantha germinata* Fabricius<br>*Argiope pulchella* Thorell.<br>*Argiope aemula* Walckaner<br>*Argiope anasuja* Thorell<br>*Cyrtophora cicatrosa* Stoliczka<br>*Araneus* sp. Clerck |
| 2 | Salticidae | *Oxyopes javanas* Thorell<br>*Telamonia* sp.<br>*Marpissa* sp.<br>*Plexippus paykulli* Saningny and Audouin |
| 3 | Metidae | *Leucauge fastigata* Simon<br>*Leucauge decorata* Blackwall |
| 4 | Oxyopidae | *Peucetia graminea* Simon<br>*Peucetia procera* Thorell |
| 5 | Lycosidae | *Lycosa* sp. |

Plate 3 : *Gastrocantha germinata* Fabricius

*Argiope pulchella* Thorell

Plate 4 : Spider species of Araneidae

Plate 5 : Spider species of Salticidae *Telamonia* sp.

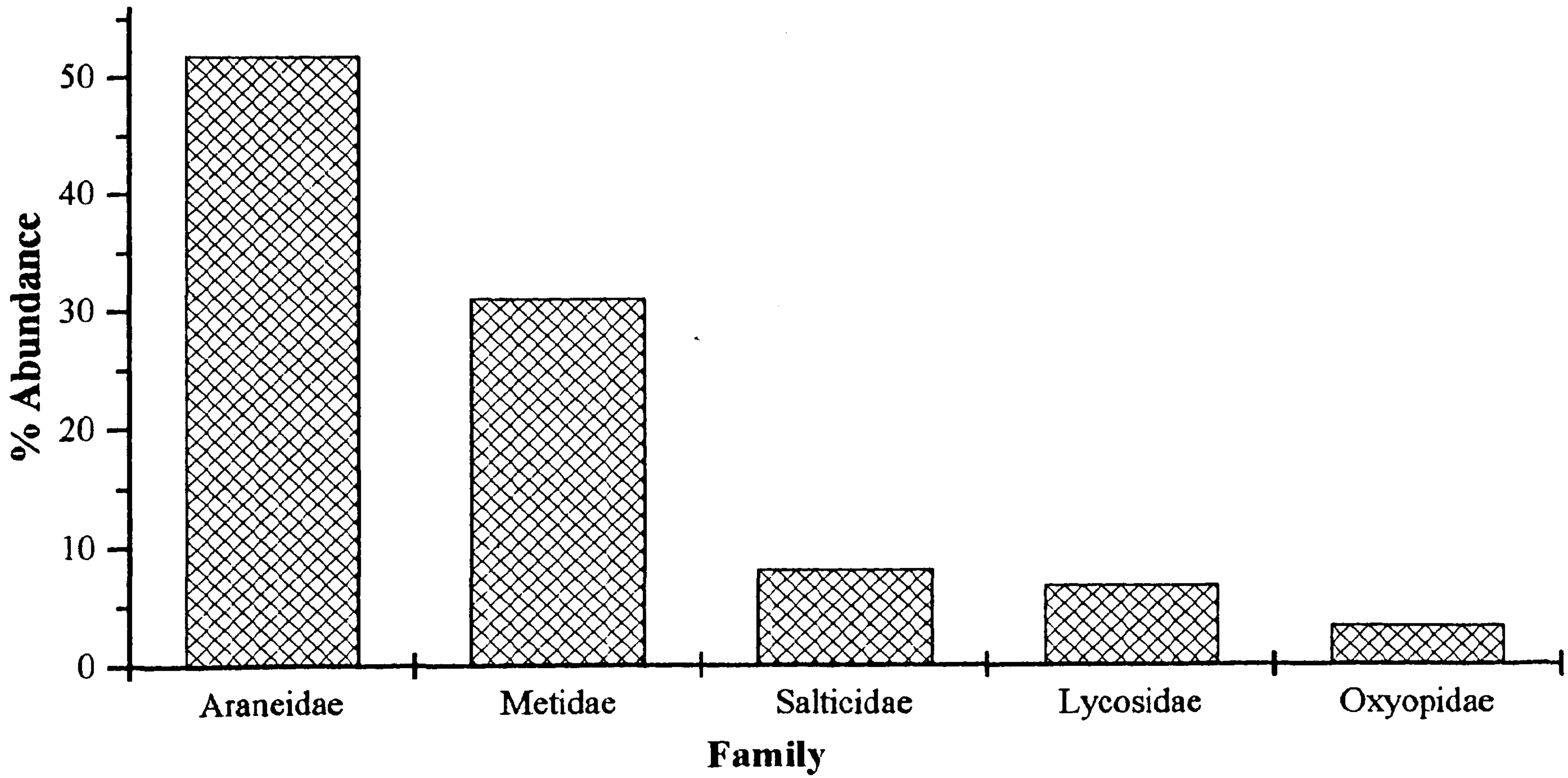


Fig. 1. Relative abundance of spider families in mango ecosystem

'able 2 : Average population of insect pests, predators and spiders per ten plants of mango between October 1998 to March 1999

| Insect pests | October | | November | | December | | January | | February | | March | | Abundance of species (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | I | II | I | II | I | II | I | II | I | II | |
| *Idioscopus* spp. | 7.6 | 8.7 | 15.2 | 25.6 | 31.2 | 21.8 | 9.4 | 7.9 | 4.5 | 2.8 | 0.9 | 0.4 | 94.28 |
| *O. smaragdina* | 0.5 | 0.3 | 0.6 | 1.2 | 0.1 | 0.3 | 0.1 | 0.2 | 0.8 | 0.2 | 0.4 | 0.4 | 3.50 |
| *E. inornatus* | 0.0 | 0.2 | 0.1 | 0.5 | 0.9 | 0.3 | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 | 0.2 | 1.72 |
| *V. cincta* | 0.1 | 0.0 | 0.0 | 0.3 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.48 |
| **Spider species** | | | | | | | | | | | | | |
| *G. germinata* | 6.4 | 7.4 | 8.4 | 7.1 | 10.5 | 6.6 | 2.6 | 2.8 | 3.6 | 2.6 | 1.0 | 1.0 | 29.7 |
| *L. fastigata* | 3.7 | 7.5 | 8.5 | 8.6 | 9.9 | 6.0 | 2.4 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 23.08 |
| *L. decorata* | 2.3 | 3.9 | 2.9 | 1.2 | 2.3 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.89 |
| *A. pulchella* | 1.0 | 1.1 | 0.9 | 1.1 | 1.7 | 0.8 | 1.0 | 1.0 | 0.9 | 1.2 | 1.3 | 1.4 | 7.15 |
| *C. cicatrosa* | 0.8 | 0.9 | 0.9 | 1.2 | 2.1 | 0.6 | 1.0 | 1.5 | 0.9 | 0.8 | 0.4 | 0.4 | 5.63 |
| *A. aemula* | 0.9 | 0.5 | 0.4 | 0.9 | 1.7 | 0.6 | 0.9 | 0.7 | 0.8 | 0.9 | 0.8 | 0.5 | 5.19 |
| *Telamonia* spp | 0.8 | 1.1 | 0.6 | 0.4 | 0.5 | 0.5 | 0.2 | 0.3 | 0.8 | 0.3 | 0.4 | 0.4 | 3.18 |
| *A. anasuja* | 0.6 | 0.6 | 0.5 | 0.6 | 0.5 | 0.4 | 0.7 | 0.6 | 0.2 | 0.3 | 0.3 | 0.5 | 2.89 |
| *Lycosa* sp. | 0.5 | 0.8 | 0.8 | 0.7 | 0.9 | 0.9 | 1.2 | 0.9 | 1.2 | 1.2 | 1.3 | 1.4 | 7.89 |
| *O. javanas* | 0.5 | 0.6 | 0.6 | 0.5 | 0.5 | 0.3 | 0.1 | 0.0 | 0.2 | 0.5 | 0.6 | 0.1 | 2.05 |
| *P. graminea* | 0.7 | 0.6 | 0.5 | 0.6 | 0.5 | 0.2 | 0.2 | 0.0 | 0.2 | 0.1 | 0.3 | 0.0 | 1.91 |
| *P. paykulli* | 0.6 | 1.0 | 0.3 | 0.3 | 0.1 | 0.1 | 0.3 | 0.0 | 0.1 | 0.2 | 0.2 | 0.0 | 1.51 |
| *Marpissa* sp. | 0.1 | 1.1 | 0.4 | 0.3 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.32 |
| *P. procera* | 0.3 | 0.3 | 0.5 | 0.6 | 0.4 | 0.2 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 1.27 |
| *Araneus* sp. | 0.6 | 0.3 | 0.4 | 0.2 | 0.6 | 0.1 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 | 0.1 | 1.22 |
| Total spider population | 19.8 | 27.7 | 26.6 | 24.3 | 32.2 | 21.0 | 10.8 | 9.3 | 10.3 | 7.0 | 7.0 | 6.7 | - |

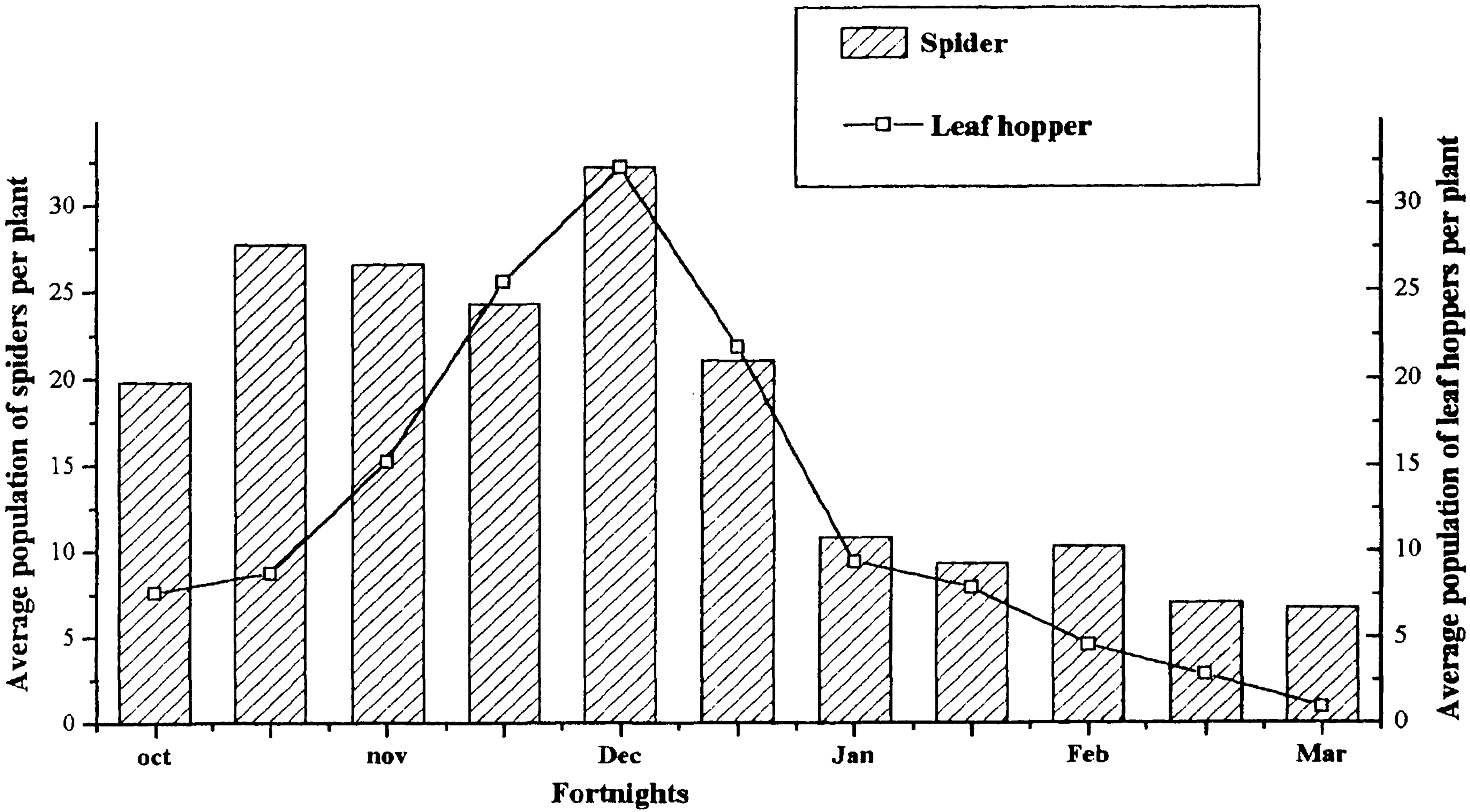


**Fig.2. Population dynamics of spiders and insect pests of Mango**

fortnight of December and January, which coincided with peak population of insect pests. *L. fastigata* and *L. decorata* of the family Metidae were present in the orchards in the month of October and their number started increasing subsequently, attaining maximum population in first fortnight of December and second fortnight of October. They formed 23.08 and 7.89 per cent of total spider population, when food of these spiders, viz., mangohopper and others was available in plenty. Salticids formed third abundant group of spiders in mango orchards. They formed 8.06 per cent of the total spider population, out of which, *Telamonia* sp. formed 3.18 per cent, *O. javanus* 2.05 per cent, *P. paykulli* 1.51 per cent and *Marpissa* sp. formed 1.27 per cent of the total spider population. The population of these spiders was maximum during the second fortnight of October and first fortnight of the November, which coincided with peak population of insect pests. The oxyopides, *P. graminea* and *P. procera* formed 1.91 per cent and 1.27 per cent of the total spider population. The population of these spiderwas maximum during first fortnight of October and the second fortnight of November, . Only one spider species belonging to family Lycosidae, i.e. *Lycosa* sp. was found occurring in mango orchards and it appeared in the month of October to March and was maximum during second fortnight of March .

The population of *G. germinata* showed highly significant negative correlation with mean maximum temperature (r = -0.74) and sunshine hours (-0.85) and positive correlation with mean relative humidity (r = 0.81, 0.79). *L. fastigata* showed significant negative correlation with mean maximum temperature (r =-0.67) and sunshine hours (r =- 0.80) and positive correlation with mean relative humidity (r = 0.65, 0.76). *L. decorata* showed significant negative correlation with mean sunshine hours (r = 0.706). *C. cicatrosa* showed significant negative correlation with mean maximum temperature (-0.65). The total spider population showed highly significant negative correlation with maximum temperature (r = -0.71) and sunshine hours (-0.78), but a highly significant positive correlation was observed with mean relative humidity (r = 0.76, 0.79).(Table 3).

**Table 3 : Correlation between population density of important spiders in mango eco-system and weather parameters**

| Sl. No. | Name of the spider species | Temperature | | Relative humidity | | Rainfall | Wind speed km/hour | Sunshine hours |
|---|---|---|---|---|---|---|---|---|
| | | Max. | Min. | 7.00AM | 14.0PM | | | |
| 1 | *G. germinata* | -0.74** | 0.21 | 0.81** | 0.79** | -0.23 | 0.21 | -0.85** |
| 2 | *L. fastigata* | -0.67* | 0.18 | 0.65* | 0.76** | -0.06 | 0.03 | -0.80** |
| 3 | *L. decorata* | -0.56 | 0.33 | 0.74** | 0.63* | 0.26 | -0.05 | -0.70** |
| 4 | *A. Pulchella* | 0.25 | 0.25 | -0.30 | 0.06 | -0.15 | 0.31 | 0.27 |
| 5 | *C. cicatrosa* | -0.65* | -0.32 | -0.44 | 0.41 | -0.06 | 0.50 | -0.54 |
| 6 | *A. aemula* | -0.38 | -0.15 | 0.08 | 0.33 | 0.08 | 0.53 | -0.17 |
| 7 | *Telamonia* sp. | -0.29 | 0.50 | 0.67* | 0.37 | 0.38 | 0.04 | -0.49 |
| | Total spider population | -0.71** | 0.25 | 0.76** | 0.79** | 0.18 | 0.09 | -0.78** |

** : Significant at 1%
* : Significant at 5 %

#### 4.1.2.2 Pest density

Population dynamics of spiders was studied in relation to the pest and predator density,*viz.*, *Idioscopus* sp., *Oecophylla smaragadina* (Fab.), *E. inornatus* and *Vespa cincta* (Fab.) in GKVK, Bangalore from October 1998 to March 1999.

In the mango orchards of GKVK, the peak population of spiders was maximum with 32.2 per tree in the first fortnight of December, whereas, *Idioscopus* sp., *E. inornatus*, *O. smaragadina* and *V. cincta* were 31.2, 0.9, 1.2 and 0.3 per trees respectively during the first fortnight of December and second fortnight of November (Table 2). *G. germinata* showed highly significant correlation with one pest and one predator, i.e. *Idioscopus* sp. (r = 0.83) and *E. inornatus* (r = 0.66). *L. fastigata* also exhibited highly significant correlation with *Idioscopus* sp. (r = 0.86) and *E. inornatus* (r = 0.66). A similar trend was observed between *C. cicatrosa* and *Idioscopus* sp. (r = 0.67) and *E. inornatus* (r = 0.69). Whereas, *A. aemula* had a significant positive correlation with *E. inornatus* (r = 0.64) and *V. cincta* (r = 0.63). Most of the species showed either negative or least positive correlation with *O. smaragdina* population. The total spider population also showed a strong positive correlation with total population of *Idioscopus* sp.(r =0.80) and *E. inornatus* (0.64) (Table 4).

#### 4.1.2.3 Diversity and Morisita similarity index

Simpson's (λ) and Shanon Weaver's ($H^1$) indices were used for measuring species diversity where Simpson's index (λ) range from 0 to 1, with a negative relationship "λ" approaches 0 and when the diversity is least, the value tends towards 1. Shanon Weaver's index ($H^1$) gives the values from 0 and onwards and has a positive correlation with the diversity of species. Therefore, in Shanon Weaver's index, the increasing values represent an increase in the diversity of species. Morisita similarity index is used as a measure of taxonomic similarity, and the values range from 0 (no similarity) to 1 (perfect similarity).

**Table 4 : Correlation between dominant spider species with population of insect pests of mango**

| Sl. No. | Spider species | *Idioscopus* sp. | *O. smaragdina* | *Endochus inornatus* | *Vespa cincta* |
|---|---|---|---|---|---|
| 1 | *G. germinata* | **0.83 | 0.13 | *0.66 | 0.47 |
| 2 | *L. fastigata* | **0.86 | 0.18 | *0.66 | 0.55 |
| 3 | *L. decorata* | 0.53 | -0.01 | 0.31 | 0.06 |
| 4 | *A. Pulchella* | 0.16 | -0.28 | 0.54 | 0.32 |
| 5 | *C. cicatrosa* | *0.67 | -0.14 | *0.69 | 0.55 |
| 6 | *A. aemula* | 0.51 | -0.26 | *0.64 | *0.62 |
| 7 | *Telamonia* sp. | 0.04 | 0.20 | 0.09 | -0.11 |
| | Total spider population | **0.80 | 0.14 | *0.64 | 0.48 |

** : Significant at 1%
* : Significant at 5%

### 4.1.2.4 Diversity of spiders

**Species richness**

A total of 10 trees were sampled for fifteen days period in each of the twelve sampling bouts. The number of species were 8 on second fortnight of January and 15 on October, November and second fortnight of December. There was no apparent trend in the maximum number of species of spiders during twelve sampling bouts.

**Species diversity**

Simpson's Index ($\lambda$) of spider species diversity varied from a low of 0.131 during I fortnight of January to 0.39 during first fortnight of December, with a pooled diversity value of 0.167 over the entire sampling period. There was no clear pattern of change in the diversity across the sampling dates. Similar trend was evident even with the Shanon's Index ($H^1$), where values varied from the lowest of 1.867 during second fortnight of January to 2.179 during first fortnight of October with a pooled diversity of 2.159 over the sampling period. (Table 5 and Fig.3). The taxonomic similarity was found to be highest between $H_2$ - $H_3$ (99.3%) followed by $H_1$ - $H_3$ (84.3%). No similarity of (0 per cent) was found between $H_0$ - $H_2$, and $H_0$ - $H_3$ (Table 6).

At height $H_1$, Simpson's Index ($\lambda$) of spider species diversity varied from a low of 0.117 during second fortnight of February to 0.253 during first fortnight of November, with a pooled diversity value of 0.175 over the entire sampling period. There was no clear pattern of change in diversity over the sampling dates. Similar trend was evident with the Shanon's Index ($H^1$), where values varied from lowest of 1.356 during first fortnight of January to 2.251 during second fortnight of February, with a pooled diversity of 2.05 over the entire sampling period.

At height $H_2$, Simpson's Index ($\lambda$) of spider species diversity varied from a low of 0.200 during first fortnight of January to 0.361 during second fortnight of December with a pooled diversity of 0.260 over the entire sampling dates. Similar

**Table 5 : Seasonal pattern of spider diversity and species richness in mango ecosystem from October 1998 to March 1999**

| Sl.No. | Date of sampling | Species richness | Shanon's index | Simpson's index |
|---|---|---|---|---|
| 1 | 13.10.98 | 15 | 2.179 | 0.164 |
| 2 | 28.10.98 | 15 | 2.092 | 0.173 |
| 3 | 12.11.98 | 15 | 1.933 | 0.217 |
| 4 | 27.11.98 | 15 | 1.952 | 0.221 |
| 5 | 12.12.98 | 14 | 1.903 | 0.390 |
| 6 | 27.12.98 | 15 | 1.883 | 0.212 |
| 7 | 11.01.99 | 12 | 2.105 | 0.131 |
| 8 | 26.01.99 | 8 | 1.867 | 0.185 |
| 9 | 10.02.99 | 11 | 1.896 | 0.210 |
| 10 | 25.02.99 | 12 | 2.095 | 0.166 |
| 11 | 12.03.99 | 11 | 2.136 | 0.136 |
| 12 | 27.03.99 | 10 | 1.971 | 0.164 |
| Pooled over sampling dates | | 15 | 2.159 | 0.167 |

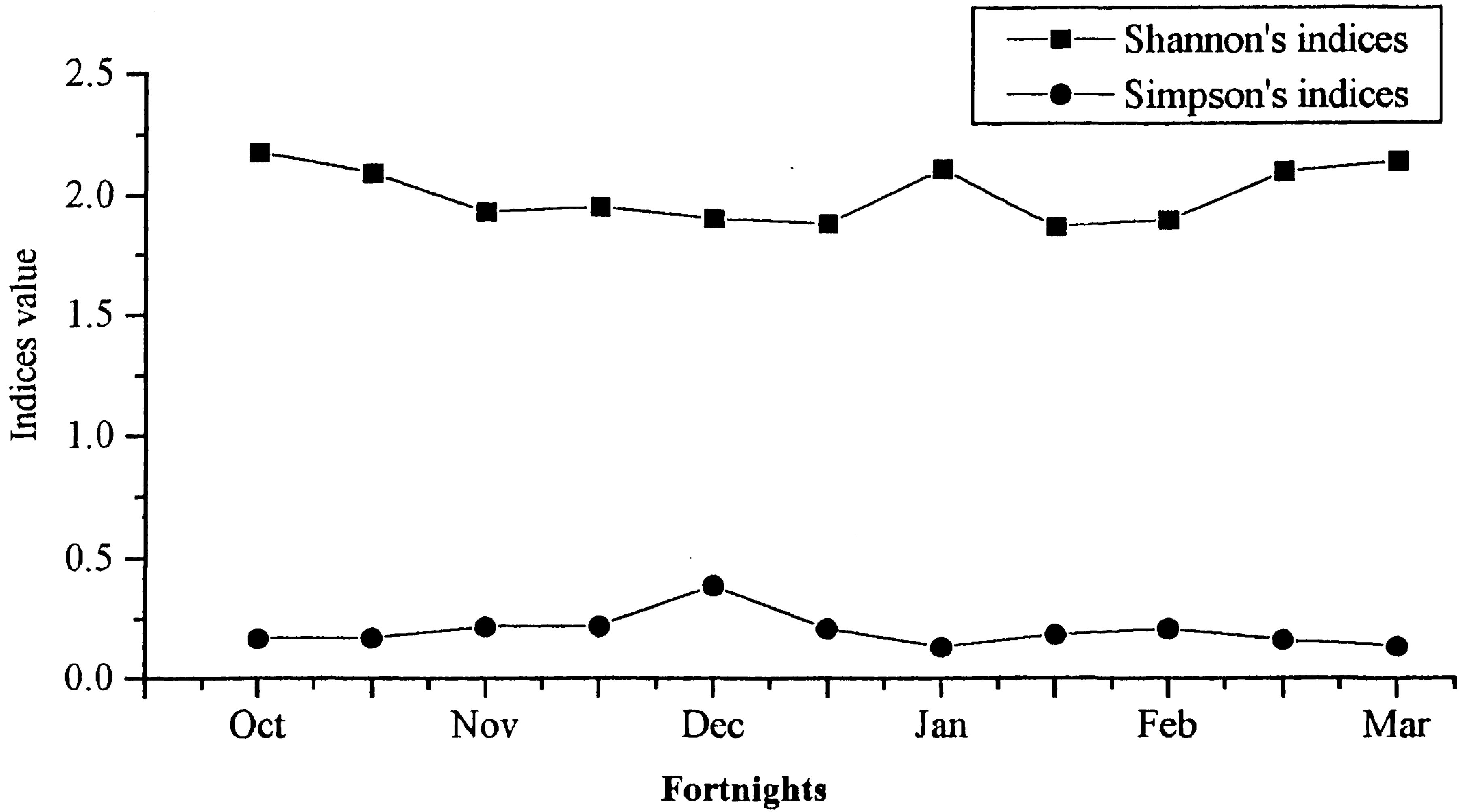


**Fig.3. Seasonal pattern of spider species diversity (Shannon weaver's and Simpson's) indices in mango during October 1998 to March '99**

**Table 6 : Morisita Taxonomic Similarity among the Spider species in mango eco-system with respect to different heights**

| | $H_0$ | $H_1$ | $H_2$ | $H_3$ |
|---|---|---|---|---|
| *$H_0$ | - | | | |
| $H_1$ | 0 | - | | |
| $H_2$ | 0 | 0.843 | - | |
| $H_3$ | 0 | 0.877 | 0.993 | - |

*$H_0$ = Ground

trend was evident with the Shanon's Index ($H^1$), where values varied from lowest of 1.292 during second fortnight of December to 1.845 during second fortnight of October, with a pooled diversity of 1.848 over the entire sampling dates. There was no clear pattern across the sampling dates in both indices.

At height $H_3$, Simpson's Index ($\lambda$) of spider species diversity varied from a low of 0.153 during first fortnight of March to 0.357 during first fortnight of December with a pooled diversity of 0.207 over the entire sampling dates. Similar trend was evident with the Shanon's Index ($H^1$), where values varied from lowest of 1.282 at first fortnight of December to 2.075 at first fortnight of October, with a pooled diversity of 1.938 over the entire sampling dates. There was no clear pattern across the sampling dates in both indices. Both Simpson's Index ($\lambda$) and Shanon's Weaver's indices ($H^1$) calculated for the pooled values over the entire sampling period at different heights showed higher diversity in height ($H_1$) ($\lambda$ = 0.175; $H^1$ = 2.05) followed by height ($H_3$) ($\lambda$ = 0.207; $H^1$ = 1.938) and height ($H_2$) ($\lambda$ = 0.260; $H^1$ = 1.848), respectively (Table 7 and Fig.4 and 5).

## 4.2 Biology of *Argiope pulchella* Thorell under laboratory condition

The biology of the spider, *A. pulchella* was studied under laboratory conditions (Appendix II). The observations are given as mean ± SD. The duration of different life stages viz., egg, spiderling, adults and their biological parameters are presented in Table 8.

### 4.2.1 Egg and egg-sac construction

A day before egg laying, the female started constructing a white sheet of web and it was slowly enlarged into a concave sac. Then she moved.to the middle to strengthen the sac with more silk. Oviposition took place in the middle of the sac and the egg mass was covered with silk. Oviposition took place during night. In most cases, the egg-sacs were

**Table 7 : Seasonal pattern of spider species diversity at different heights in mango orchards during October 1998 – March 1999**

| Sl. No. | Date of Sampling | $H_1$ | | $H_2$ | | $H_3$ | |
|---|---|---|---|---|---|---|---|
| | | Simpson's index | Shanon's index | Simpson's index | Shanon's index | Simpson's index | Shanon's index |
| 1 | 13.10.98 | 0.193 | 1.966 | 0.227 | 1.732 | 0.191 | 2.075 |
| 2 | 28.10.98 | 0.248 | 1.712 | 0.233 | 1.845 | 0.177 | 2.067 |
| 3 | 12.11.98 | 0.253 | 1.689 | 0.283 | 1.697 | 0.267 | 1.662 |
| 4 | 27.11.98 | 0.228 | 1.835 | 0.297 | 1.557 | 0.220 | 1.923 |
| 5 | 12.12.98 | 0.183 | 1.964 | 0.244 | 1.727 | 0.357 | 1.282 |
| 6 | 27.12.98 | 0.251 | 1.561 | 0.361 | 1.292 | 0.271 | 1.861 |
| 7 | 11.01.99 | 0.201 | 1.356 | 0.200 | 1.764 | 0.227 | 1.604 |
| 8 | 26.01.99 | 0.208 | 1.728 | 0.246 | 1.645 | 0.254 | 1.658 |
| 9 | 10.02.99 | 0.203 | 1.791 | 0.316 | 1.581 | 0.260 | 1.446 |
| 10 | 25.02.99 | 0.117 | 2.251 | 0.268 | 1.561 | 0.246 | 1.625 |
| 11 | 12.03.99 | 0.136 | 2.078 | 0.207 | 1.770 | 0.153 | 1.955 |
| 12 | 27.03.99 | 0.171 | 1.982 | 0.209 | 1.660 | 0.253 | 1.476 |
| Pool over sampling dates | | 0.175 | 2.05 | 0.260 | 1.848 | 0.207 | 1.938 |

**Table 8 : Mean duration of different life stages of the spider *Argiope pulchella* under laboratory**

| Stage | Male (Days) | | Female (Days) | |
|---|---|---|---|---|
| | Mean ± SD | Range | Mean ± SD | Range |
| Incubation period | 13.00 ± 0.89 | 11.00-14.00 | 13.00 ± 0.89 | 11.00-14.00 |
| Post embryo | 3.30 ± 0.45 | 3.00-4.00 | 3.30 ± 0.45 | 3.00-4.00 |
| I instar | 34.00 ± 2.28 | 32.00-39.00 | 34.10 ± 3.14 | 31.00-38.00 |
| II instar | 10.90 ± 3.50 | 8.00-17.00 | 10.40 ± 2.33 | 8.00-14.00 |
| III instar | 8.30 ± 2.05 | 6.00-12.00 | 8.70 ± 2.79 | 4.00-13.00 |
| IV instar | 9.40 ± 3.29 | 4.00-14.00 | 9.00 ± 3.00 | 6.00-14.00 |
| V instar | 9.00 ± 2.02 | 6.00-12.00 | 9.40 ± 2.41 | 6.00-13.00 |
| VI instar | - | - | 8.00 ± 1.41 | 6.00-10.00 |
| VII instar | - | - | 8.30 ± 1.54 | 6.00-11.00 |
| VIII instar | - | - | 24.50 ± 2.40 | 20.00-27.00 |
| IX instar | - | - | 16.50 ± 2.24 | 14.00-20.00 |
| Adult period | 72.20 ± 6.363 | 65.00-80.00 | 153.90 ± 25.90 | 113.00-208.00 |
| Egg to adult period | 92.1 ± 5.85 | 85.00-100.00 | 151.8 0± 22.80 | 111.00-206.00 |

Plate 6 : Egg-sac of *A. pulchella*

Table 9 : Length and breadth of cephalothorax and abdomen of different stages of spider *Argiope pulchella* *

| Stage | Cephalothorax (mm) | | | | Abdomen (mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | Length | | Breadth | | Length | | Breadth | |
| | Range | Mean ± SD | Range | Mean ± SD | Range | Mean ± SD | Range | Mean ± SD |
| I instar | 0.40-0.52 | 0.50 ± 0.04 | 0.40-0.50 | 0.44 ± 0.04 | 0.57-0.75 | 0.63 ± 0.05 | 0.45-0.60 | 0.53 ± 0.04 |
| II instar | 0.63-0.73 | 0.70 ± 0.03 | 0.60-0.70 | 0.65 ± 0.04 | 0.76-0.86 | 0.82 ± 0.04 | 0.66-0.73 | 0.69 ± 0.02 |
| III instar | 1.00-1.10 | 1.06 ± 0.03 | 0.90-1.10 | 1.00 ± 0.05 | 1.05-1.25 | 1.17 ± 0.05 | 0.90-1.10 | 1.01 ±0.07 |
| IV instar | 1.33-1.50 | 1.40 ± 0.04 | 1.20-1.40 | 1.30 ± 0.07 | 1.50-1.66 | 1.60 ± 0.07 | 1.33-1.53 | 1.40 ± 0.07 |
| V instar | 1.50-1.60 | 1.52 ± 0.03 | 1.33-1.53 | 1.42 ± 0.08 | 1.60-1.73 | 1.65 ± 0.05 | 1.53-1.66 | 1.58 ± 0.06 |
| Adult (♂) | 1.80-2.20 | 2.11 ± 0.11 | 1.80-2.10 | 2.01 ± 0.08 | 2.00-2.50 | 2.34 ± 0.12 | 2.00-2.30 | 2.17 ± 0.09 |
| VI instar | 2.10-2.30 | 2.20 ± 0.06 | 2.00-2.20 | 2.07 ± 0.08 | 2.30-2.50 | 2.36 ± 0.06 | 2.10-2.20 | 2.15 ± 0.05 |
| VII instar | 2.00-2.50 | 2.30 ± 0.02 | 1.00-2.00 | 1.30 ± 0.45 | 3.00-4.00 | 3.35 ± 0.39 | 2.00-3.00 | 2.40 ± 0.48 |
| VIIIinstar | 2.00-3.00 | 2.70 ± 0.45 | 1.50-3.00 | 2.20 ± 0.45 | 4.00-6.00 | 4.60 ± 0.66 | 3.00-4.00 | 3.40 ± 0.48 |
| IX instar | 3.00-4.00 | 3.50 ± 0.50 | 2.00-3.00 | 2.80 ± 0.40 | 5.00-6.00 | 5.20 ± 0.40 | 3.00-5.00 | 3.90 ± 0.53 |
| Adult (♀) | 4.00-5.00 | 4.80 ± 0.40 | 3.00-4.00 | 3.50 ± 0.50 | 6.00-7.00 | 6.60 ± 0.48 | 5.00-6.00 | 5.50 ± 0.50 |

* : Mean of ten observations

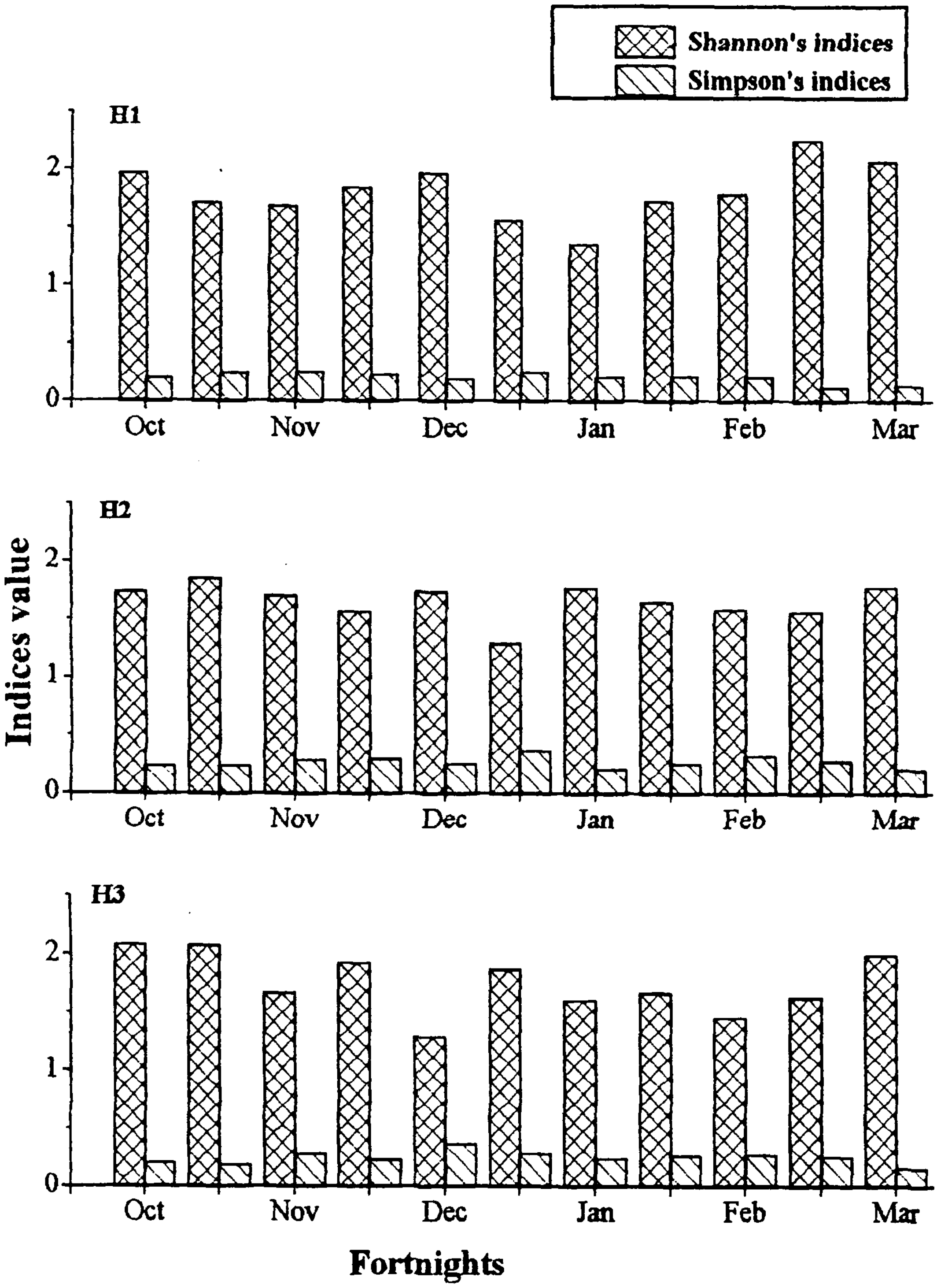


**Fig.4. Seasonal pattern of spider species (Shannon and Simpson) diversity at different heights in mango**

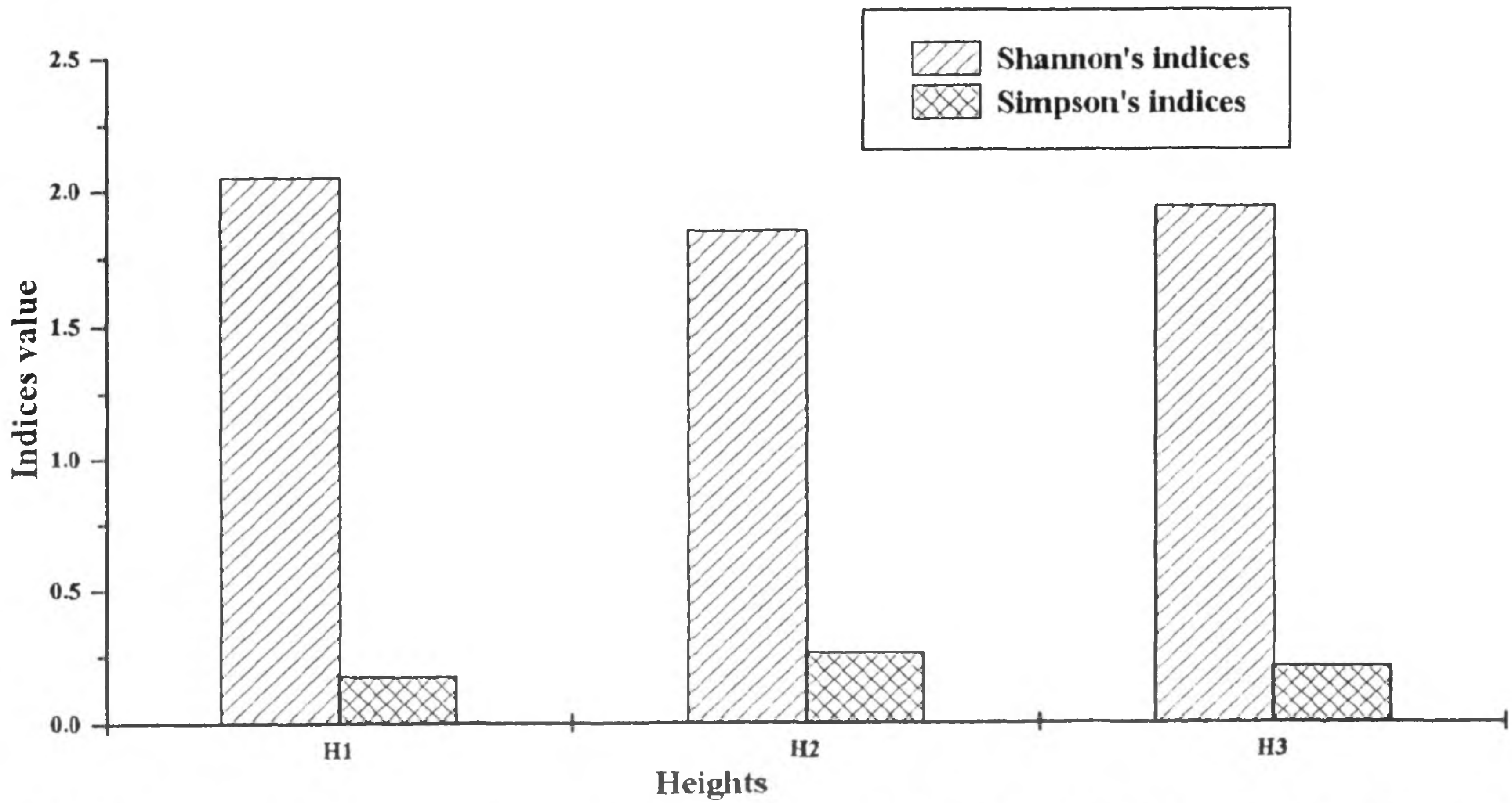


**Fig.5. Diversity (Shannon Weaver's and Simpson's) Indices of spider at different heights in mango**

found to be attached to the either side of the web by means of silken threads. After oviposition, the female joined to the center of the web (Plate 6).

The eggs were spherical or round and pale yellow or creamy white in colour, measuring 0.89 mm. The egg-sac (sacs) measured 10-23 mm in length and 6-14 mm in breadth. The freshly laid egg-sacs were greyish brown in colour and gradually turned to grey with a greenish tinge.

### 4.2.2 Hatching and development

There was no apparent change in colour of the egg from oviposition to hatching. Table 9 presents duration in days of the various developmental stages. The incubation period of egg ranged from 11-14 days ( $\bar{x}$ =13 ± 0.89) . A few hours before hatching, one end of the chorion of the egg turned slightly white, then there was split in the chorion in the region of spiderling prosoma. The prosoma emerged first, followed by prosomal appendages. The chorion remained attached to the posterior tip near the spinnerets after emergence of the abdomen. In the newly emerged spiderling, or post embryo, the appendages (legs, chelicerae and pedipalps) were kept close to the body. The body was enclosed in a transparent membrane with the chorion attached to the posterior end. The motionless post embryo stage lasted 3-4 days, ($\bar{x}$ = 3.30 ± 0.45). Chorion was shed with the exuvium of post embryo.

#### 4.2.2.1 Male

First instar: The first instar spiderlings emerged from the post embryo with a cream white to transparent prosoma, whitish legs and as yellowish abdomen. They did not feed. First instar spiderlings were smooth bodied, without colour markings, hairs or setae. They remained in the egg-sac, when they were not disturbed.

At room temperature, the first instar lasted for 34.0 ± 2.28 days with a range of 32-39 days. The cephalothorax of spiderlings measured 0.4 - 0.52 mm

($\bar{X}$ = 0.50 ± 0.04 mm) in length and 0.4 - 0.5 mm ($\bar{X}$= 0.44 ± 0.04 mm) in breadth and abdomen length of 0.57 - 0.75 mm ($\bar{X}$= 0.63 ± 0.05) in length and 0.45 - 0.60 mm ($\bar{X}$= 0.53 - 0.04) in breadth.

Second instar: The second instar spiderlings were quite active, emerged from the egg-sac and fed readily on *D. melanogaster*. These were creamy white, with setae scattered profusely over the body. The duration was found to be 10.9 ± 3.50 days at room temperature with a range of 8-17 days. The cephalothorax of second instar spiderling measured 0.63 - 0.73 mm ($\bar{X}$ = 0.7 ± 0.03) in length and 0.60 - 0.70 mm ($\bar{X}$ = 0.65 ± 0.04) in breadth and the abdomen length was 0.76 - 0.86 mm ($\bar{X}$= 0.82 ± 0.04) in length and 0.66 - 0.73 mm ($\bar{X}$ =0.69 ± 0.02) in breadth.

Third instar: The third instar resembled the second instar in all respects except size and duration. The duration of third instar was found to be 8.30 ± 2.05 days at room temperature with a range of 6.0 - 12.0 days. Its cephalothorax measured 1.0 - 1.10 mm ($\bar{X}$ = 1.06 ± 0.03) in length and 0.90 - 1.1 mm ($\bar{X}$ = 1.0 ± 0.05) in breadth and abdomen length 1.05- 1.25 mm ($\bar{X}$ = 1.17 ± 0.05) in length and 0.96 - 1.1 mm ($\bar{X}$ =1.01 ± 0.07) in breadth.

Fourth instar: The fourth instar resembled the earlier instar in all respects except in size and duration. The fourth instar lasted 9.4 ± 3.29 days with a range of 4-14 days. Spiderling cephalothorax measured 1.33 - 1.50 mm ($\bar{X}$ = 1.46 ± 0.04) in length and 1.20 - 1.40 mm breadth ($\bar{X}$ = 1.30 ± 0.07) and abdomen 1.50 - 1.66 mm ($\bar{X}$ = 1.60 ± 0.07) in length and 1.33 - 1.53 mm ($\bar{X}$ = 1.40 ± 0.07) breadth.

Fifth instar: The cephalothorax of fifth instar spiderling was light brown with white hairs. Legs were long, light brown and hairy. Abdomen was light brown, hairy, broadest posteriorly, dorsum yellowish white with transverse brown bands. Ventrum was dark brown with a pair of longitudinal yellow patches. The duration of fifth instar was 9.0 ± 2.02 days, ranging between 6-12 days. Its cephalothorax measured 1.50 - 1.60 mm ($\bar{X}$ = 1.52 ± 0.03 mm) in


Plate 7 : Spiderling instars (1-5) of *A. pulchella* Thorell
(Magnification 10x)

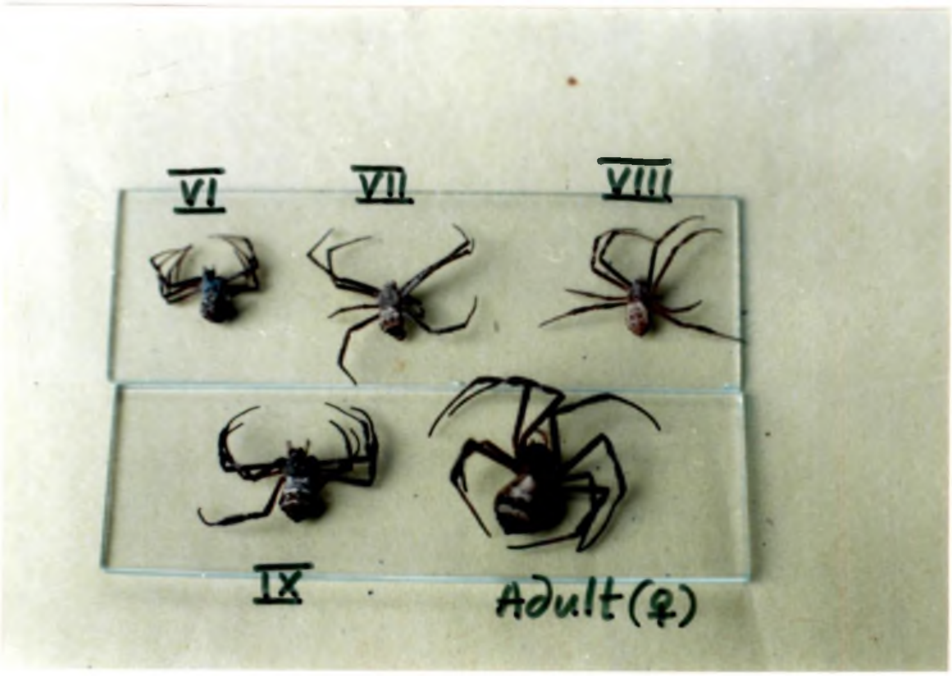


Plate 8 : Spiderling instars (6-9) and Adult female of *A. pulchella*

length and 1.33 - 1.53 ($\bar{X}$ = 1.42 ± 0.08 mm) in breadth and abdomen 1.60 - 1.73 mm ($\bar{X}$ = 1.65 ± 0.05 mm) in length and 1.53 ± 1.66 mm (($\bar{X}$ = 1.58 ± 0.06 mm) in breadth. In this instar the tip of pedipalp was enlarged, making the male distinct from the female (Plate 7).

Adult : The cephalothorax was brownish red to yellowish brown with black eye margins, and two yellow bands on the ventral side of the abdomen. The cephalothorax of the male measured 1.8 to 2.2 mm ($\bar{X}$ = 2.11 ± 0.11) in length and 1.80 ± 2.1 mm ($\bar{X}$ = 2.01 ± 0.08) in breadth. Abdomen 2.0 - 2.5 mm ($\bar{X}$ = 2.34 ± 0.12) in length and 2.0 - 2.3 mm ($\bar{X}$ = 2.17 ± 0.09) in breadth (Plate 9).

#### 4.2.2.2 Female

First instar: The first instar resembled the first instar male in all respects except duration. The duration of first instar female was 34.1 ± 3.14 days at room temperature with range of 31 - 38 days.

Second instar: The second instar also resembled the male second instar in all respects except duration. Its duration ranged between 8 – 14 days ($\bar{X}$ = 10.4 ± 2.33).

Third, Fourth and Fifth instars: In all respects the third and fourth instars resembled third and fourth instars of male except in duration. The fifth instar was different in respect of enlarged pedipalps in case of male. At room temperature, the third instar lasted for 8.70 ± 2.79 days (range = 4-13), the fourth instar lasted for 9.0 ± 3.0 days (range = 6-14) and the fifth instar lasted for 9.4 ± 2.41 days (range = 6-13).

Sixth and seventh instars: The sixth and seventh instars are characterised by cephalothorax light brown with white silvary hairs, legs long, light brown, hairy, abdomen yellowish brown, hairy, broad posteriorly, dorsum yellowish white with transverse brown bands, ventrum dark

Plate 9 : *Argiope pulchella* Adult Male

Plate 10 : *Argiope pulchella* Adult Female

brown with a pair of longitudinal yellow patches. The duration of sixth instar was 8.0 ± 1.41 at room temperature with a range of 6-10 days. The cephalothorax of this instar measured 2.1 to 2.3 mm ($\overline{X}$ = 2.2 ± 0.06) in length and 2 to 2.2 mm ($\overline{X}$ = 2.07 ± 0.08) in breadth Abdomen 2.30 - 2.50 mm ($\overline{X}$ = 2.36 ± 0.06) in length and 2.1 - 2.2 mm ($\overline{X}$ = 21.5 ± 0.05) in breadth.

At room temperature the seventh instar lasted for 8.3 ± 1.54 days (range = 6-11). The cephalothorax measured 2 to 2.50 mm ($\overline{X}$ = 2.30 ± 0.02) in length and 1.0- 2.0 mm ($\overline{X}$ = 1.3 ± 0.45) in breadth and abdomen measured 3-4 mm ($\overline{X}$ = 3.35 ± 0.39) in length and 2-3 mm ($\overline{X}$ = 2.40 ± 0.48) in breadth.

Eighth instar: Resembled the earlier sixth and seventh instars except in duration and measurement. At room temperature, the eighth instar lasted for 24.5 ± 2.40 days (range = 20-27). The cephalothorax measured 2-3 mm ($\overline{X}$ = 2.7 ± 0.45) in length and 1.5-3.0 mm ($\overline{X}$ = 2.2 ± 0.45) in breadth. Abdomen measured 4-6 mm ($\overline{X}$ = 4.6 ± 0.66) in length and 3.0-4.0 mm ($\overline{X}$ = 3.40 ± 0.48) in breadth.

Ninth instar: The cephalothorax was brown covered with thin silvary white hairs, legs were dark brown in colour, long hairy, abdomen was dark brown with yellowish silvary bands and patches towards anterior side and lateral margin (Plate 8).

The duration of ninth instar was 16.50 ± 2.24 days at room temperature with (range = 14-20). Its cephalothorax measured 3-4 mm ($\overline{X}$ = 3.50 ± 0.5) in length and 2-3 mm ($\overline{X}$ = 2.80 ± 0.46) in breadth. Abdomen measured 5.0-6.0 mm ($\overline{X}$ = 5.20 ± 0.40) in length and 3-5 mm ($\overline{X}$ = 3.90 ± 0.53) in breadth.

Adult female: The adult female spider was greyish brown, hairy and thickly pubescent, and was charectarised by greyish brown, long strong hairy and spiny legs; abdomen pentagonal, broadest posteriorly, hairy, pubescent dorsum yellowish white with transverse brown bands, ventrum dark brown with a pair of longitudinal yellow patches. Its cephalothorax measured 4-5 mm ($\overline{X}$ = 4.90 ± 0.40) in length and 3-4 mm ($\overline{X}$ = 3.50 ± 0.50) in breadth. Abdomen measured 6-7 mm ($\overline{X}$ = 6.60 ± 0.48) in length and 5-6 mm ($\overline{X}$ = 5.50 ± 0.50) in breadth (Tables 8 and 9 ) (Plate 10).

Egg to adult period: At room temperature, the egg to adult period of female was 151.80 ± 22.80, (range = 111-206), where as that of male was 92.10 ± 5.85 days (range = 85-100) (Table 8).

**Mating**

Spiders showed a 75 per cent success of mating at 1st, 3rd and 5th day after attaining adult stage and it decreased to 50 and 25 per cent success at 10th and 20th day after attaining the adult stage, respectively (Table 10).

### 4.2.3 Adult longevity

Males survived for 65 to 80 days ($\overline{X}$ = 72.20 days). Females lived longer duration than males, the adult longevity ranging between 113 to 208 days (with a $\overline{X}$ = 153.9 days) (Table 15).

### 4.2.4 Feeding potential

The first instar spiderlings did not feed. However, all the remaining instars and adults spiders consumed *D. melanogaster* adults. Maximum consumption was noticed in the seventh, eighth, nineth instars and in adult stages (Table 11). Considering per day consumption, the feeding rate increased progressively from the second instar to the final instar. As compared to the immature stages, the rate of consumption was quite high in the adult stage The average number of *D. melanogaster* consumed by adult female was higher

**Table 10 : Success of mating in *Argiope pulchella* after attaining the adult stage**

| Sl. No. | Sexual starvation days after attaining adult stage | No. of Pairs | Success in egg laying | Percentage of success |
|---|---|---|---|---|
| 1 | 1 | 4 | 3 | 75 |
| 2 | 3 | 4 | 3 | 75 |
| 3 | 5 | 4 | 3 | 75 |
| 4 | 10 | 4 | 2 | 50 |
| 5 | 20 | 4 | 1 | 25 |

than that of the male. Consumption of prey per individual in case of females was from 24.80-35.70 ($\overline{X}$ = 30.10 ± 2.91), which was higher than that for males, which ranged from 4 to 7.60 per day ($\overline{X}$ = 5.94 ± 1.31) (Table 11 and Fig. 6). The number of *D. melanogaster* consumed varied from 240-290 ($\overline{X}$ = 264.70 ± 13.40) for male and 3000-5800 ($\overline{X}$ = 4646.90 ± 983.90) for female spiders (Table 12).

#### 4.2.4.1 Functional response of *A. pulchella*

The functional responses of male and female of *A. pulchella* to the *D. melanogaster* density were carried out. The mean number of *D. melanogaster* consumed by the male *A. pulchella* was 5.4, 11.6, 13.4, 15.4, 16.6, 16.8 and 17 flies at the density of 10, 50, 100, 150, 200, 250 and 300, respectively. While at the same prey densities the female consumed an average of 10, 49.2, 80.8, 135, 150, 164.2 and 168.6 *D. melanogaster* adults (Table 13 and Fig. 7).

### 4.2.5 Pre-copulation, pre-oviposition, oviposition and post-oviposition period

Pre-copulation period ranged from 1 to 3 days ($\overline{X}$ = 1.4 days), pre-oviposition period varied from 9 to 13 days ($\overline{X}$ = 10.7 days), oviposition period varied from 90 to 150 days ($\overline{X}$ = 119 days) and post-oviposition period varied between 11 to 27 days ($\overline{X}$ = 22.8 days) (Table 14).

### 4.2.6 Mating

The spiders started mating one to three days after attaining the adult stage. Prior to mating both sexes faced each other. The male spider made a vigorous shaking of its entire body up and down and raised its front legs to touch the female. Many a times the female refused and tried to avoid the approaching male for mating. In some cases, this behaviour was also vice-versa. When the female responded, the male mounted the female by holding the cephalothorax with chelicerae, inserted both the pedipalps on underside of the female abdomen. The mating lasted for few seconds and after mating, the female killed the male and fed.

**Table 11 : Mean prey consumption of different stages of *Argiope pulchella* ***

| Stage | Prey consumption per day | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | Mean ± SD | Range | Mean ± SD | Range |
| I instar | 0.00 ± 0.00 | 0 | 0 | 0 |
| II instar | 0.87 ± 0.18 | 0.60 - 1.28 | 0.75 ± 0.07 | 0.62 - 0.87 |
| III instar | 0.82 ± 0.11 | 0.66 - 1.00 | 2.01 ± 0.38 | 1.50 – 2.60 |
| IV instar | 1.81 ± 0.13 | 1.66 - 2.16 | 2.06 ± 0.55 | 1.00 – 3.00 |
| V instar | 3.97 ± 0.58 | 3.30 - 5.00 | 5.97 ± 0.45 | 5.00 – 6.60 |
| VI instar | - | - | 5.12 ± 0.67 | 5.00 – 6.00 |
| VII instar | - | - | 9.79 ± 0.58 | 9.00 – 10.9 |
| VIII instar | - | - | 14.6 ± 0.73 | 13.0 – 16.0 |
| IX instar | - | - | 20.4 ± 1.01 | 19.0 – 23.0 |
| Adult | 5.94 ± 1.31 | 4.00 - 7.60 | 30.1 ± 2.91 | 24.8 – 35.7 |

* : Prey offered adults of *Drosophila melanogaster*

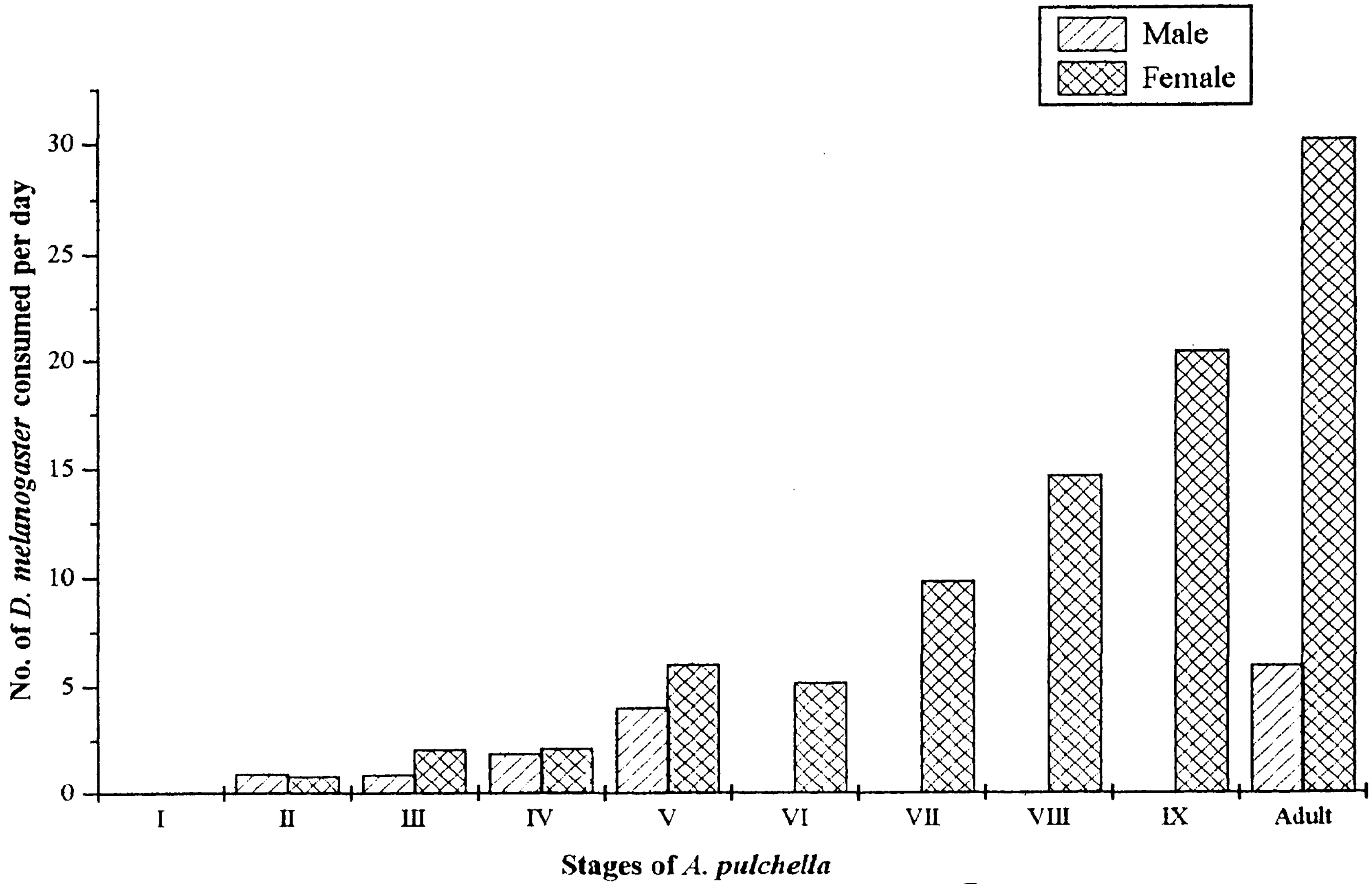


**Fig. 6: Consumption of adults of *D. melanogaster* by the immature & adult stage of *A. pulchella***

**Table 12 : Mean prey consumed in different immature and adult stages of *Argiope pulchella****

| Stage | Prey consumption per stage | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | Mean ± SD | Range | Mean ± SD | Range |
| I instar | 0 | 0 | 0 | 0 |
| II instar | 8.00 ± 1.61 | 5.00 - 10.00 | 7.60 ± 1.90 | 5.00 - 10.00 |
| III instar | 7.20 ± 1.78 | 4.00 - 10.00 | 6.90 ± 2.44 | 3.00 - 13.00 |
| IV instar | 14.10 ± 6.45 | 7.00 - 26.00 | 15.0 ± 4.02 | 11.00 - 22.00 |
| V instar | 36.40 ± 7.98 | 30.00 - 42.00 | 36.8 ± 7.22 | 30.00 - 42.00 |
| VI instar | - | - | 31.2 ± 6.73 | 30.00 - 40.00 |
| VII instar | - | - | 79.2 ± 21.7 | 54.00 - 90.00 |
| VIII instar | - | - | 340.5 ± 38.2 | 290.00 - 405.00 |
| IX instar | - | - | 334.7 ± 52.6 | 280.00 - 400.00 |
| Adult | 264.7 ± 13.40 | 240.00 - 290.00 | 4646.9 ± 983.9 | 3000.00 - 5800.00 |

* : Prey offered : Adult *Drosophila melanogaster*

**Table 13 : Functional response of spider *Argiope pulchella* to prey density ***

| Sl.No. | Prey density | Female consumed Mean ± SD | Male consumed Mean ± SD |
|---|---|---|---|
| 1 | 10 | 10.00 ± 0.00 | 5.40 ± 0.48 |
| 2 | 50 | 49.20 ± 0.97 | 11.60 ± 0.48 |
| 3 | 100 | 80.80 ± 7.85 | 13.4 ± 1.01 |
| 4 | 150 | 135.0 ± 8.14 | 15.4 ± 1.01 |
| 5 | 200 | 150.0 ± 3.40 | 16.6 ± 1.01 |
| 6 | 250 | 164.2 ± 13.6 | 16.8 ± 0.97 |
| 7 | 300 | 168.6 ± 21.4 | 17.0 ± 1.41 |

* : Prey offered : Adult *Drosophila melanogaster*

**Table 14 Biological parameter of adult female of *Argiope pulchella***

| Sl. No. | Biological Parameters | N | Observation values Mean ± SD | Range |
|---|---|---|---|---|
| 1 | Precopulation (days) | 10 | 1.40 ± 0.80 | 1-3 |
| 2 | Preoviposition(days) | 10 | 10.7 ± 1.61 | 9-13 |
| 3 | Oviposition (days) | 10 | 119 ± 21.1 | 90-150 |
| 4 | Fecundity | 10 | 1615.2 ± 178.2 | 1393-2068 |
| 5 | Post oviposition (days) | 10 | 22.8 ± 6.01 | 11-27 |
| 6 | Adult longevity (days) | 10 | 153.9 ± 25.9 | 113-208 |

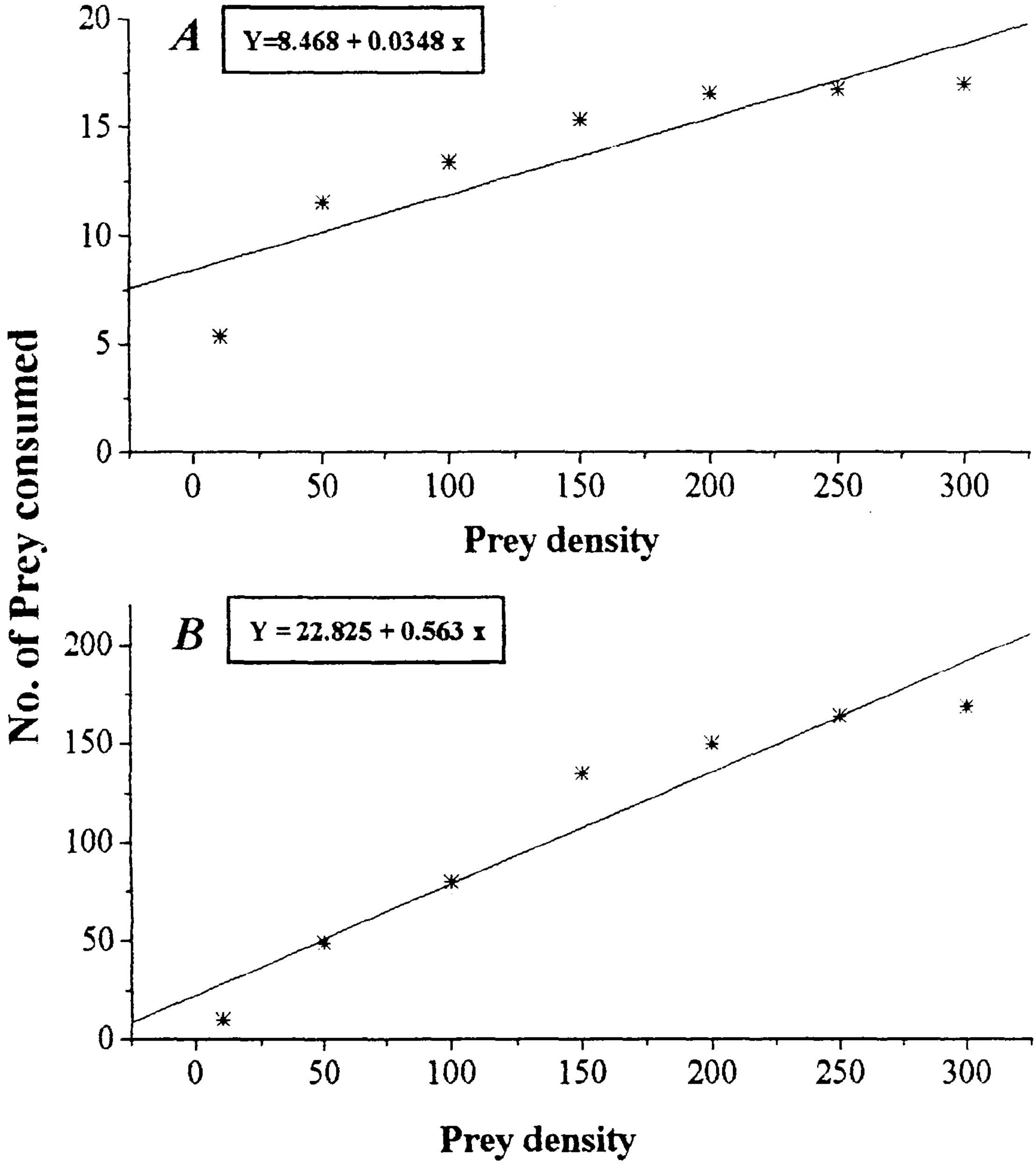


**Fig.7: Functional response of (A) Male and (B) Female *A. pulchella* with adults *D. melanogaster***

### 4.2.7 Oviposition

The female *A. pulchella* laid nine to ten batches of egg-sacs ($\overline{X}$ = 9.80 egg-sac per female) during her life time. The female laid the first batch of eggs between 10-16 days ($\overline{X}$ = 12 days), second batch between 19-33 days ($\overline{X}$ = 22.1 days), third batch between 28-49 days ( $\overline{X}$ = 32.6 days), fourth batch between 38-65 days ($\overline{X}$ = 44.3 days), fifth batch between 46-83 days ($\overline{X}$ = 56.5 days), sixth batch between 55-100 days ($\overline{X}$ = 69.4 days), seventh batch between 63-118 days ($\overline{X}$ = 82.9 days), eight batch between 76-137 days ($\overline{X}$ = 98.3 days), ninth batch between 91-156 days ($\overline{X}$ = 114.9 days) and tenth batch between 102-181 days ($\overline{X}$ = 131 days). The interval between first and second egg batches varied between 9-17 days ($\overline{X}$ = 10.1 days), 9-16 days ($\overline{X}$ = 10.5 days) between second and third batches, 10-16 days ($\overline{X}$ =11.7 days) between third and fourth, 8-18 days (with a $\overline{X}$ 12.2 days) between fourth and fifth, 9-17 days ($\overline{X}$ = 12.9 days) between fifth and sixth, 8-18 days ($\overline{X}$ = 13.5 days) between sixth and seventh, 13-19 days ($\overline{X}$ = 15.4 days) between seventh and eighth, 15-19 days ($\overline{X}$ = 16.6 days) between eighth and ninth and 11-25 days ($\overline{X}$ = 17.0 days) between ninth and tenth egg batches.

### 4.2.8 Fecundity

The number of eggs in each egg-sac of first to tenth batches ranged between 200-450, 150-230, 115-260, 137-220, 90-298, 100-215, 100-160, 100-220, 90-130 and 70-120, respectively. Similarly, mean number of eggs in each egg-sac was 292.6, 187, 183.2, 167, 165, 151.1, 136.6, 129.9, 110.3 and 92.5, respectively from first to tenth batches. The number of eggs per female varied between 1393-2068 ($\overline{X}$ = 1615.2).

### 4.2.9 Starvation studies

The male *A. pulchella* survived without food, without water and without food and water for 39.1, 47.1 and 24.8 days, respectively, whereas the female under the same condition survived for 41.2, 133 and 27.5 days, respectively (Table 15).

## 4.3 Webbing pattern of spiders

### 4.3.1 Number of radii constructed by different species of spider in the field

Analysis of variance of the number of radii constructed by four different species revealed that there were highly significant differences between the species. The highest number of radii was recorded in *A. pulchella* followed by *L. fastigata, L. decorata* and *G. germinata* with a mean of 43, 33, 32 and 28, respectively (Table 16).

### 4.3.2 Number of spirals constructed by different species of spider in the field

Analysis of variance of direction of spirals in the webs of four species of spiders revealed that there were highly significant differences between species. The highest number of spirals was recorded in *A. pulchella* followed by *L. fastigata, L. decorata* and *G. germinata* with a mean of 50, 46, 35and 33, respectively. In *A. pulchella* highest number of spirals was recorded in South followed by East, North and West directions, with a mean of 52, 51, 49 and 49, respectively. In *L. fastigata*, the highest number of spirals was recorded in North followed by South, East and West with a mean of 47, 46, 45, and 44, respectively. In *L. decorata*, the highest number of spirals was recorded in South, followed by East, West and North with a mean of 37, 35, 35, and 34, respectively. In *G. germinata,* the highest number of spirals was recorded in South, followed by West, North and East, with a mean of 34, 33, 32 and 32, respectively. There was no significant difference among the directions. Similarly, there was no significant difference between species and compas direction interaction (Table 17).

### 4.3.3 Changes of web with age

#### 4.3.3.1 Number of radii and spirals formed by different instars under laboratory condition

The highest number of radii was formed by the adult followed by the remaining instars, with a mean of 39.3 ± 1.26, 39.0 ± 0.89, 38.6 ± 1.28, 37.6 ± 1.49, 36.5 ± 1.62,

**Table 15 : Longevity of adult in *Argiope pulchella* under different stress condition**

| Sl. No. | Longevity in different condition | Mean number of days ± SD | |
|---|---|---|---|
| | | Male | Female |
| 1 | With normal food and water | 72.20 ± 6.36 | 153.9 ± 25.9 |
| 2 | No food but with only water | 39.10 ± 4.14 | 41.2 ± 2.48 |
| 3 | No water but with only food | 47.10 ± 5.35 | 133 ± 13.6 |
| 4 | With no food and water | 24.8 0 ± 6.88 | 27.5 ± 3.82 |

**Table 16 : Mean number of radii constructed by different species of spiders in field**

| Spider Species | Mean |
|---|---|
| *G. germinata* | 28 |
| *L. fastigata* | 33 |
| *L. decorata* | 32 |
| *A. pulchella* | 43 |
| Sem ± | 1.152 |
| CD | 3.345 |

**Table17 : Mean number of spirals constructed by different species of spiders in field**

| CD/SP | *G. germinata* | *L. fastigata* | *L. decorata* | *A. pulchella* | Mean |
|---|---|---|---|---|---|
| N | 32 | 47 | 34 | 49 | 40 |
| S | 34 | 46 | 37 | 52 | 42 |
| E | 32 | 45 | 35 | 51 | 41 |
| W | 33 | 44 | 35 | 49 | 40 |
| Mean | 33 | 46 | 35 | 50 | |

| For comparision | F.test | S.E.m | CD at 5% |
|---|---|---|---|
| Species (A) | ** | 1.078 | 2.113 |
| Compas direction(B) | NS | | |
| A X B | NS | | |

33.8 ± 2.13, 28.7 ± 1.67, 25.9 ± 2.25, 23 ± 1.84 and 20.4 ±2.10, respectively. Similarly, highest number of spirals was also formed by the adult followed by remaining instars, with a mean of 38.5 ± 0.10, 37.6 ± 0.46, 37 ± 0.60, 37.9 ± 0.31, 36.6 ± 0.28, 32.8 ± 1.16, 29.6 ± 0.68, 23.3 ± 0.83, 20.5 ± 0.70 and 19.5 ± 0.89, respectively. A trend of increasing number of radii and spirals with increasing age was observed (Table 18).

### 4.3.4 Behaviour of spider

#### 4.3.4.1 Prey and prey capture

The orbwebs of *G. germinata, A. pulchella* and *Araneus* sp. were made within the branches of mango tree. These spiders fed only on living arthropods, eg. leafhoppers, grasshoppers, leafwebbers, butterflies, blowflies, ants, honeybees, reduviids and spiders, which they first subdued with poison. The spider injected digestive juices into its prey to break down its body tissues and then sucked out the resultant broth. Webs were made or repaired almost everyday as a result of damage caused by wind, rain and accidents.

### 4.3.5 Construction of an orbweb

The orbweb by Araneid spiders was built in three distinct stages. First, the spider constructed the frame work by trailing a line of silk in the air, then it stuck it to a branch and then pulled it. Sometimes, it anchored a line to the starting point and then walked across to the next intended anchor point, trailing a silken line which was then pulled taut. Then, non sticky spokes (temporary spirals), varying with the species, but usually under 50 in number, were laid, radiating from a centered point and joining the initial frame work at the other end. The spider then built a platform of tight spirals at the center, forming a hub, on which later on waited for prey and followed this with a temporary loose spiral of non-sticky silk starting from near the center and circling outwards until the increasing gaps between the spokes indicated to it when to stop, or to provide support and guidance during the construction of the permanent spiral. It than turned around and the begans to follow the spiral, eating it bit by bit as it proceeded to conserve protein and laying the sticky spiral

**Table 18: Webbing pattren of different instars of *Argiope pulchella* on fourty centimeter bamboo frames**

| Instar | Radii Mean ± SD | Spirals | | | | Mean ± SD |
|---|---|---|---|---|---|---|
| | | North | South | East | West | |
| I | 20.4 ± 2.10 | 20.7 | 19.1 | 18.3 | 19.9 | 19.5 ± 0.89 |
| II | 23.0 ± 1.84 | 21.4 | 21.1 | 19.9 | 19.8 | 20.5 ± 0.70 |
| III | 25.9 ± 2.25 | 24.0 | 22.2 | 23.0 | 24.3 | 23.3 ± 0.83 |
| IV | 28.7 ± 1.67 | 28.6 | 30.4 | 29.5 | 30.1 | 29.6 ± 0.68 |
| V | 33.8 ± 2.13 | 31.9 | 34.7 | 32.9 | 31.8 | 32.8 ± 1.16 |
| VI | 36.5 ± 1.62 | 37.1 | 36.7 | 36.3 | 36.6 | 36.6 ± 0.28 |
| VII | 37.6 ± 1.49 | 37.8 | 37.9 | 38.5 | 37.7 | 37.9 ± 0.31 |
| VIII | 38.6 ± 1.28 | 37.6 | 37.7 | 36.5 | 36.4 | 37.0 ± 0.60 |
| IX | 39.0 ± 0.89 | 37.4 | 38.4 | 37.2 | 37.4 | 37.6 ± 0.46 |
| Adult | 39.3 ± 1.26 | 38.5 | 38.5 | 38.7 | 38.7 | 38.5 ± 0.10 |

(permanent spiral) line behind. The final adjustment of hub consisted of the removal of tangled remains of the earlier work of radius building. The holes exposed in the platform may be left open or may be criss crossed by new threads. The hatched band or stabilimentum, was added at the end of the web building. Then spider took its station, abdomen upward, legs extended to grasp radial threads, vigilant for the first contact of prey with the web.

### 4.3.6 Time required to make the webs

For an adult female *A. pulchella* radial and structure elements were accomplished well under 5 minutes the construction of the viscid spiral took another 25 minutes or longer. Orb-web building took on an average half an hour.

### 4.3.7 Means of killing the prey

Spiders killed their prey by means of venom secreted by a pair of glands in the cephalothorax; the ducts from these glands open, one on each side through a minute, pore at the tip of the fang of the chelicera. Most of the web-building species swathe their victims in a sheet of silk. The act of swathing could easily observed by throwing large insects on the web of *Argiope* sp. and *Araneus* sp. The spider first rushed at the insect and pierced it with the fang of its chelicerae and then darted back into a position of safely. This was repeated several times, as if the spider was not afraid of its victim. However, the repeated biting was not needed. Then the spider approached the insect and pulled out a sheet against the insect. In doing this, the spider used first one hind leg and then the other. In case of *A. pulchella* this sheet of silk was sometimes an inch in length the body of the spider being held that far from the insect and under this condition, the sheet was seen to be composed of a very large number of parallel threads. As soon as the sheet is fastened used to the insect, the spider rolled the insect over and over, thus managing to wrap it completely in its shroud. After the prey was sucked only a small mass of undigestible material such as chitinous elements remained which was discarded.

## 4.4 Effect of interference behaviour of spider *A. pulchella* with the reduviid *E. inornatus*

There was highly significant difference between the number of prey consumed by the spider *A. pulchella* and the reduviid *E. inornatus*. Out of 30 *D. melanogaster* supplied the spider consumed on an average 24 *D. melanogaster* in one day. Whereas, the reduviid consumed on an average 16. In the third treatment, both spider and reduviids were placed in the same polyethylene bag cage and 60 *D. melanogaster* were supplied as food for them. But an average of only 37 *D. melanogaster* were consumed by them and the reduviid was killed by the spider in all the replications (Table 19).

**Table 19 : Effect of interference behaviour of spider *Argiope pulchella* on Reduviid *Endochus inornatus***

| Treatments | Mean number of *D. melanogaster* consumed |
|---|---|
| $T_1$ | 24 |
| $T_2$ | 16 |
| $T_3$ | 37 |
| $T_4$ | 1 |
| SEM ± | 0.858 |
| CD | 2.533 |

$T_1$ = Spider with 30 *D. melanogaster*

$T_2$ = Reduviid with 30 *D. melanogaster*

$T_3$ = Spider + Reduviid 60 *D. melanogaster*

$T_4$ = Control (Prey only) 30 *D. melanogaster*

# DISCUSSION

# V DISCUSSION

The results of the present investigations are discussed objective-wise in this chapter.

## 5.1 Survey of spiders

### 5.1.1 Spider fauna in mango orchards in and around Bangalore between October 1998 and March 1999

During the survey, fifteen species of spiders belonging to 11 genera representing 5 families were encountered in the mango orchards at GKVK and IIHR, Bangalore. The spiders of the family Araneidae (6 species), Salticidae (4 species)) being the predominant groups. In the present study all the 15 species are new records in mango eco-system from Bangalore. Previous workers (Meena Kumari, 1986 ; Venkateshan, 1992 and Satish Kumar, 1996) have recorded 20 species in mango eco-system. Salticidae being the predominant group with 12 species of the spider followed by Lycosidae (3 species). These results indicate the need for more research on the species richness of spiders in mango eco-system.

### 5.1.2 Population dynamics of spiders in relation to season, pest density and weather parameters

#### 5.1.2.1 Season and weather parameters

The spider population recorded in the present investigation revealed a seasonal succession of spider species, as some of the spiders were present only during particular months. Two species i.e., *L. fastigata* and *L. decorata* were predominant in October. Their population increased gradually in January second fortnight and December second fortnight. The population of three other species *viz.*, *G. germinata*, *A. pulchella* and *C. cicatrosa* increased subsequently during the first fortnight of December after which it started decreasing in February and March.

A seasonal succession of spider species was also observed by Elliot (1930), while studying ecology of spiders of beech maple forests. He found that each season was represented by a few principal species, of which two or three species were numerically dominant.

Whitcomb *et al.* (1963) from Arkansas and Arora and Monga (1993a) from Haryana also observed a seasonal succession of spiders with some forms abundant early in the season and others later and some even with two population peaks.

The present study reveals that the total spider population was maximum during the first fortnight of December. The population gradually increased till first fortnight of December and there was a decline in February - March. The peak population of spiders in December first fortnight, coincided with peak population of insect pests. Similar observations were recorded by Chew (1961) who, in a study of southern desert shrub community found that densities were lowest in February. Dondale from Novascotia (1958) observed that fluctuation in spider population was due to environments influences in the apple orchards, where in there were two peaks in the number of active spiders, a small peak in the spring and a large peak in the late summer and a period of decline was found in late June or early July and in late September and October. Turnbull (1960) also observed two peaks in population of active spiders on Oak, one in the mid summer and other in October. Ecology of spiders of a finnish forest was studied by Huhta (1965) and it was fount that there were two maxima, the first one in the spring and second in the autumn. The abundance of insects and spiders in a ecosystem is influenced by seasonal fluctuations. This has been observed by other workers like Nentwig (1985), Losale and Armando (1985).

In the present study the spider population gradually decreased from the second fortnight of December till the end of March. This may be probably due to pesticide usage in the mango orchards, and the low population of spiders in March can also be attributed to the fact that prey numbers had decreased. Turnbull (1966) observed relationship between spiders, their physical environment and their potential prey. He observed that the over all population remained stable due to these factors, but the variations in the number of spiders were ascribed to birth, death and migration caused by changing weather.

In the present study *G. germinata, L. fastigata, A. pulchella* and *L. decorata* showed highly significant negative correlation with mean maximum temperature and sunshine hours, whereas, *G. germinata, L. fastigata* and *A. pulchella* showed significant positive correlation with mean relative humidity. The total spider population showed highly significant negative correlation with mean maximum temperature and sunshine hours and highly positive correlation with mean relative humidity. These observations are in conformity with those of Easwaramoorthy *et al.* (1994) who also reported that all species they studied had negative correlation with maximum temperature and rainfall and positive correlation with relative humidity.

**5.1.2.2 Pest density**

The total spider population also exhibited a strong positive correlation with total pest population, and the present findings are in close agreement with the earlier findings of Singh (1967), who also found a strong positive correlation between population of sugarcane pest, *P. perpusilla* with that of the spider, *C. dressodes*. Similar correlation was also observed by Sadana and Kaur (1974) and Sadana and Sandhu (1977), between population of spiders and insect pests of citrus and grapevine orchards respectively. Whereas a positive correlation between spider populations and leafhoppers was recorded by Meenakumari (1986) and Rabindran *et al.* (1992).

While, Arora and Monga (1993a) found a strong positive correlation between spider population and population of insect pest of pigeonpea, Satish Kumar (1995) found a strong positive correlation between spider population and population of insect pests of mango. Mansour *et al.* (1980) found a significant decrease in damage caused by the larvae of the apple pest, *S. littoralis* on trees occupied by spiders as compared to those from which spiders were removed.

**5.1.2.3 Diversity of Spider**

In the present study species richness was low during second fortnight of January, while it was maximum during October, November and in the second fortnight of December.

Simpson's Index ($\lambda$) of spider species diversity was low during first fortnight of January, while the maximum was observed during first fortnight of December. Shanon's Index ($H_1$) of spider species sample, indicated maximum species during first fortnight of October. Fluctuation in the diversity may be due to high environmental complexity that allowed a large number of predatory species to co-exist within a given habitat as pointed out by Hatley *et al.* (1960). Uetz (1975) observed that a seasonal peak in species diversity ($H_1$) and species richness in mid summer was significantly correlated with prey abundance but not with temperature, humidity or rainfall supports the present findings.

Taxonomic similarity of spider species was found to be highest between Height 2 – Height 3 ($H_2$-$H_3$) followed by Height 1 – Height 3 ($H_1$-$H_3$) and Height 1 – Height 2 ($H_1$-$H_2$), and there was no similarity between Height 0 – Height 1 ($H_0$-$H_1$), Height 0 – Height 2 ($H_0$-$H_2$) and Height 0 – Height 3 ($H_0$-$H_3$). This may be due to the habitat and niche of the spider species. Both Simpson($\lambda$) and Shanon Weaver ($H_1$) indices showed highest diversity in $H_1$ followed by $H_3$ and $H_2$. This is probably due to the abundance of prey at that particular height. This is a new report on spider diversity from Karnataka.

## 5.2. Biology of *A. pulchella*

The biology of *A. pulchella* using *D. melonogaster*, under laboratory conditions, was studied for the first time. These observation are discussed below.

The data on the durations of different immature stages and on the longevity of different sexes are presented in Table - 9. There were five instars for male and nine instars for female spiders, and females lived longer than males. Easwaramoorthy *et al.* (1996) observed the average incubation cum first instar period of egg 58.6 days in case of *C. cicatrosa.* They reported that there were nine instars in the females and female lived for 66 days (range 58 – 79). But they did not mention the number of instars and the longevity of male. The present findings are closely related to the findings of Muniappan and Chada (1970) on *M. celer.* According to them, the differences in the duration of each instar of the above spiders species was attributed to genetic variation existing in the population and environmental factors such as variations in temperature, relative humidity and influence of host.

### 5.2.1 Biological parameters of adult females

In the present study the average pre-ovipostion period of *A. pulchella* was on par compared to that in *L. pseudoannulata* which took 9 days after emergence for first oviposition when adult females consumed 4 BPH prey per day (Suzuki and Kiritani, 1974). Each female *A. pulchella* deposited 9-10 egg-sacs, with an average fecundity of 1615.2. However, the present findings closely agree with the egg-sacs of *C. cicatrosa* reared on *Chilo infuscatellus* Snellen ad Libtun which reared 6-10 egg-sacs. Easwarmoorthy *et al.* (1996), but they failed to mention the fecundity of *C. cicatrosa.* In the present study the period of interval between the deposition batches of egg-sacs increased with the age of the female. Fecundity of the spider decreased with increase in age, which could be attributed to the reduced feeding capacity, as it became older. Similar observations have been recorded by Venkateshalu, 1996. Though several workers (Muniyappa *et al.*, 1970 ; Suzuki and Kirtani, 1974 ; Gavara and Raros, 1975 ; Charles *et al.*, 1978 ; Mansour *et al.*, 1980a ; Samal and Misra, 1985, Sathiamma *et al.*, 1986 ; Meenakumari, 1986 ; Kim and Lee, 1994 ; Dhulia and Yadav, 1994; Ganesh Kumar *et al.*, 1995 ; Eshwarmoorthy *et al.*, 1996 ; Venkateshalu, 1996), attempted to study the biology of different spider species but they failed to furnish the detailed information. Therefore, comparisons could not be made with the present study.

### 5.2.2 Feeding potential of *A. pulchella*

The results of the present study on instar wise feeding potential of *A. pulchella* on *D. melanogaster* under laboratory condition revealed that both the male and female of *A. pulchella* consumed *D. melanogaster* during all stages of their growth, except first instar spiderlings which depended on the egg yolk for their food and were never observed to feed on the prey *D. melanogaster*. The rate of feeding per day increased progressively from second instar to final instar. The rate of consumption was quite high in adult spiders, compared to the immature stages. The prey consumption of adults varied from 3000 to 5800 in case of female while the consumption by males was significantly low (240-290).

Similarly instar-wise feeding potential of spider *R. indicus* was observed by Sathiamma *et al.* (1986). The spider started feeding on early instar caterpillar of *Opisina* from the second instar onwards and prey consumption varied from 49 to 207 in case of females while it was 12 to 31 by the males. The first instar spiderlings depended on the egg yolk for their food and were never observed to feed on the prey caterpillars. Further they also noted that males of *Cheiracanthium*, except the first instar, all the eleven instars consumed. *Opisina* caterpillars and the rate of feeding was observed to vary from 60-151. However, they did not specify the *Opisina* instars on which the spider predated.

Sadana and Kumari (1991) observed on the predatory potential of *L. sikkimensis* on the mangohopper, *I. clypealis* and revealed that the spiders are the highly beneficial predators. The adults have significantly higher predatory potential compared to their developmental instars. Sadana and Sandhu (1977) observed the feeding intensity of *M. ludhianensis* on *Brahmabole* sp. and observed that the adult spiders were voracious feeders, while the feeding intensity of 1st and 2nd instar was quite less compared to 3rd to 7th instars. Similar trend of adult spider feeding potential was observed in the present study. Nyffeler (1987) studied the feeding ecology of the orb weaving spider, *A. aurantia* in a cotton agro-ecosystem and found that the major food component of *A. aurantia* were aphids (30%), diptera (26.8%), grasshoppers (17.9%) and Hymenoptera (12.6%). It was found that the adult females of *A. aurantia* have a potential to kill the prey upto 200% of their own size.

Though Holmberg and Turnbull (1982) observed that *P. vancouveri* fed on male and female fruitflies, *D. melanogaster* small and large larvae of *Tenebrio* sp.and nymphal milk weed bugs, *O. fasciatus*, but failed to mention about instar wise feeding potential of the predator. Similarly, Huhton (1917) observed that salticid spiders fed on sugarcane froghopper, *Torriapsid* sp. and Misra (1917) observed spiders preying on nymphs of *Pyrilla* sp. playing a significant role in their control. Similarly, Snetsinger (1955) observed *P. audax* and *P. rimoter* feeding on orthopterous, dipterous, heteropterous and homopterous insects. Harrison (1968) found that spiders also feed on lepidopterous banana pests, whiteflies, moths and beetles.

In addition there are numerous reports regarding the records of prey diversity of spiders belonging to different families (Harrison, 1913 ; Johnson, 1913 ; Veitch, 1919 ; Savory, 1928; Bristow, 1941 ; Wite, 1953 ; Snetsinger, 1955 ; Whitcomb *et al.*, 1963 ; Kajak, 1965 ; Sadana *et al.*, 1974 ; Temeraka, 1981 ; Richert *et al.*, 1984 ; Sathiamma, 1987 ; Vandenberge *et al.*, 1987 ; Nyffeler *et al.*, 1988 ; Parquet *et al.*, 1990 ; Tanaka, 1991 ; Rehfeldt, 1992 ; Sterling *et al.*, 1992 ; Miyashita, 1992 ; Arora and Monga, 1993).

### 5.2.2.1 Functional response of *A. pulchella*

Number of *D. melanogaster* fed by male and female *A. pulchella* increased with increasing density of prey but a plateau was reached at a density of 300 and further increase in the prey population did not increase prey consumption. The plateau was highest for the female 168.6 ± 21.48 compared to the male (17 ± 1.41). The functional response curve of *A. pulchella* to prey density obtained in the present study (Fig. 7) is similar to the sigmoid curve of Haynes and Sisojevic (1966) of the spider, *Philodromus rufus* Walckenaer (Arachinida: Thomisidae) to the density of *D. melanogaster*. Similarly the feeding response curves were in agreement with Hollings type II curve (Holling, 1959), as once satiation level was reached further feeding was not possible at any increase in prey density. This phenomenon was also reported with *L. pseudoannulata* (Anonymous, 1984 ; Heong and Rubia, 1990) *Theridion octomaculatum* ; (Ge and Chen, 1989) and for *L. pseudoannulata* (Heong and Rubia, 1989) on BPH and GLH.

Similarly Mansour *et al.* (1980b) demonstrated that the number of *S. littoralis* (Boisduval) larvae consumed appeared to level off (188.9) at the highest density of 250 and 300 per spider in case of *C. mildei.* Likewise, *L. pseudoannulata* reached satiation level at fairly higher density with nymphs of WBPH (Anonymous, 1984). In addition, the functional response of spiders to prey density was also observed by Nakumara, 1977 ; Zhou *et al.*, 1986 ; Yan *et al.*, 1987 ; Heong, 1989 ; Rubia *et al.*, 1990 ; Somu *et al.*, 1993 from different localities. However, the present study on functional response *A. pulchella* on *D. melanogaster* appears to be new to science.

## 5.3 Webbing pattern of spiders

In the present study the webbing pattern of *A. pulchella* was observed in the laboratory as well as under field conditions whereas, in case of other three spider species, *viz.*, *G. germinata*, *L. fastigata* and *L. decorata*, only field observation were under taken. The comparative results of investigations are discussed below.

### Field condition

The web of *A. pulchella* had significantly higher number of radii and spirals followed by *L. fastigata*, *L. decorata* and *G. germinata*. This was due to the body size or weight of the particular spider. In *A. pulchella* the body size or weight was more compared to remaining species. To hold its own weight it had to web more number of radii and spirals to strengthen the web. Web of *A. pulchella* had 43 radii and 50 spiral turns, whereas, Peter and Witt (1968) observed 35 radii and 40 spiral turns in case of *Araneus diadematus* web.

### Laboratory condition

The web of adult *A. pulchella* had significantly more number of radii compared to that of remaining instars, which was similar to the report of Koenig (1951) who found fewer radii in the smaller webs of young *Araneus diadematus* than in webs of full-grown individuals. However, Wiehle (1927) counted more radii in webs of young spiders than in those of adults. Savory (1952) observed a slight decrease in the number of radii in outdoor, *A. diadematus* webs, but pointed out that there was considerable variation. Tilquin (1942) who counted radii in many webs of *A. bruennichi* which he kept indoors and related the number of radii to moulting. He described a slight increase in average number of radii (from 22 to 29) around third moulting. For the rest of the spiders life the average number remained relatively constant. Its counts varied between 10 and 40 radii in webs of young spiders as compared to between 19 and 41 in adult webs. These results are contradictory to the observation made in the present study. Construction of the web, behaviour of the orbweaver, social spiders, time taken to make the webs was explained in the results chapter. The present findings are in close agreement with the earlier findings of Witt *et al.* (1968) and Biswas (1987), Vijayalakshmi (1993), Biswas (1995).

### 5.4 Effect of spider on other predators

The interaction between the different species of spiders and various insect predators were observed by Morse (1988), Gaillebeau *et al.* (1989), Young (1989). In the present study when spider *A. pulchella* and reduviid *E. inaratus* were allowed to feed on *D. melanogaster* together in the polythelene bag, the spider consumed comparatively more number of prey than the reduviids, and the reduviids were hunted by the spiders when they were caught in the spider web.

# SUMMARY

# VI SUMMARY

Fifteen species of spiders belonging to 11 genera representing 5 families were recorded in the mango eco-system during the present investigations at UAS, GKVK, Bangalore. The highest number of species were represented in the family Araneidae and Salticidae, with the highest percentage of individuals from *G. germinata*, dominated among the webbing spiders and *Telamonia* sp. among the hunting spiders.

Peak population of spiders were observed maximum during first fortnight of December which coincided with the peak population of insect pest on the mango crop. The spider population revealed a seasonal succession of species, as some of the species were present only during particular months in a year. The population of spiders in March was less compared to December and November.

The population of *G. germinata* and *L. fastigata* showed significant and negative correlation with mean maximum temperature and sunshine hours, but significant and positive correlation with mean relative humidity. In general the total spider population showed similar trend.

All the four dominant species of spiders, *viz.*, *G. germinata, L. fastigata, C. cicatrosa* and *A. pulchella* showed significant correlation with the population of insect pests and predators, namely *Idioscopus* sp., *O. smaragadina*, *E. inarnatus* and *V. cincta*. Height $H_1$ showed highest diversity compared to $H_2$ and $H_3$. In mango orchards the species richness and species diversity showed that no new species of spider occurred during study period. However, the number of species went on changing with time.

Studies on the biology of the spider, *A. pulchella* revealed that the egg to adult period lasted for 151.8 days for female and 92.1 days for male in the laboratory conditions.

The female had nine instars while the male completed its development with only five instars. Males of *A. pulchella* survived for 72.2 days and consumed 5.94 *D. melanogaster* per day, while females lived for 153.9 days and consumed 30.14 *D. melanogaster* per day. The rate of consumption was significantly high in the adult stage compared to the immature stages.

Premating, pre-oviposition, oviposition and post-oviposition periods lasted for 1.4, 10.7, 119 and 22.8 days, respectively. A female after a single mating, lasted for few seconds and laid 1615.2 eggs in 9-10 batches, with an average of 161.5 eggs/batch.

Both sexes of *A. pulchella* showed sigmoid functional response to *D. melanogaster* density. However, a plateau was reached with a consumption level of 17 flies for male and 168.6 flies for female *A. pulchella* at the density of 300.

Studies on webbing pattern of spiders in the field revealed that webs of *A. pulchella* had significantly higher number of radii and spirals compared to *L. fastigata*, *L. decorata* and *G. germinata*, respectively. In the laboratory, webs of adult *A. pulchella* had more number of radii and spirals compared to the remaining instars.

The results on the effect of interference behaviour of spiders on the population of reduviid. *E. inarnatus* with the spider *A. pulchella* revealed that the spider consumed significantly higher number of prey than the reduviid. When the two were kept together, the reduviid also became a prey for the spider. This clearly shows that spiders do not discriminate among their prey and in bio-control programmes involving spiders and other predators, this point should be kept in mind.

# FUTURE LINE OF WORK

- The Spiders, should be extensively surveyed for promising species under different localities over an extended period of time. Techniques for mass multiplying such spiders should be worked out.

- Measures should be worked out for effective conservation of spiders since it is much more feasible then mass multiplication and field release.

- More intensive studies on the interaction of various natural enemies should be conducted and the most hormonious combination to be worked out so that the pest population can be kept well below the economic threshold level.

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# VII REFERENCES


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* Originals not seen.

# APPENDICES

# APPENDIX I

**Weather data at UAS, GKVK, Bangalore from October 1998 to March 1999**

| Weather Conditions | October | | November | | December | | January | | February | | March | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | I | II | I | II | I | II | I | II | I | II |
| Max. temperature ($^0$c) | 27.1 | 26.9 | 27.7 | 27.3 | 25.2 | 26.2 | 26.3 | 27.6 | 28.7 | 29.7 | 32.1 | 33.7 |
| Min. temperature ($^0$c) | 19.5 | 17.7 | 17.7 | 15.9 | 16.2 | 14.3 | 13.9 | 13.2 | 15.4 | 15.4 | 16.4 | 18.7 |
| Relative humidity (%) | | | | | | | | | | | | |
| 7 AM | 93.8 | 88.8 | 89.4 | 84.0 | 89.4 | 89.9 | 65.0 | 84.5 | 84.5 | 69.7 | 62.9 | 63.6 |
| 14 PM | 66.2 | 55.5 | 67.4 | 53.4 | 67.6 | 49.4 | 62.0 | 32.6 | 43.0 | 39.2 | 34.8 | 29.6 |
| Rain fall (mm) | 16.5 | 0.58 | 2.36 | 0.11 | 0.98 | 0.00 | 0.00 | 0.00 | 0.52 | 0.00 | 0.00 | 0.00 |
| Wind speed (Km/hr.) | 5.56 | 5.60 | 6.91 | 3.57 | 9.40 | 5.38 | 6.06 | 6.25 | 7.81 | 8.26 | 5.08 | 5.10 |
| Evaporation (mm) | 3.24 | 3.58 | 2.98 | 3.51 | 2.88 | 3.55 | 4.12 | 4.86 | 4.99 | 7.21 | 8.26 | 7.01 |
| Sunshine hours/day | 3.00 | 6.10 | 4.56 | 7.92 | 3.24 | 8.23 | 8.54 | 8.74 | 9.20 | 9.40 | 10.1 | 8.85 |

Source: AICRP on Agro-meterology, UAS, GKVK, Bangalore.

# APPENDIX II

**Laboratory recordings of mean maximum and minimum temperature and relative humidity prevailing during 1999.**

| Months | Maximum temperature (°C) | Minimum temperature (°C) | Relative humidity (%) |
|---|---|---|---|
| January | 25.5 | 20.3 | 87.25 |
| February | 26.3 | 22.2 | 84.75 |
| March | 30.5 | 23.6 | 80.46 |
| April | 29.5 | 24.7 | 92.24 |
| May | 28.4 | 23.1 | 72.46 |
| June | 28.3 | 22.5 | 72.97 |
| July | 26.2 | 20.7 | 81.37 |
| August | 26.7 | 20.7 | 75.78 |
| September | 26.8 | 23.1 | 78.63 |
| October | 26.9 | 21.1 | 88.00 |
| November | 26.9 | 21.3 | 80.50 |
| December | 25.6 | 20.3 | 65.93 |