

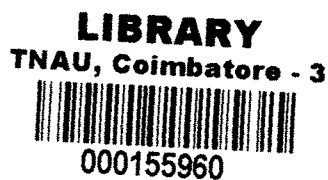
STUDIES ON SPIDERS IN COTTON PEST MANAGEMENT

*Thesis submitted in part fulfilment of the requirements for the degree of
Master of Science (Agriculture) in Agricultural Entomology to
the Tamil Nadu Agricultural University, Coimbatore-3.*

By

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2000

CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON SPIDERS IN COTTON PEST MANAGEMENT" submitted in part fulfilment of the requirements for the award of the degree of **Master of Science** (Agriculture) to the Tamil Nadu Agricultural University, Coimbatore, is a record of **bonafide** research work carried out by **Mr.K.VANITHA**, ID.No. **98-602-009** under my supervision and guidance and that no part of this thesis has been submitted for the award for any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular Journal or Magazine.

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(K. VANITHA)



ABSTRACT

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STUDIES ON SPIDERS IN COTTON PEST MANAGEMENT

By

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Quantitative estimates of abundance of spiders in the cotton ecosystem revealed the highest species richness in Coimbatore cotton fields. Twenty eight species of spiders were recorded in the survey viz., *Araneus* sp., *Argiope pulchella* (Thorell), *Argiope* sp., *Bianor* sp., *Clubiona drassodes* Cambridge, *Clubiona viridanus* sp. nov, *Cryptophora citricola* (Forskal), *Gasteracantha unguifera* (Simon), *Leucauge decorata* (Black wall), *Leucauge* sp., *Neoscona theis*, (Walck), *Neoscona elliptica* (Tikader), *Neoscona* spp., *Olios* sp., *Oxyopes javanus* (Thorell), *Oxyopes rufisternum* (Thorell), *Pardosa* spp., *Pardosa pseudoannulata* (Boes), *Peucetia viridana* (Stoliczka), *Plexipus paykulli* (Audouin), *Salticus* spp., *Tetragnatha* sp., *Thomisus pugilis* (Stoliczka), *Thomisus cherapunjens* (Tikader), *Vicaria preymandibularis* and *Vicaria monostriata* sp. nov. and the host range of the spiders were found to be all the sucking pests, some lepidopteran pests, dipterans, hemipterans, hymenopterans and some other predators. The population fluctuations of the pest and other predators had no impact on the population dynamics of spiders, whereas the weather factors such as minimum temperature

and evening relative humidity were found to be detrimental. The spider populations in the cotton ecosystems increased as the stage of crop advanced. Among the sampling techniques, the whole plant sampling technique was found to be efficient for sampling the spiders of cotton ecosystem followed by pitfall traps. The predatory potential of the spiders was in increasing order from earlier to late instars, where the adult consumed more number of prey insects. The prey preference of the hunting spiders were in the order of leafhoppers, aphids and whiteflies among the sucking pests followed by caterpillar pests whereas web spiders preferred leafhoppers and whiteflies, also a negligible amount of aphids and caterpillar pests. Studies on inter-predation among spiders and cross predation indicated that the hunting spiders feed on the early instars of other spiders. Cross predation by the three hunting spiders affected the population of *Chrysoperla carnea*. The fully grown grubs of *Chrysoperla* consumed the spider egg masses during the absence of the mother spider. Among the cultural practices, variety, spacing and fertilizer levels were observed to influence the population density of spiders.

Among the recommended chemicals for cotton, monocrotophos and methyl demeton showed more contact toxicity whereas quinalphos and monocrotophos were found to leave more residual toxicity towards the spider species tested. The chemicals like imidacloprid and chlorpyrifos were safer to the spiders, whereas *B.t* and neem oil did not show any adverse effects on spiders. The residual toxicity affected the predation rate when treated with chemicals like monocrotophos and quinalphos. Imidacloprid, chlorpyrifos and *B.t* affected the predation rate to a minimum extent, whereas the neem oil did not affect the predation rate. The LC_{50} values were less for monocrotophos and endosulfan and were more for acephate and chlorpyrifos.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Spiders are among the most abundant predators of insects of terrestrial ecosystems (Edwards *et al.*, 1976). Young and Edwards (1990) analysed 29 faunal surveys of spiders found in field crops of United States and revealed that rich spider fauna were monitored especially in cotton (> 300 species). Spiders may play an important role as stabilizing agents or regulators of insect populations in agro and forest ecosystems and other terrestrial ecosystems. Thus their presence in an ecosystem may well influence the population dynamics of other arthropods present.

In the pursuit of the identification of selective biocontrol agents the spiders can be considered for the control of insect pests because

1. They are natural entomophagous predators
2. They can kill a large number of insects per unit time
3. They have high searching ability (especially hunting spiders) and
4. They predate on a wide variety of insects.

Spiders as predators of cotton pests are the least studied arthropods, where they are found in abundance. In past the reports of their actions were largely anecdotal and studies were mostly confined to reports of occurrence and construction of species lists. A very little quantitative information was generated as predators. During last 20 years numerous studies on the spider fauna in agricultural habitats have been published all over the world. (Nyffeler and Benz, 1987). Despite of their importance highlighted by several workers in India a few workers have attempted the study of spiders. The occurrence of spiders in cotton ecosystem was reported by Dhulia and Yadav (1991), but detail studies were not

carried out where these creatures are abundant. Keeping this lacunae in view, the present study was carried out with the following objectives.

1. To identify and estimate the abundance of spider species in the cotton ecosystem.
2. To study the seasonal incidence of spiders in cotton ecosystem.
3. To identify an effective sampling technique for collection of spiders from cotton fields.
4. To study the predatory potential of spider groups against different pests of cotton.
5. To study the impact of different cultural practices on spider population in cotton.
6. To study the impact of different insecticides on spider population in cotton.



REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

There is a little rhyme of English origin, but of uncertain age and derivation which says

“If you wish to live and thrive,
Let a spider run alive”.

2.1. Taxonomic status

After the five largest insect orders, the order Araneae ranks seventh in global diversity of animals among arachnids (Parker, 1982).

As reported by Mitter *et al.* (1988), spiders are exceptional among the other taxa for their complete dependence on predation as a trophic strategy. In contrast, the diversity of insects and mites may result from their diversity in dietary strategies, notably polyphagy and parasitism. In terms of species described and anticipated, spiders are one among the most diverse groups on earth. The earliest records date spiders to some 300 million years ago, 150 million years before flies began buzzing around (Ranjit Lal, 1995).

Around 22,400 valid species of spiders were estimated by Bonnet (1960) in which 400 valid genera and about 15 families of living spiders were described upto 1939. About 4850 additional species were described between 1948 and 1958. In the global scene United States of America leads the world on studies of Aranea, both on systematics as well as applied research (Chamberlin and Ivie, 1945 and Forster, 1967). The notable contributors are Kaston (1978 and 1981), Roth (1985), Platnik (1989), Coddington *et al.* (1990) and Levi (1981, 1983 and 1991).

Spiders studies particularly on taxonomy is meagre in Asia. Tikader (1960-1982) concentrated on spider studies in the Indian subcontinent. The proper

systematic studies were started by Tikader (1962) who published several books viz., Spider fauna of Sikkim (1970), Key to Indian spiders (1977), The Fauna of Indian spiders, Araneae Vol.I and II (1980 and 1982) and Hand Book of Indian Spiders (1987). Various aspects like importance of spiders in agriculture, taxonomic status, ecology, predator prey interactions, toxicity of chemicals etc were studied by other Indian workers, Palanichamy (1980), Baldev Parshad (1985), Rao *et al.* (1981), Gupta *et al.* (1986), Rajendran (1987), Nirmala (1990), Vijayalakshmi and Preston Ahimaz (1993), Ganesh Kumar (1994) and Samiayyan (1996).

2.2. Ecology

2.2.1. Habitat selection

In all terrestrial environments, spiders occupied virtually every conceivable habitat (Coppel, 1960 ; Judd, 1970). Many weather factors like humidity (Jones, 1941) temperature (Barnes and Barnes, 1954) air currents or winds (Cherrett, 1964) and sunlight (Pointing, 1965) were known to influence the choice of website. Several authors studied the ecology of spiders in detail (Chant, 1956; Specht and Dondale, 1960; Dabrowska Port *et al.*, 1968; Dorris, 1969). Peck and Whitcomb (1970) found that the relative humidity less than 45 per cent could cause stress to early instars of *Chiracanthium inclusum* (Hent.). Dean *et al.* (1982) reported that the spider *Peucetia viridans* (Hentz) was uncommon in semiarid characteristics and found abundantly in Texas cotton fields having high rainfall.

Lowries (1948) and Duffy (1968) reported that the presence of certain platforms as support will have an influence on distribution of spiders. The spider distribution is also affected by substrate structure (Barnes and Barnes, 1955). Utez (1975) has correlated the species diversity in guilds with that of the litter depth. Nyffeler and Benz (1987) have reported that the spiders were abundant in grass

lands where they could feed and reproduce in vegetation without human interference.

Architectural properties of habitat might be an important determinant of the distribution and species diversity of predatory spiders (Hatley and Macmahon, 1980). The species diversity, number of species and guilds were positively correlated with indicators of shrub volume and shrub foliage diversity. Similarly crop stage also had an influence on the abundance of the spiders. Skinner (1974), Dietz *et al.* (1976) and Lockley *et al.* (1981) observed the increase in the density of striped lynx spider as the cotton plant matures.

2.2.2. Distribution

There are about 80 families of spiders recorded from all over the world, and of these, 43 families were reported in India (Tikader, 1987). Some of these are true orb-web weavers, some make the irregular webs, a few make the umbrella shaped inverted complicated webs and others make the sheet webs expanding on ground with a funnel retreat. According to web building ability, the spiders are generally considered as weavers or non weavers. Weavers make snares to trap insects as food, while non weavers hunt the prey by chasing or stalking (Tikader, 1987).

2.2.3. Spiders recorded in cotton ecosystem

The predaceous insects of cotton have been well studied and catalogued, but the spiders have received relatively little attention in cotton. At first the occurrence of Green lynx spider (hunting spider), *P. viridans* was reported in Arkansas cotton fields by Whitcomb *et al.* (1963) and also in Texas by Dean *et al.* (1982). The jumping spider *Oxyopes salticus* (Hentz) was reported to be the most abundant spider in cotton fields of Arkansas by Whitcomb *et al.* (1963) and also by Dean *et al.* (1982) in Texas cotton fields. This spider was suspected to be a major predator of insects in cotton habitats. Plagens (1983) estimated the

populations of *Misumenops* sp. (Araneida : Thomisidae) in the cotton fields of Arizona, and concluded that the spiders form a major component of the general predators contributing to 44.2 to 57.6 per cent. The araneid *Tetragnatha laboriosa* (Hentz) was also one of the commonly encountered spider in cotton (Dean *et al.*, 1987).

Predators on cotton pests included 17 species of spiders in 11 families and 10 species of insects in 9 families (Breene *et al.*, 1989). Muralidharan and Chari (1992) recorded 17 species of spiders belonging to eight families in Gujarat. Several groups of true spiders were identified and reported from the cotton fields of Uganda by Heneidy and Sekamatte (1996).

2.3. Sampling technique

2.3.1. Foliar spiders

Extraction of arthropods from vegetation was first reported by Turnbull and Nicholos (1966) with an air suction device and vacuum collector in flooded rice. Utilisation of an aspirator containing a small amount of 70 per cent ethyl alcohol, to inactivate the spiders was reported by Specht and Dondale (1960). Barrion and Litsinger (1981) have compared four different sampling techniques *viz.*, FARMCOP, D-VAC, sweep netting and hand picking or vial tapping and concluded that airsuction D-VAC and FARMCOP techniques were more productive in collecting spiders. Perfect *et al.* (1983) have observed that when D-VAC suction sampler was used in conjunction with enclosure, the productivity was more. Easterbrook (1998) has utilised the suction traps to determine the abundance of predators in strawberry fields along with the spiders.

Leigh and Hunter (1969) described the use of ground cloth method for sampling of arthropods in cotton ecosystem. The use of waterpan and a carbondioxide sampler for estimating the population of spiders and other natural enemies in direct seeded and transplanted rice in Philippines was reported by

Ferrer and Shephard (1988). The whole plant bag sampling method for arthropods in cotton ecosystem was mentioned by Vanden berg *et al.* (1990). Bishop and Richert (1990) gave an account on sweep net and visual counting methods. Lewis *et al.* (1996) have given a report on the utilisation of sweep, shake and whole plant sampling methods to monitor the seasonal abundance of spiders along with other insects in three cotton fields in Georgia. Costello and Daane (1997) compared the three sampling techniques in vineyards *viz.*, Drop cloth, funnel and D-VAC methods and concluded that the funnel method was more efficient to estimate the species richness of spiders.

The utilisation of plastic pitfall traps (10 cm diameter) with ethylene glycol as killing solution was first reported by Morrill (1975). Gravesen and Toft (1987) and Nentwig (1988) reported that the pitfall trapping was the predominant method of sampling the spider fauna. Bishop and Riechert (1990) have given an account on use of pitfall traps and sticky traps to quantify the spider dispersal. Braman and Pandley (1993) demonstrated the efficiency of pitfall traps in centipede grass for monitoring the arthropod predators. The use of pitfall traps for assessing the predator population was reported by Sivasubramaniam *et al.* (1995). The transects of pitfall traps were found to be efficient in monitoring the densities of epigeal arthropods like carabids and spiders (Lewis *et al.*, 1996). Hengmoss *et al.* (1998) made comparative studies for sodplug samples and pitfall traps and found that the pitfall traps were more effective (>2.5 times).

2.4. Development, Dispersal and Movement

Spiders like other arthropods, develop by passing through number of stages or instars. The first juvenile stage is similar in the form to the parent, but changes in the proportion of parts, spination and colouration took place as the spider matured (Peck and Whitcomb, 1968). Spiders are oviparous. The

impregnated female deposits her eggs in a silken sac, a week after copulation. The egg sacs are cared for, in various ways (Tikader, 1987).

Studies were conducted by Bilsing (1920), Deevy (1949), Bonnet (1960) and Turnbull (1960) for correlating the quantity of food and rate of development. Juveniles of many species disperse by a process known as ballooning (Gardner, 1965). The spiderlings will climb on the tip of plant where they stand with abdomen uplifted and ejected out silken strands which cast on to air currents, when enough silk is airborne to provide sufficient lift, the spider releases it's hold on substratum and soars up away to be carried by the air current. The spiders were capable of ballooning both in the juvenile as well as in adult stage. Horner (1972) and Greenstone (1982), reported that spider ballooning is elicited by warm ambient temperatures and moderate intermittent breezes.

2.5. Spiders in Natural Pest Control

Spiders are the most abundant predators of insects of terrestrial ecosystems (Van Hook, 1971; Moulder and Reichle, 1972; Schaefer, 1974; Edwards *et al.*, 1976). Under favourable conditions they can reach a maximal densities of approximately 1000 nos./m² (Widemann, 1978). Therefore spiders play an important role as stabilizing agents / population regulators in agro and forest ecosystems and other terrestrial ecosystems. (Moulder and Reichle, 1972 ; Nyffeler, 1982, 1983). In the pursuit of the identification of selective biological control agents, the spiders can be given due consideration because of their efficiency in hunting large number of insects and polyphagous nature. They are curious animals and kill more number of insects than what they actually consume (Greenstone, 1978; Palanichamy, 1983).

Spiders have several adaptations associated with phylogeny and life style like, low maintenance energy requirements (Anderson, 1974), ability to store large amount of fats (Collatz and Mommsch, 1975), ability to lower metabolic rates

during periods of starvation (Namakura, 1972; Anderson, 1974) and ability to gorge during prey abundance because of highly distensible abdomen (Palanichamy, 1980) thus surviving for a longer period. The regulation of insect populations by spiders in agricultural and epidemiological settings is receiving more attention as integrated pest management (IPM) replaces the chemical control (Nyffeler and Benz, 1987; Breene *et al.*, 1988; Riechert and Bishop, 1990).

2.5.1. Spiders as predators of insect eggs

The phenomenon of oophagy was more common in spiders than previously thought. In majority of the cases spiders were found preying upon eggs of lepidopteran pests. However an evidence was provided by Richman *et al.* (1983) for spiders feeding on coleopteran eggs also. Examples of oophagy of spiders are given below.

Oophagy by spiders upon eggs of insects

Spider Taxa	Egg	Habitat	Method	Area	Authors
<i>Metaphidippus flavipedes</i> (G and E. Peckham)	CF	Fir	C	USA	Jenings and House Weart (1978)
<i>Chiracanthium diversum</i> L.koch	HS	Cotton	a, c	Australia	Room (1979)
Thomisidae	NO	Soybean	a	USA	Mc Carty <i>et al.</i> (1980)
Lycosidae <i>Lycosa antelucana</i> (montgomery)	NO	Soybean	a	USA	Mc Carty <i>et al.</i> (1980)
Thomisidae <i>Misumenops</i> sp.	HV	Cotton	c	USA	Mc Daniel and Sterling (1982)
Oxyopidae <i>O.salticus</i> (Hentz)	HV	Cotton	a	USA	Mc Daniel and Sterling (1982)
<i>Trachelas deeptus</i> (Banks)	DA	Citrus	c	USA	Richman <i>et al.</i> (1983)
Anyphaenidae <i>Aysha velox</i> (Becker)	DA	Citrus	c	USA	Richman <i>et al.</i> (1983)
<i>P. viridans</i>	AA	Cotton	a	USA	Gravena and Sterling (1983)
<i>Phidippus audax</i> (Hentz)	HZ	Cotton	a	USA	Nuessely (1986)

a - Radio isotope studies; c - Direct observation;

Egg Taxa - AA *Alabama agrillaceae* (Hiibner);

NO - Noctuidae;

HV - *Heliothis virescens* (Fab.); MS - *Manduca sexta* (L.);

HS - *Heliothis* sp.; HZ - *Heliothis zea* (Boddie);

CF - *Choristoneura fumiferana* (Celemes); DA - *Diaprepes abbreviatus* (L)

2.5.2. Food preferences

Spiders have no discriminatory reaction and consume whatever prey is offered. However spiders do have preferences indicated by disagreeable odours

and tastes, which cause them to reject many of the potential preys. Turnbull (1960, 1962) has given a hypothesis which states that spider food preferences are based on morphological and seasonal factors in prey that cross species, genus, family and even order boundaries and incorporate large number of diverse animals which vary as their abundance varies seasonally. He found an evidence that spiders preferred prey with which it had previous experience. Most of the spiders are polyphagous insectivores (Wise, 1993). As such they constitute a significant portion of the beneficial natural enemy complex in agro ecosystems (Nyffeler *et al.*, 1992; Riechert and Bishop, 1990; Plagens, 1983).

Peck and Whitcomb (1970) reported that the readiness with which a spider takes food is apparently based on several factors other than preference i.e. it's physiological state of hunger, strength, rate of growth, proximity to ecdysis, etc. Spiders are considered to be predators of live and moving prey only (Turnbull, 1960, 1973). According to Nentwig (1987), the optimal prey length of a spider ranged from 50-80 per cent of the spiders own length. During the severe outbreak of pests, spiders can increase their predation rates (i.e. functional response). Breene *et al.* (1990) and Pasquet and Leborgne (1990) have studied the prey intercepted by the orbwebs of four species of spiders and reported that *Araneus marmoreus* and *Argiope brunnichii* (Scop) have attempted to capture only large insect (more than 2 mm). Similarly *A. brunnichii* has been reported to prey selectively on insects with a body length of more than 10 mm, approximately 86 per cent of the biomass of total prey (Malt *et al.*, 1990). Wise (1993) reported that most of the spiders feed on prey that are small relative to their own size (Prey length \leq Spider length).

2.5.3 Strategies

According to Rovner and Knost (1974), lycosids were also known for post immobilization prey wrapping, an adaptive character for retention of the captured

prey. Nyffeler *et al.* (1990) reported that spiders adopted much broader range of foraging strategies including oophagy, scavenging, feeding on pollen and artificial diets.

Since the spiders were not capable of feeding on solid food, the prey body was first digested by the enzymes, secreted from mouth and then consumed by pharyngeal pump (Turnbull, 1973). This process was also assisted by crushing the prey in some spiders. Baldev Parshad (1985) studied the qualitative feeding preferences for about 40 spider species.

2.5.4. Predatory potential of spiders in cotton ecosystem

The spiders and their host range identified so far in cotton ecosystem in overseas and India are presented in following table

Spider	Host range	Author
1. Clubionidae, Ctenidae Gnaphosidae Lycosidae Pisauridae	Pink bollworm	Clark and Glick (1961)
2. Clubionidae	<i>Spodoptera littoralis</i> (Boisd)	Mansour <i>et al.</i> (1980)
3. <i>P. audax</i>	<i>Heliothis virescens</i> (Fab) eggs 1 spider - 5.9 eggs/24 hrs	McDaniel and Sterling (1982)
<i>Misumenops</i> spp.	0.4 eggs/24 hrs	
<i>C. inclusum</i> (Hentz)	14.2 eggs/24 hrs	
Araneidae	1.9 eggs/24 hrs	
Erigonids	0.1 eggs/24 hrs	
Salticids	3.2 eggs/24 hrs	

Spider	Host range	Author
4. <i>Misumenops</i> sp. (Thomisidae)	<i>Lygus</i> , <i>Nabis</i> nymphs, <i>Orius</i> , Fleahoppers, Geocorids, <i>Chrysoperla</i> , Leafhoppers and other spiders	Plagens (1983)
5. <i>P. viridans</i>	Bollworm, Leafworm, Moths, Looper, Fleahoppers (29% of prey). Prey includes Hymenoptera (41%), Heteroptera (9%), Coleoptera (4%), Diptera (15%), Lepidoptera (15%), Araneae (7%)	Whitcomb <i>et al.</i> (1963)
6. Stirped lynx spider <i>O. salticus</i>	Leafhoppers, Aphids, workers of red imported fire ant, Spiders, <i>Chrysoperla</i> and Syrphids.	Nyffeler <i>et al.</i> (1987)
7. <i>O. salticus</i>	<i>Heliothis</i>	Agnew and Smith (1989)
8. <i>O. salticus</i> <i>P. viridana</i> , <i>P. audax</i> <i>Metaphidippus galathea</i> (Walckenaer) <i>Hentzia palmarum</i> <i>M. celer</i>	Cotton fleahopper	Breene <i>et al.</i> (1989)
9. Pisaurid spider <i>Pisaurina mira</i>	<i>Lygus</i> sp.	Young (1989)
10. Lycosid spider <i>Pardosa astrigera</i>	<i>Heliothis</i> , Aphids	Zhao <i>et al.</i> (1989)
11. <i>O. salticus</i> (42%) <i>P. audax</i> (66%) <i>M. celer</i> (32%)	Cotton fleahopper	Breene <i>et al.</i> (1990)

Spider	Host range	Author
12. <i>Theridion volubile</i> (Keyserling) <i>Chryso pulcherrima</i> (Mello - Leitao) <i>Misumenops</i> sp, <i>Chiracanthium</i> sp	Cotton leafworm	Gravena and Da cunha (1991)
13. <i>Oxyopes</i> <i>Clubiona</i> <i>Argiope</i> <i>Neoscona</i> <i>Thomisus</i>	Jassids, <i>Heliothis</i> larvae Bollworms, leafrollers <i>Earias</i> and <i>Bemesia</i> <i>tabaci</i> (Gen) <i>Earias</i> and <i>Anomes flava</i> (Fb) <i>A. flava</i> , <i>Heliothis</i>	Dhulia and Yadav (1991)
15. Striped lynx spider	Other spiders like Oxyopids, Salticids, Thomisids, other web building Spiders, Ants, Damsel bugs, etc.	Nyffeler <i>et al.</i> (1992)
16. <i>O. salticus</i> <i>P. viridana</i>	Polyphagous (Feeds on pest, and beneficials)	Nyffeler <i>et al.</i> (1992)
17. <i>Oxyopes</i>	Polyphagous	Nyffeler <i>et al.</i> (1994a)

2.5.4.1. Cannibalism

The worst enemies of spiders were the other spiders. Cannibalism often occurred among the spiders whenever the food available was inadequate and it was proved by Chiu *et al.* (1974) with dwarf spider *Oedothorax insecticeps* (Black wall). Barrion and Litsinger (1981) opined that spiders were highly cannibalistic. Baldev Parshad (1985), Nirmala (1990) and Ganesh Kumar (1994) have observed that the female spider was prone to attack and prey upon male of it's own species especially during mating.

2.5.4.2. Intraguild predation

Spiller (1986) had investigated the interspecific competition between two orbweb spiders *Metapeira grinelli* (Coolidge) and *Cyclosa turbinata* (Walckenaer) which influenced the effective control of pest. Guillebeau and All (1989) confirmed the cross predation among geocorids and striped lynx spiders in laboratory experiments. Geocorids consumed a negligible number of spiders whereas spiders consumed all the stages of Geocorids. Dinter (1998) reported that the female erigonid spiders had significantly higher effect on lacewing larvae in the absence of alternate prey, causing 98 per cent mortality.

2.6. Impact of Improved varieties and cultural practices

Schuster *et al.* (1976) evaluated the influence of nectariless cotton on natural enemies and reported that the spiders of families Thomisidae, Lycosidae, Oxyopidae and Araneae were reduced by 17 per cent in nectariless cotton. Myint *et al.* (1986) reported that the varietal resistance enhanced the activity of natural enemies by reducing the pest vigour and played as an additive character.

Hatley and Macmahon (1980) opined that the planting and harvesting procedures utilized in agricultural systems are perhaps the disruptive sources for the spider community than that of pesticidal use. Riechert and Lockley (1984) have suggested that maintaining the compost heaps in the fields would attract beneficial arthropods and enhance spiders an abundance of prey when the pest is present in limited number. Mangan and Byers (1989) reported that minimum tillage will conserve the spider species. Gluck and Ingrish (1990) concluded that the occurrence of lycosids in arable land depends on agricultural management as well as on the presence of undisturbed areas nearby. Mowing the meadows had an adverse effect on the spider fauna ranging from mild to massive. However, it could promote the migration to nearby areas.

The augmentation of beneficial arthropods by strip management in wheat fields and by artificial introduction of orbweb spiders was reported by Nentwing (1988). Artificial habitat manipulations like making holes of 5 cm to 9.5 cm diameter can cause a spectacular increase in spider densities. Alderweireldt (1994); Costello and Daane (1998) reported that the maintenance of ground cover in grape vineyards increased the species diversity of spiders.

2.7.Effect of pesticides on spiders

Selective use of pesticides is the first step in developing an integrated pest control programme. Employing the pesticides which are relatively harmless to spiders could increase the effectiveness of natural predation and thus reduce the population of injurious insects in agro ecosystems. Various authors have pointed out that pesticides and botanicals used to control insect pests are detrimental to spider populations in cotton. The toxicity levels indicated by them are presented in the following table .

Table . Effect of pesticides on spider population

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
1.	Acephate	0.8 kg ai/ha	Broadcasting	<i>O. insecticeps</i>	More toxic	Chen and Chiu (1979)
2.	Diazinon	0.2%	Spray	Spiders	Population reduced to 50.8%	Choudary and Alam (1979)
3.	Carbofuran 3G	1 kg ai/ha	Broadcasting	<i>Tetragnatha</i> sp. <i>Oxyopes</i> sp.	More toxic	Kushakull <i>et al.</i> (1979)
4.	Fenvalerate	0.11 kg ai/ha	Foliar application	<i>Oxyopes</i> sp.	Toxic	Roach and Hopkins (1981)
	American cyanamid	0.056 kg/ha			Toxic	
	Toxophene + Methyl parathion	2.24 + 1.12 kg/ha			Toxic	
	Monocrotophos	1.56 kg/ha			Toxic	
5.	Ethylton 45% EC	0.75 to 1 kg ai/ha	Foliar application	<i>Lycosa</i> sp.	More toxic to spider than to prey	Reissing <i>et al.</i> (1982)
	MTMC 32% EC			<i>Tetragnatha</i> sp. <i>Araneus</i>		
	Endosulfan 35% EC					
	Propoxur 20% EC					
6.	Carbofuran	1.12 kg ai/ha	Spray	<i>Tetragnatha</i> sp.	Significant reduction	Culin and Yeagan. (1983)
	Dimethoate	0.41 kg ai/ha			Short term reduction	
	Azinphos methyl	0.41 kg ai/ha				

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
7.	Quinalphos		Foliar spray	Spiders	Less toxic	Raman and Uthamsamy (1983)
	Phosalone,	0.04%				
	Fenthion,	0.04%				
	Permethrin	0.04%				
	Methamidophos	0.04%				
	Phosphamidon					
	Carbosulfan					
8.	Cypermethrin		Potters spray tower	<i>Lycosa</i>	Highly toxic	Febellar and Heinrichs (1984)
	Deltamethrin					
	Endosulfan & Ethyl DDD		Potters spray tower	Spiders	Less toxic	
9.	Carbaryl	2.26 kg ai/ha		<i>Tetragnatha</i>	More toxic	Whitford <i>et al.</i> (1987)
	Fenvalerate	0.1 kg ai/ha			Toxic	
10.	Acephate 40 EC		Foliar spray	Spider	Relatively safe but reduced growth and predation	Thang <i>et al.</i> (1987)
	Propaphos 50 EC					
	BPMC 50 EC			<i>Lycosa</i>		
	Carbamate 20 EC				Safe 1-3 days after treatment.	

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
	Cypermethrin 5 EC					
	Endosulfan 35 EC					
11.	Deltamethrin	10 g ai/ha		Erigonid	89% population reduced	Thomas <i>et al.</i> (1990)
12.	Fenvalerate 10 EC	0.3 lit/ha	Spray	<i>Pardosa</i>	57% mortality	Mansour <i>et al.</i> (1992)
	Endosulfan 35 EC	0.3 lit/ha	"	Erigonid	100% mortality	
	Pyrazophos EC	2 lit/ha	"			
13.	Oleo Rustica Fastae (Pyrethroid)	2-4 µg	Microsyringe applicator	<i>Aranus</i>	Safe but suppressed the webbuilding behaviour	Samu and Vollarth (1992)
14.	Deltamethrin Methamidophos Pyrazophos		Spray	Spiders	Reestablished after 4-5 weeks	Volkmar and Wetzel (1993)
15.	Primicarb	0.64 µg	Eppendoff pipette	Web building spiders like <i>Larinioides</i>	Adversely affected Web with less radii and affected the regularity of spiral turns.	Lengwiler and Benz (1994)
	Deltamethrin	5-10 ⁻³ µl/mg	Eppendoff pipette			
	Diazinon	5-10 ⁻⁴ µl/mg				
	Dicofol	9.6-10 ⁻³ µl/mg				

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
16.	Imidacloprid	5-15 g ai/ha	Spray	Spider	No significant effect	Lixin and Liang (1995)
17.	Chlorpyrifos		Spray	Lycosid spider	No ill effects	Curtis and Horne (1995)
18.	Cypermethrin Chlorpyrifos		Spray	Spider	No significant effect	Barbour and Brandenberg (1995)
19.	Fenvalerate		Topical application	<i>Erigona atra</i> (Black wall)	More toxic	Dinter and Poehling (1992)
20.	Lambda cyhalothrin Gossyflare			<i>Oedothorax apicatus</i>	Less toxic	
	Fenvalerate	500 ml/ha	Spray	Thomisid spiders	No detrimental effect	Muthukrishnan and Balasubramanian (1995)
21.	Monocrotophos Imidacloprid	500 ml/ha	Spray	Spider	Reduced the spider population	
	Heptenphos	9.35 g ai/ha			1:0.23 ratio of pest and spider	Guifen <i>et al.</i> (1996)
	Malathion	342 g ai/ha	Spray	Spiders	No significant effect Population reduced	

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
22.	Cypermethrin	28 ai/ha			Significant reduction	Easter brook (1997)
	Pirimicarb	280 ai/ha			No significant effect	
	Chlorpyrifos	480 ai/ha			Significant reduction	
	Demeton-s-methyl	325 ai/ha			Significant reduction	
23.	Deltamethrin	0.25 g ai/ha	Foliar application	<i>Pardosa</i>	Toxic	Coung <i>et al.</i> (1997)
24.	Spinosad			<i>Tetragnatha</i> Spider	Non disruptive	Murray & Lloyd (1997)
25.	Lambda-cyhalothrin		Spray	Spider	Little impact on ground spiders	Cole <i>et al.</i> (1997)
26.	Tubofenozide	750 ml ai/ha	-	Spider	Non toxic	Barberi (1997)
27.	Primiphos methyl + UAN			Spider	Less harmful	Pekar <i>et al.</i> (1997)
28.	Fenitrothion Diazinon		Spray	Spider	Toxic	Nagata <i>et al.</i> (1997)
29.	Fenobucarb Carbaryl Dichlorvos Imidacloprid Monocrotophos	108 g ai/ha	Foliar application	<i>Pardosa</i>	Adversely affected	Vanden berg <i>et al.</i> (1998)

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
	Lambda cyhalothrin	5 g ai/ha			Reduced the population	
30.	Deltamethrin		Foliar spray	Spider	Detrimental	Viestola (1998)
31.	Dimethoate		Spray	Spider	Paralysis for 1-2 day	Toft and Jensen (1998)
	Cypermethrin				increased the activity	
32.	Flucycloxuron			Spider	Drastic effect on spiders	Pekar and Seldon (1998)
	Tefluthexuron			Spider	Less harmful	
	Hexaflumuron					
	Botanicals					
	Neem oil					
33.	Chinaberry seed oil	50 g ai/ha		<i>Lycosa</i>	Less toxic	Saxena <i>et al.</i> (1983)
	Custard apple seed oil		Potters tower spray			
	Neem formulations					
34.	NO	4%	Foliar spray with atomiser	<i>Lycosa</i>	Less toxic	Rajendran (1987)
	NCE	1%				
35.	NSKE		Foliar spray	Araneae	No reduction	Kareem <i>et al.</i> (1988a, 1988b, 1988c)

Sl. No.	Pesticide	Formulation and concentration	Mode of application	Predator	Remarks	Reference
36.	Neem seed bitters	10,000 ppm	Spray	Araneae	No reduction	Saxena <i>et al.</i> (1989)
37.	Neem oil 3%		Foliar spray	Spider	No adverse effect	Raguraman and Rajasekaran (1996)
38.	NSKE 5% Azadirachtin			Spider	Sensitive to spiderlings	Punzo (1997)
39.	Herbicides Dinoseb	2.53 kg/ha	Spray	Spider	More toxic	Stam <i>et al.</i> (1977)
40.	Diuron MSMA Arsenical herbicides	0.45 kg/ha 1.7 kg/ha			Less toxic More toxic	Breene (1991)
41.	Fungicides Bayfidan	125 g ai/ha		Web building spiders	Significant reduction in population	
	Sportak	400 g ai/ha		Orbweb spiders	Not affected significantly	Samu and Vollrath (1992)
42.	Fenpropimorph Pyrazophos Propiconazole Prochlorz Carbendazim			Spiders	Harmful	
				Spiders	Affected moderately	Volkmar and Schutzel (1997)
				Spiders	High degree	



MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Field, pot culture and laboratory studies were conducted at the Department of Agricultural Entomology and Department of Cotton, Tamil Nadu Agricultural University, Coimbatore from 1998-2000. Survey was conducted in predominantly cotton growing tracts of Coimbatore district.

3.1. Survey, collection and identification of spiders under different cotton ecosystems

3.1.1 Survey of spider population at cotton breeding station

Two different cotton fields were selected at cotton breeding station, Tamil Nadu Agricultural University, Coimbatore and the collection was done randomly from 100 plants in each field, at different stages of crop growth. Both foliar as well as the ground spiders were collected. The methods followed for collecting foliar spiders were the visual searching and hand picking, collecting in test tubes and polybags by shaking the foliage. Very small spiders were collected by using a camlin hair brush dipped in alcohol, and later transferred in to the vials.

Pitfall traps were used for the collection of ground spiders. The arthropods were collected by using plastic pitfall traps of size 4.5 cm diameter and 9 cm height containing 70 per cent ethyl alcohol, the killing solution added by a little amount of liquid soap to reduce the evaporation. These pitfall traps were placed at the centre of each 1 m² marked plot. These traps were operated continuously for one week in a month. The collected spiders were recorded daily.

3.1.2. Survey of spiders in Coimbatore

The spider fauna from different cotton growing tracts in Coimbatore district was surveyed at Alanthurai, Annur, Coimbatore and Kinathukadavu. The samples

were collected from cotton fields of Coimbatore district representing all the four directions. The cotton fields as well as the bunds were observed for the spider population.. During the survey, the spider population per plant was recorded and the dominant species in each locality were recorded. The new species found were preserved in 70 per cent alcohol and identified.

3.1.3. Preservation and identification of spiders

The method described by Tikader and Bal (1981) was followed for the preservation of the field collected spiders. The spiders collected by various methods were brought to the laboratory and killed by placing a small cotton swab dipped in ethyl acetate or chloroform inside the polythene bags. Care was taken to avoid over flooding of the killing solution in the bags. After killing, the specimens were preserved in 70 per cent ethyl alcohol in glass vials individually. The preserved specimens were photographed and identified based on the taxonomic characters.

3.2. Estimation of species richness and seasonal abundance of spiders in cotton ecosystem

3.2.1. Species richness

The quantitative estimation of species abundance of spiders was computed in different environments which varies with the season. The data obtained from surveys were made use to estimate the species richness. The species richness was computed based on Shannon - Wiener formula,

Richness (ma) was computed using the formula

$$ma = \frac{S - 1}{\log 10^N}$$

where,

S = Total number of species collected

N = Total number of individuals in all the species



The population of spiders was recorded twice a week from the selected cotton fields, bunds and adjoining weedy fallow. The collections were made by following hand picking, net sweeping and pitfall trapping methods.

3.2.2. Estimation of seasonal abundance

The spider population of cotton fields along with other insects was recorded once in a fortnight from the selected cotton fields, by following whole plant (counting) sampling method. The observations were taken on 25 plants selected randomly, starting from 45 days after sowing upto harvest. The population levels were correlated with available meteorological data like maximum temperature, minimum temperature, sunshine, rainfall and relative humidity prevailed during the period. To find out the relationship between spiders and other insect pest (sucking complex), predators (*Chrysoperla*, coccinellids) and weather factors, the regression analysis was worked out.

3.3. Standardisation of sampling technique

For standardisation of an effective sampling technique for spiders in cotton ecosystem, some of the proposed sampling techniques were tested and compared for the sampling of spiders. Various methods like sweepnet sampling (Howell and Pienkowski, 1971), counting the websites, (Nyffeler *et al.*, 1986), whole plant sampling method (Lewis *et al.*, 1996) and utilization of pitfall traps (Volkmar and Schutzel, 1997) were tested in the same field for their efficiency in trapping the spider population over a period of time. Later the comparison was made to standardise an effective one.

3.3.1. Net sweeping

In case of net sweeping, in each sampling two successive double strokes were made, at the top of canopy. The number of spiders attained by each stroke were counted, on 10 randomly selected plants.

3.3.2. Counting the websites

The number of webs per each plant and between adjacent plants were counted for 10 randomly selected plants.

3.3.3. Whole plant sampling method

The number of spiders on each plant were counted visually, in 10 plants selected randomly.

3.3.4. Pitfall traps

In this method small plastic cups of size (height 9 cm diameter 4.5 cm) were kept buried in the ground upto its brim in between the rows in cotton fields, at the rate of 1 per m^2 area (Plate 1). The cups were filled with 70 per cent ethyl alcohol upto three fourth level, and a little amount of liquid soap was added. These traps were operated continuously for one week, and the number and type of the spiders collected in each cup were recorded daily. The alcohol was replaced at regular intervals.

3.4. Mass culturing techniques for predator and prey

3.4.1. Mass culturing of spiders

The adult female spiders with egg sacs were collected from the insecticide exposure free cotton fields. They were kept in the plastic cups with lids (7 cm ht and 6 cm diameter) and fed with rice moths. After hatching out the spiderlings were separated from the mother and maintained in separate test tubes. Immediately after emergence they were fed with the eggs of rice moth. Right from the third moult, the larvae of second to final instar and adult moths were given as feed. After fully grown they were transferred in to plastic cups with lids containing pores for aeration. This process was continued for entire period of mass culturing. The mass cultured spiders were utilized both for experimental and further for multiplication purpose. The plastic cups and test tubes were cleaned twice in a week to remove the dead prey and the webbing.

Plate 1



Pitfall trap

3.4.2. Mass culturing of *Chrysoperla carnea* (Stephens) grubs

The *Chrysoperla* grubs required for various experiments were mass cultured under laboratory conditions by the standard technique developed by TNAU (1992).

3.4.3 Mass culturing of prey insects

3.4.3.1. Sucking pests

The sucking type prey insects of spiders of cotton ecosystem viz., the leaf hopper *Amrasca biguttula biguttula* (Ishida), aphid. *Aphis gossypii* G., and whitefly *Bemisia tabaci* Gen. were also mass cultured in laboratory. But often the required prey insects were collected from the unsprayed cotton fields.

3.4.3.2. Mass culturing of lepidopteran caterpillars *Corcyra cephalonica* (Staint), *Helicoverpa armigera* (Hub) and *Spodoptera litura* (Fab).

The larvae and moths of *C. cephalonica*, *H. armigera* and *S. litura* were mass cultured under laboratory conditions by the standard techniques developed by TNAU (1992).

3.5. Prey preference and predatory potential of spiders

The predatory potential and prey preferences were studied under greenhouse conditions.

3.5.1. Finding the host range

Out of 28 species of spiders collected, host range was found out for each spider by offering all the cotton pests. The spiders were released into the plastic cups along with the known number of pest insect and the number of insects killed or fed were noticed after 24 hours.

3.5.2. Predatory potential of spiders

The predatory potential of spiders was studied both for, sucking pests and lepidopteran caterpillars of cotton. Five predominant spider species viz., *O. javanus*, *P. viridana*, *C. drassodes*, *A. pulchella* and *L. decorata* were used separately. For all the predatory potential studies the spiders were prestarved of 24 hrs. All the following predatory potential experiments were conducted in completely randomized design replicated three times (Plate 2).

3.5.3. Sucking pests

The required instars of the each species of spiders were collected from the culture and released on to the caged plants along with 10 number of each insect type separately. The second to fourth instars of spiderlings were released with first and second instars of leafhoppers. Similarly for fifth to seventh instars of spiderlings, third and fourth instars of leafhoppers and for eighth instar and adult spiders, fifth instar leafhoppers were provided.

Treatment 1 - 1 spiderling/adult + 10 leafhoppers

Treatment 2 - 1 spiderling/adult + 10 aphids

Treatment 3 - 1 spiderling/adult + 10 whiteflies

In case of aphids only two stages of pest were considered, nymph and adult. Spiderlings from second to fourth instar were provided with nymphs and from fifth instar to adult, adults ^{aphids} were given. In case of whiteflies only adults were taken. Control was also maintained with 10 number of each prey insect alone to determine any natural mortality.

3.5.4. Lepidopteran pests

First to early third instars of *S. litura* and *H. armigera* were used as prey for this experiment. The spiderlings of second to fourth instars were given the neonates and fifth to last instars of spiders were provided with second instar larvae

Plate 2



Predatory potential studies of spiders

whereas adult spiders were fed with early third instar larvae. For each stage of spider 10 prey insects were released separately into the caged cotton along with the required instar of the spider, and the consumption was recorded after 24 hrs.

Treatment 4 - 1 spiderling /adult + 10 *H. armigera* larvae

Treatment 5 - 1 spiderling /adult + 10 *S. litura* larvae ✓

3.6. Prey preference in mixed population of sucking pests

The prey preference studies were conducted for six predominant species viz., *O. javanus*, *P. viridana*, *C. drassodes*, *Salticus* sp, *A. pulchella* and *L. decorata* of spiders in cotton ecosystem. The adult spiders of each species were introduced separately along with the mixed population of sucking pests on 60 days old potted cotton plants covered with mylar cages. Five number of each sucking insect as prey viz., leafhopper, aphid and whiteflies were released into the cage, thus 15 insects were maintained in each. The observations were taken daily and the experiment was continued for one week. Five replications were maintained for each species of spiders.

3.7. Cross predation in spiders

The *Chrysoperla* grubs were obtained from the culture maintained in the laboratory. The required spiders were collected from the field along with egg sacs. The experiment was conducted as per the methods suggested by Guillebeau and All (1989). The predators (spiders) were starved for 24 hrs before each experiment to ensure a better feeding response.

The following spider-prey combinations were investigated.

- * One female of *O. javanus* with five *C. carnea* grubs.
- * One female of *P. viridana* with five *C. carnea* grubs.
- * One female of *C. drassodes* with five *C. carnea* grubs.

The following combinations of spider-prey (spiderlings) were studied in presence of alternate prey (leafhopper).

- * One adult female spider of *O. javanus* + five leafhopper nymphs + five spiderlings of *P. viridana*.
- * One adult female spider of *O. javanus* + five leafhopper nymphs + five spiderlings of *C. drassodes*.
- * One adult female spider of *C. drassodes* + five leafhopper nymphs + five spiderlings of *P. viridana*.
- * One adult female spider of *C. drassodes* + five leafhopper nymphs + five spiderlings of *O. javanus*.
- * One adult female spider of *P. viridana* + 5 leafhopper nymphs + five spiderlings of *C. drassodes*
- * One adult female spider of *P. viridana* + five leafhopper nymphs + five spiderlings of *O. javanus*.

The following *Chrysoperla* - spider (prey) combinations were also investigated.

- * Two fully grown grubs of *C. carnea* + one egg sac of *O. javanus* along with mother.
- * Two *C. carnea* grubs with 5 spiderlings of *O. javanus*.
- * Two *C. carnea* grubs with *O. javanus* egg sac with mother excluded.

Same procedure was followed for the spider *P. viridana* and *C. drassodes* also. Newly hatched spiderlings were used in all the experiments.

The subjects of each experiment were placed in petridishes (60 x15 mm) with a moistened filter paper rolled into a ball. Petridishes with prey alone served as control. Any dead prey was assumed to have been killed by the predator unless mortality was observed in corresponding control. The results were recorded after 24 hrs. Egg sacs of spiders were opened and examined under a dissecting

microscope at the end of each experiment to determine the number of eggs per sac and number that had been consumed by predator. Any egg that appeared deflated was counted as consumed. Each experiment was replicated 15 times.

Data from two choice experiments was subjected to a students 'Z' test (Gomez and Gomez, 1984) to determine significant differences ($P = 0.05$) in the proportions of diet made up of each prey insect.

3.8. Studies on impact of cultural practices on spider population

The field trial was conducted during kharif '99 to study the impact of cultural practices on spider population, with four varieties viz., MCU 5, TCH 1569, CW ROCK, CNH 120 MB, two spacings viz., (S_1 - 75 x 30 cm; S_2 - 75 x 45 cm) and three levels of fertilizers viz., (F_1 - 40:20:20; F_2 - 80:40:40; F_3 - 120:60:60). The predator count was taken on 5 plants in each treatment and mean was worked out.

3.9. Toxicity of insecticides to spiders

3.9.1. Studies on effect of persistent toxicity and residual toxicity on mortality per cent and effect of residual toxicity on predation rate of spiders

The methodology suggested by Ganesh Kumar (1994) was followed for studying the persistent and residual toxicity of selected insecticides to spiders.

3.9.1.1. Persistent toxicity of insecticides

60 days old potted cotton plants were sprayed with the following chemicals

Chemicals	Concentration
Chlorpyriphos 25EC	1.25 ml/lit
Endosulfan 35EC	4 ml/lit
Imidacloprid 200SL	0.2 ml/lit
Methyl demeton 35EC	1 ml/lit

Monocrotophos 36EC	2 ml/lit
Quinalphos 25EC	2 ml/lit
<i>B.t</i>	2 g/lit
Neem oil	3%

The experiment was conducted in a factorial completely randomized design for four species of spiders (*O. javanus*, *P. viridana*, *C. drassodes* and *A. pulchella*) with an untreated control, replicated ^{thrice} ~~three times~~ (Plate 5). The insecticides were sprayed using an atomizer and allowed to dry in shade. The plants were caged with adults along with 10 nymphs and adults of leafhoppers released at 1, 3, 7, 10 and 15 days after spraying. The survival of predator was observed at 24 hrs after caging. The dead ones were replaced with fresh predators and prey. The mortality was corrected as per Abbot (1925).

3.9.1.2. Effect of Residual toxicity on percent mortality and predation rate of spiders

The recommended doses of insecticides were sprayed on potted cotton plants and allowed to dry in the shade for one hour. The 60 nymphs and adults of leafhoppers / aphids / whiteflies were released on to the treated plants and covered with a mylar film cage. Experiment was conducted for three hunting spiders *O. javanus*, *P. viridana*, and *C. drassodes*. Each treatment was replicated thrice with three spiders per replication. Twenty four hours after spray, the live spiders from each cage were collected and introduced onto untreated plants in separate pots and covered with mylar film cage. These spiders were fed with untreated prey daily for observing mortality. The predation rate was worked out as follows (Thang *et al.*, 1985).

$$PR = \frac{\text{Number or per cent of prey consumed by treated spiders}}{\text{Number or per cent of prey consumed by untreated spiders}}$$

Plate 3



Toxicology studies of spiders

3.9.1.3. Determination of LC_{50} of certain insecticides for spiders *O. javanus* and *P. viridana*

The method described by Ganesh Kumar (1994) was followed. The LC_{50} for insecticides in cotton like acephate, endosulfan, monocrotophos, quinalphos and chlorpyrifos were determined for two lynx spiders *O. javanus* and *P. viridana*, using five graded concentrations of each insecticide in acetone. One microlitre of each concentration with the help of microsyringe was placed over the cephalothoracic region of each spider. Three replications were maintained. Acetone alone was used for control. Mortality was corrected as per Abbot (1925). Probit analysis was done as suggested by Finney (1962).

Statistical analysis

For the purpose of statistical analysis, the data with percentage values were subjected to angular transformation. Duncan's multiple range test was applied for comparing treatment means (Gomez and Gomez, 1984).



EXPERIMENTAL RESULTS

CHAPTER VI

RESULTS

4.1. Collection and identification of spiders under cotton ecosystems

The survey conducted during kharif 99 in four directions of Coimbatore viz., Alanthurai, Annur, Coimbatore and Kinathukadavu to collect the spider fauna existing in the cotton ecosystem has revealed a wide array of species with 28 species under 17 genera and 8 families. Plates (5-26).

The spider species dominating in the cotton ecosystem of Coimbatore included *Araneus* sp., *A. pulchella*, *Argiope* sp., *Bianor* sp., *C. citricola*, *C. drassodes*, *C. viridanus*, *L. decorata*, *Neoscona* sp., *N. theis*, *O. javanus*, *O. rufisternum*, *Olios* sp., *P. paykulli*, *Pardosa* sp., *P. pseudoannulata*, *P. viridana*, *Salticus* sp., *T. cherapunjens*, *Tetragnatha* sp., *V. preymandibularis*, and *V. monostriata*. From the cotton ecosystem of Kinathukadavu the species namely *C. citricola*, *C. drassodes*, *N. theis*, *N. elliptica*, *Neoscona* sp., *O. javanus*, *P. paykulli*, *Pardosa* sp., *P. pseudoannulata*, *Salticus* sp., *T. cherapunjens* and *Tetragnatha* sp., were collected. Seventeen spider species, *Argiope* sp., *A. pulchella*, *Bianor* sp., *C. citricola*, *C. viridanus*, *Leucauge* sp., *N. theis*, *N. elliptica*, *Neoscona* spp., *Olios* sp., *O. javanus*, *O. rufisternum*, *P. paykulli*, *Pardosa* sp., *P. viridana*, *T. pugilis* and *T. cherapunjens* were collected from the cotton ecosystems of Annur and the species namely *Araneus* sp., *Argiope* sp., *Bianor* sp., *C. citricola*, *G. unguifera*, *L. decorata*, *Leucauge* sp., *Neoscona* spp., *O. javanus*, *O. rufisternum*, *Pardosa* sp., *P. viridana*, *Salticus* sp., *T. pugilis*, *T. cherapunjens*, *Tetragnatha* sp., and *V. preymandibularis* were collected from the cotton ecosystem of Alanthurai. These spiders were reported for the first time in cotton fields of Tamil Nadu.

Plate 4



Araneus sp.

Plate 5



Argiope pulchella (Thorell)

Plate 6



Argiope sp.

Plate 7



Bianor sp.

Plate 8



Clubiona drassodes cambridge

Plate 9



Crytophora citricola (Forsk.)

Plate 10

Gasteracantha unguifera (Simon)





Leucauge decorata (Black wall)

Plate 12

Leucauge sp.



Plate 13



Neoscona elliptica (Tikader)

Plate 14



Neoscona sp

Plate 15 *Olios* sp.

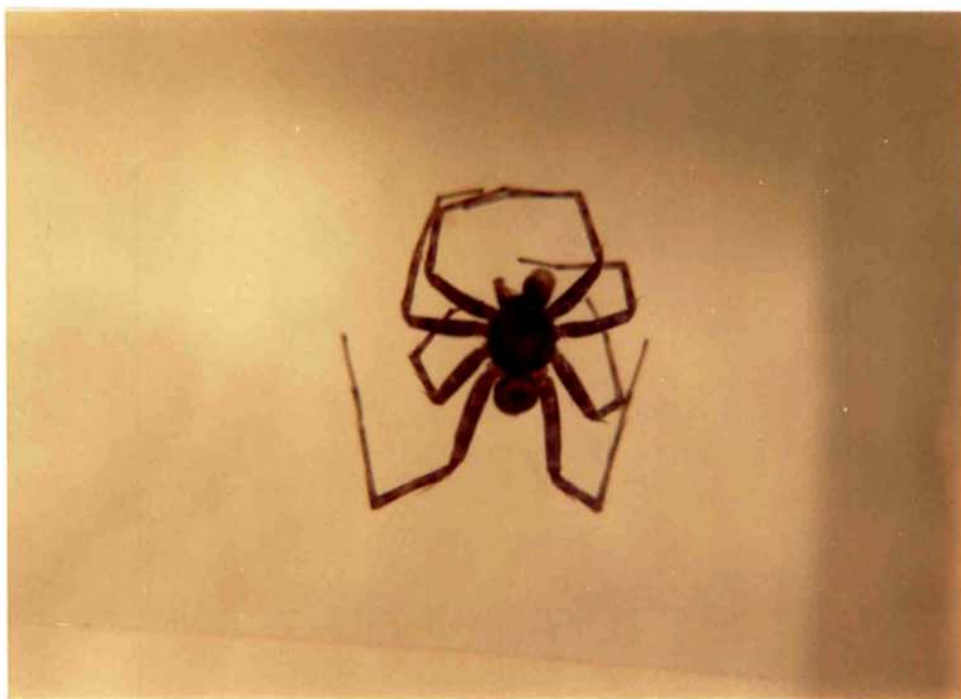


Plate 16



Oxyopes javanus (Thorell)

Plate 17



Pardosa pseudoannulata (Boes)

Plate 18



Pardosa spp.

Plate 19

Peucetia viridana (Stoliczka)



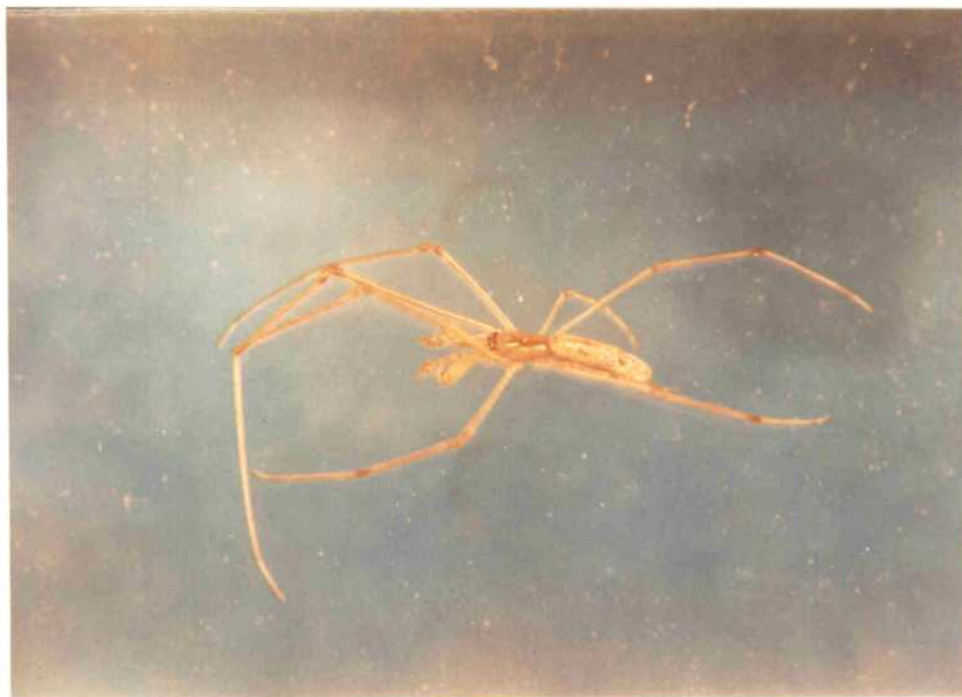
Plate 20



Plexippus paykulli (Audouin)



Plate 21



Tetragnatha sp.

Plate 22 *Thomisus cherapunjens* (Tikader).

Plate 23



Thomisus pugilis (Stoliczka)

Plate 24



Vicaria monostriata sp. nov.

Plate 25



Vicaria preymandibularis

Table 1. Fauna of spiders in cotton ecosystem

S.No.	Spider species	Family	Cotton ecosystem				Host range	Period of abundance
			Al	An	Cb	Kk		
1.	<i>Araneus</i> sp.	Araneidae	+	-	+	-	AP, LH, DP, Hym	November - February
2.	<i>Argiope pulchella</i> (Thorell)	Argiopidae	-	+	+	-	WF, AP, DP, HEI, SPD, Er	November - February
3.	<i>Argiope</i> sp.	Argiopidae	+	+	+	-	WF, AP, DP, HEI, SPD, Er	All through the season
4.	* <i>Bianor</i> sp.	Salticidae	+	+	+	-	AP	All through the season
5.	* <i>Clubiona drassodes</i> Cambridge.	Clubionidae	-	-	+	+	AP, LH, WF, HEI, SPD, DP	January - March
6.	* <i>Clubiona viridanus</i> sp. Nov.	Clubionidae	-	+	+	-	AP, LH, WF, HEI, SPD	November - January
7.	<i>Cryptophora citricola</i> (Forsk.)	Araneidae	+	+	+	+	LH, DP, Hym	November - January
8.	<i>Gasteracantha unguifera</i> (Simon)	Araneidae	+	-	-	-	WF, LH	December - March
9.	<i>Leucauge decorata</i> (Black wall)	Araneidae	+	+	+	-	WF, LH, HEI, SPD, AP	November - February
10.	<i>Leucauge</i> sp.	Araneidae	+	+	-	-	WF, LH, AP, HEI	November - February
11.	<i>Necoscona theis</i> (Walck)	Araneidae	-	+	+	+	AP, WF, CL	October - January
12.	<i>Neoscona elliptica</i> (Tikader)	Araneidae	-	+	-	+	AP, LH	October - January
13.	<i>Neoscona</i> sp.	Araneidae	+	+	+	+	AP, LH	October - February
14.	<i>Neoscona</i> sp.	Araneidae	+	+	-	+	AP, LH, DP	October - February
15.	* <i>Olios</i> sp.	Heteropodidae	-	+	+	-	DP, moths, LH	January - March

Contd.

S.No.	Spider species	Family	Cotton ecosystem				Host range	Period of abundance
			Al	An	Cb	Kk		
16.	<i>*Oxyopes javanus</i> (Thorell)	Oxyopidae	+	+	+	+	AP, LH, WF, HEI, SPD	All through the season
17.	<i>*Oxyopes rufisternum</i> (Thorell)	Oxyopidae	+	+	+	-	AP, LH, WF, HEI, SPD	All through the season
18.	<i>*Pardosa pseudoannulata</i> (Boes)	Lycosidae	-	-	+	+	AP	August - October
19.	<i>*Pardosa</i> sp.	Lycosidae	+	+	+	+	AP	August - October
20.	<i>*Pardosa</i> sp.	Lycosidae	+	-	-	-	AP	August - October
21.	<i>*Peucetia viridana</i> (Stoliczka)	Oxyopidae	+	+	+	-	AP, LH, WF, HEI, SPD	All through the season
22.	<i>*Plexippus paykulli</i> (Audouin)	Salticidae	-	+	+	+	LH, bugs, spiders	December - March
23.	<i>*Salticus</i> spp	Salticidae	+	-	+	+	AP, LH	October - February
24.	<i>Tetragnatha</i> sp.	Tetragnathidae	+	-	+	+	AP, LH, HM	October - December
25.	<i>Thomisus cherapunjens</i> (Tikader)	Araneidae	+	+	+	+	WF, AP, LH	November - March
26.	<i>Thomisus pugilis</i> (Stoliczka)	Araneidae	+	+	-	-	WF, DP, LH	December - March
27.	<i>*Vicaria monostrata</i>	Salticidae	-	-	+	-	LH, HM, Spiders	November - March
28.	<i>*Vicaria premandibularis</i> sp.nov	Salticidae	+	-	+	-	LH, HM, spiders	November - February

*	-	Hunting spiders	+ present
		others are webbing spiders	- absent
Cb	-	Coimbatore	
Kk	-	Kinathukadavu	
An	-	Annur	
Al	-	Alanthurai	
WF	-	Whiteflies	
LH	-	Leafhoppers	
AP	-	Aphids	
DP	-	Dipterans	
Hym	-	Hymenopterans	
HEL	-	<i>Helicoverpa armigera</i> (Hubner)	
SPD	-	<i>Spodoptera litura</i> (Fab)	
CL	-	Coleopterans	
HM	-	Hemipterans	
Er	-	<i>Earias</i>	
Spi	-	Spiders	

4.1.1 Host range and seasonal abundance

For all the spider species identified, the host range was found by offering different prey insects available in the cotton ecosystem and also through the observations made under field conditions.

The species under family Araneidae were observed to prey upon aphids whiteflies, leafhoppers, dipterans, hymenopterans, *Helicoverpa*, *Spodoptera* and a few on coleopterans also. Dipterans, leafhoppers and a few moths were observed forming food source for spiders belonging to family Heteropodidae. The Clubionids were observed feeding on aphids, leafhoppers, whiteflies, *Helicoverpa*, *Spodoptera* and also on dipterans whereas the Salticids were observed feeding on aphids, leafhoppers whiteflies, *Helicoverpa*, *Spodoptera*, hemipterans and other spiders. The *Tetragnatha* was feeding on aphids leafhoppers and hemipterans, whereas spiders belonging to the family Argiopidae were feeding on whiteflies, aphids, *Helicoverpa*, *Spodoptera*, *Earias* and dipterans. The wolf spiders (Lycosids) were feeding exclusively on aphids whereas the lynx spiders (Oxyopids) were feeding on a wide array of prey such as aphids, leafhoppers, whiteflies, *Helicoverpa* and *Spodoptera*.

The spider species under family Araneidae and Salticidae were observed at the peak during the months October'99 to March 2000. The family Heteropodidae was occurring for a very short period from January to March 2000. From October to December'99 the spiders under the family Tetragnathidae were observed in abundant. The peak time for Argiopids was from November'99 to February 2000 and for Lycosids from August to October'99. The spiders belonging to the families Oxyopidae Salticidae and Clubionidae were noticed throughout the growing season.

Among the spiders belonging to 8 families the family Araneidae was observed to be predominant in cotton ecosystem comprising 11 species of spiders,

each, Clubionidae and Argiopidae with 2 species each, Heteropodidae and Tetragnathidae each with one species.

4.1.2. Abundance of spiders in agro-ecosystems

Quantitative estimates of abundance of spiders in the cotton agro-ecosystem was carried out in Coimbatore district. The results of the survey conducted in four different cotton growing locations viz., Alanthurai, Annur Coimbatore and Kinathukadavu are presented in the table 2.

Among the different locations, Coimbatore registered maximum species richness of 6.1145 as well as maximum population of 3806 per ha. This was followed by 5.5346 species richness at Alanthurai and 5.4472 at Annur. The Kinathukadavu has recorded the lowest species richness of 3.7006. The overall result indicated that the cotton fields have more diverse and richer population of spiders. The border weeds also contain relatively less spider population in all the surveyed areas (Table 2).

4.1.3 Seasonal incidence of spiders along with other pest and predators

Seasonal incidence of spiders in cotton during the cropping season was assessed and the results are given in the table 3. Initially during the month of August 1999 at square initiation stage, the spider population was maintained at constant level of 0.8 / plant and by September, the population decreased further to 0.68 / plant. From the middle of September the population increased constantly upto the end of January 2000, (boll maturity stage) from 1.32 to 3.32 spider / plant. At boll bursting stage it was decreased slightly to 3.04 / plant (Table 3).

4.1.4. Inter-predation studies

Population of spiders along with other insect pests and predators were assessed in the cotton field at different periods to study the influence of them on

Table 2. Abundance of spiders under different cotton ecosystems

Situation	No. of individuals in all species (N)	No. of species (S)	Species richness (ma)
Coimbatore			
Cultivated field	3806	22	6.1445
Border weeds	900	7	2.7080
Alanthurai			
Cultivated field	1785	19	5.5346
Border weeds	376	7	2.3300
Annur			
Cultivated field	2016	19	5.4472
Border weeds	965	9	3.0155
Kinathukadavu			
Cultivated field	1749	13	3.7006
Border weeds	860	8	2.3854

Table 3. Seasonal incidence of spiders in cotton ecosystem

Stage of the crops (DAS)		Spider population per plant *
October	65	0.8 ^h (1.05)
October	80	0.8 ^h (1.05)
November	95	0.68 ⁱ (1.10)
November	110	1.32 ^g (1.39)
December	125	1.48 ^f (1.31)
December	140	1.76 ^e (1.82)
January	155	2.04 ^d (1.91)
January	170	2.8 ^c (1.96)
February	185	3.32 ^a (1.97)
February	200	3.04 ^b (1.83)

* Mean of five replications

Values in the parenthesis are $(\sqrt{x} + 0.5)$ transformed values

In a column, means followed by same alphabet (lower case) are not significantly different ($P = 0.05$) by DMRT.

spider population. The multiple regression was worked out between the population of spiders and sucking pests namely, aphids, leafhoppers and whiteflies. The analysis (Table 4) indicated that the pest population was not having any influence on the population dynamics of spider. Similarly another multiple regression was worked out between the population of spiders and other predators namely *Chrysoperla* and coccinellids. The analysis indicated that both the predators were not having any influence on the population dynamics of the spider (Table 4.1).

4.1.5 Influence of weather factors on the spider population

The weather parameters such as minimum temperature, maximum temperature, relative humidity (morning and evening), rainfall and sunshine hours were correlated with spider population during the cropping period to study the influence of weather factors on spider population.

None of the weather factors except minimum temperature and relative evening humidity had influenced the population of spiders. The minimum temperature and relative evening humidity had correlation with spiders. For every 1°C decrease of minimum temperature there would be an increase of 4.54 spiders. Similarly for every unit increase in relative evening humidity there would be 3.29 decrease in the spider population (Table 5).

4.2. Standardization of sampling technique

Four different sampling methods / techniques viz., net sweeping, counting the web sites, whole plant sampling and pitfall trapping were tested in the cotton field to assess the sampling efficiency.

Of the four different sampling techniques tested, the whole plant sampling technique has recorded maximum collection of 2.2 spiders/plant. This was followed by pitfall trapping (1.4), net sweeping (1.2) and counting the web sites

Table 4. Multiple regression between the population of spiders and cotton pests

Variable	Partial regression coefficient (b)	Standard error (SEd)	t
Pest			
X1 (leafhoppers)	0.02	0.01	2.41 ns
X2 (aphids)	-0.14	0.14	1.01 ns
X3 (whiteflies)	-0.46	0.17	2.66 ns

ns = not significant

$R^2 = 0.70$ ns

A = 0.55

Regression equation $Y = 2.24 + (0.02) (\text{leafhoppers}) - 0.1 (\text{aphids}) - 0.5 (\text{whiteflies})$

Table 4.1 Multiple regression between the population of spiders and other predators

Variable	Partial regression coefficient (b)	Standard error (SEd)	t
Predators			
X1 (coccinellids)	-0.25	0.51	-0.49 ns
X2 (<i>Chrysoperla</i>)	4.00	2.28	1.75 ns

ns = not significant

$R^2 = 0.47$ ns

A = 0.32

Regression equation $Y = 1.20 - 0.2 (\text{coccinellids}) + 0.4 (\text{Chrysoperla})$

Table 5. Multiple regression between the population of spiders and weather factors .

Variable	Partial regression coefficient (b)	Standard error (SEd)	t
X1 (min. temperature °C)	-0.46	0.10	4.54*
X2 (max. temperature °C)	-0.05	0.09	-0.60 ns
X3 (Relative morning humidity %)	0.20	0.07	2.97 ns
X4 (Relative evening humidity %)	-0.06	0.02	-3.29*
X5 (Rainfall, mm)	-0.00	0.03	-0.24 ns
X6 (sunshine, h)	-0.00	0.00	-0.54 ns

ns = not significant

$R^2 = 0.98$

A = 0.93

Regression equation

$Y = -1.74 - 0.5 (X1) - 0.1 (X2) + 0.2 (R.H, M) - 0.1 (R.H, E) - 0.001 (R.F) - 0.002 (Ss.h)$

Table 6. Standardisation of sampling technique for collection of spiders from cotton ecosystem

S. No.	Method followed	No. of spiders obtained per method*
1.	Net sweeping	1.2 ^b
2.	Counting web sites	0.5 ^d
3.	Whole plant sampling	2.2 ^a
4.	Pitfall traps	1.9 ^c

* Mean of 5 observations and 10 replications

(0.5). Among the methods tested, the whole plant sampling technique was significantly superior to the other three methods tested (Table 6).

4.3. Predatory potential of spiders on cotton pests

The predatory potential of five commonly occurring spiders viz., *O. javanus*, *P. viridana*, *C. drassodes*, *A. pulchella* and *L. decorata* and at different stages over a period of 24 hrs was studied under green house conditions against sucking pests viz., aphids, leafhoppers and whiteflies and caterpillar pests *S. litura* and *H. armigera*.

4.3.1. *O. javanus*

Among the sucking pests the adult of this lynx spider consumed more number of leafhoppers per day (6/day) while aphids were given the next preference consuming 5.34/day, followed by whiteflies 4.34/day. Among the lepidopteran pests *H. armigera* was preferred more where the consumption rate was 4.34/day, whereas for *S. litura* it was 3/day. The predatory potential has increased with the stage of spider for all the pests i.e. from II instar to adult and the predation rate of V and VI instars was on par (Table 7).

4.3.2. *P. viridana*

The predatory potential of the green lynx spider followed an increasing order with the stage of the spider for all the pests. Anyhow the predation rate of IV and V instars was statistically on par with each other. Among the sucking pests tested the *P. viridana* showed almost equal preference to aphids and leafhoppers consuming 7.0 and 6.0 respectively, whereas the whitefly consumption was only 3.34. Among the lepidopteran pests, *H. armigera* was consumed at the rate of 3 larvae/day whereas *S. litura* was preferred less (2 larvae/day) (Table 8).

Table 7. Predatory potential of *O. javanus* on cotton pests

Instar	Prey consumed (Nos / spider / day)*						Mean
	Sucking pests			Caterpillars			
	Aphids	Leaf hoppers	Whiteflies	Spodoptera	<i>Helicoverpa</i>		
II	0.34 ^{Bg} (0.89)	1.0 ^{Af} (1.22)	0.34 ^{Bf} (0.88)	0.0 ^{Cd} (0.71)	0.0 ^{Cf} (0.71)	0.34 ^f (0.88)	
III	1.0 ^{Bf} (1.22)	1.67 ^{Ae} (1.46)	0.34 ^{Cf} (0.88)	0.0 ^{Dd} (0.71)	0.0 ^{Df} (0.71)	0.60 ^e (0.99)	
IV	2.0 ^{Be} (1.58)	2.34 ^{Ad} (1.68)	1.34 ^{Ca} (1.34)	0.0 ^{Dd} (0.71)	0.34 ^{Da} (0.88)	1.20 ^d (1.24)	
V	3.0 ^{Bb} (1.87)	3.67 ^{Ac} (2.03)	1.67 ^{Cd} (1.46)	1.0 ^{Dc} (1.22)	1.67 ^{Cd} (1.46)	2.20 ^c (1.61)	
VI	3.67 ^{Bd} (2.27)	4.34 ^{Ab} (2.27)	1.0 ^{Dc} (1.58)	1.34 ^{Cb} (1.34)	1.0 ^{Dd} (1.58)	2.27 ^c (1.76)	
VII	4.0 ^{Bb} (2.20)	4.67 ^{Ab} (2.27)	2.34 ^{Cd} (1.68)	1.34 ^{Db} (1.34)	1.34 ^{Dc} (1.34)	2.74 ^b (1.77)	
Adult	5.34 ^{Ba} (2.41)	6.0 ^{Aa} (2.55)	4.34 ^{Ca} (2.20)	3.0 ^{Da} (1.87)	4.34 ^{Ca} (1.12)	4.60 ^a (2.23)	
Mean	2.76 ^B (1.74)	3.38 ^A (1.93)	1.62 ^C (1.43)	0.95 ^E (1.13)	1.24 ^D (1.26)		

* Mean of three replications

Values in theparenthesare ($\sqrt{x + 0.5}$) transformed values

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

Table 8. Predatory potential of spider *P. viridana* on cotton pests

Instar	Prey consumed (Nos / spider / day)*						Mean
	Sucking pests			Caterpillars			
	Aphids	Leaf hoppers	Whiteflies	Spodoptera	<i>Helicoverpa</i>		
II	0.34 ^{Cg} (0.93)	1.34 ^{Ad} (1.08)	0.67 ^{Bf} (1.05)	0.0 ^{Dd} (0.71)	0.34 ^{Ce} (0.88)	0.54 ^f (0.93)	
III	1.34 ^{Bf} (1.29)	1.0 ^{Ce} (1.22)	1.67 ^{Ac} (1.34)	0.67 ^{Dc} (0.88)	0.34 ^{Ee} (1.58)	1.00 ^e (1.26)	
IV	2.0 ^{Be} (1.77)	2.67 ^{Ac} (1.46)	1.0 ^{De} (1.22)	1.0 ^{Dc} (1.22)	1.34 ^{Cd} (1.34)	1.80 ^d (1.41)	
V	3.0 ^{Ad} (1.87)	2.34 ^{Bc} (1.68)	1.34 ^{Db} (1.44)	1.0 ^{Ec} (1.17)	2.0 ^{Ccb} (1.58)	1.94 ^d (1.55)	
VI	4.34 ^{Bc} (1.20)	5.0 ^{Ab} (2.35)	2.0 ^{Db} (1.58)	1.34 ^{Eb} (1.34)	3.0 ^{Ca} (1.87)	3.14 ^c (1.87)	
VII	5.34 ^{Ab} (2.41)	5.0 ^{Bb} (2.35)	3.0 ^{Ca} (1.87)	1.67 ^{Eb} (1.46)	2.34 ^{Db} (1.68)	3.47 ^b (1.95)	
Adult	7.0 ^{Aa} (2.73)	6.0 ^{Ba} (2.55)	3.34 ^{Ca} (1.95)	2.0 ^{Ea} (1.58)	3.0 ^{Da} (1.87)	4.27 ^a (1.50)	
Mean	3.34 ^A (1.89)	3.34 ^A (1.81)	1.86 ^B (1.50)	1.10 ^C (1.20)	1.77 ^B (1.54)		

* Mean of three replications

Values in the parenthesis are $(\sqrt{x + 0.5})$ transformed values

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different ($P = 0.05$) by DMRT.

4.3.3. *C. drassodes*

Aphids were the major food source for this spider, where the adult was consuming 7.34 aphids/day, followed by leafhopper (6.34/day) and whiteflies (3.34/day). *H. armigera* was the most preferred one among the caterpillar pests, where it was consumed at the rate of 4.34 / day and was statistically superior to the consumption of *S. litura* (3 / day). The feeding potential of all the instars differs significantly and was in increasing order with the stage of the spider (Table 9).

4.3.4. *A. pulchella*

This web spider has shown priority to whiteflies where the adult consumed 9 insects / day, next to the leafhoppers where it consumed 8 insects / day. The consumption of aphids was negligible accounting for 1.34 / day. Both of the lepidopteran pests also were preferred at negligible rates 0.67 and 0.34 respectively. When the instar wise consumption rate was observed it followed the increasing order for all the prey insects offered and the consumption rate of V and VI instars was on par (Table 10).

4.3.5. *L. decorata*

Among the sucking pests major predation was observed on leafhoppers 5.34 / day, followed by whiteflies 5 / day. The preference shown to aphids, was negligible 0.34 / day and the consumption of caterpillar pests was nil during all the instars. The instar wise consumption rate followed the increasing order.

Among the five species tested, three hunting spiders were observed showing more preference to aphids except *O. javanus* (which preferred leafhoppers) and then to leafhopper nymphs, where the web spiders preferred adults of leafhoppers. In all the spiders, as the stage of spider advanced the consumption of prey also increased, until the stage of the prey insect was altered.

Table 9. Predatory potential of spider *C. drassodes* on cotton pests

Instar	Prey consumed (Nos / spider / day)*						Mean
	Sucking pests			Caterpillars			
	Aphids	Leafhoppers	Whiteflies	Spodoptera	Helicoverpa		
II	0.34 ^{DG} (0.93)	0.34 ^{CG} (0.88)	1.0 ^{Ae} (1.22)	0.0 ^{De} (0.71)	0.34 ^{Cg} (0.88)	0.47 ^S (0.95)	
III	2.0 ^{Af} (1.58)	1.0 ^{Cf} (1.22)	1.67 ^{Bd} (1.46)	0.34 ^{Dd} (1.88)	0.0 ^{Ef} (0.71)	1.00 ^f (1.17)	
IV	2.67 ^{Ae} (1.77)	2.34 ^{Be} (1.68)	2.0 ^{Cc} (1.58)	1.34 ^{Dc} (1.34)	1.0 ^{Ee} (1.22)	1.87 ^e (1.52)	
V	3.34 ^{Ad} (1.95)	3.0 ^{Bd} (1.87)	2.0 ^{Cc} (1.58)	1.0 ^{Ed} (1.22)	1.34 ^{Dd} (1.34)	2.14 ^d (1.59)	
VI	4.0 ^{Ac} (2.12)	4.0 ^{Ac} (2.12)	2.34 ^{Bb} (1.68)	1.34 ^{Dc} (1.58)	2.0 ^{Cc} (1.58)	2.74 ^c (1.77)	
VII	6.0 ^{Ab} (2.55)	5.34 ^{Bb} (2.41)	3.34 ^{Ca} (1.95)	2.0 ^{Eb} (1.58)	3.0 ^{Db} (1.87)	3.94 ^b (2.07)	
Adult	7.34 ^{Aa} (2.80)	6.34 ^{Ba} (2.61)	3.34 ^{Da} (1.94)	3.0 ^{Ea} (1.87)	4.34 ^{Ca} (2.20)	4.80 ^a (2.28)	
Mean	3.72 ^A (1.98)	3.19 ^B (1.83)	2.24 ^C (1.63)	1.28 ^D (1.28)	1.72 ^E (1.40)		

* Mean of three replications

Values in the parenthesis are $(\sqrt{x + 0.5})$ transformed values

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

Table 10. Predatory potential of spider *A. pulchella* on cotton pests

Instar	Prey consumed (Nos / spider / day)*						Mean
	Sucking pests			Caterpillars			
	Aphids	Leaf hoppers	Whiteflies	<i>Spodoptera</i>	<i>Helicoverpa</i>		
II	0.0 ^{Cc} (0.71)	1.0 ^{Ag} (1.22)	0.34 ^{Bg} (0.88)	0.0 ^{Cb} (0.71)	0.0 ^{Cb} (0.71)	0.26 ^f (0.85)	
III	0.0 ^{Cc} (0.71)	1.67 ^{Af} (1.46)	1.0 ^{Bf} (1.22)	0.0 ^{Cb} (0.71)	0.0 ^{Cd} (0.71)	0.53 ^e (0.96)	
IV	1.0 ^{Cb} (1.22)	2.0 ^{Be} (1.58)	2.67 ^{Ae} (1.77)	0.0 ^{Db} (0.71)	0.0 ^{Db} (0.71)	0.93 ^d (1.20)	
V	1.0 ^{Cb} (1.22)	3.0 ^{Bd} (1.87)	3.34 ^{Ad} (1.95)	0.0 ^{Db} (0.71)	0.0 ^{Db} (0.71)	1.47 ^c (1.30)	
VI	0.0 ^{Bc} (0.71)	4.0 ^{Ac} (2.12)	4.0 ^{Ac} (2.12)	0.0 ^{Bb} (0.71)	0.0 ^{Bb} (0.71)	1.6 ^c (1.27)	
VII	0.0 ^{Cc} (0.71)	6.0 ^{Ab} (2.55)	5.0 ^{Bb} (2.35)	0.0 ^{Cb} (0.71)	0.0 ^{Cb} (0.71)	2.2 ^b (1.40)	
Adult	1.34 ^{Ca} (1.35)	8.0 ^{Ba} (2.92)	9.0 ^{Aa} (3.08)	0.34 ^{Ea} (0.88)	0.67 ^{Da} (1.05)	3.87 ^a (1.85)	
Mean	0.48 ^B (0.95)	3.67 ^A (1.96)	3.62 ^A (1.91)	0.04 ^C (0.73)	0.10 ^C (0.76)		

* Mean of three replications

Values in the parenthesis are $(\sqrt{x + 0.5})$ transformed values

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

Table 11. Predatory potential of spider *L. decorata* on cotton pests

Instar	Prey consumed (Nos / spider / day)*						Mean
	Sucking pests			Caterpillars			
	Aphids	Leaf hoppers	Whiteflies	Spodoptera	Helicoverpa		
II	0.0 _{Cd} (0.71)	1.0 _{Ag} (1.22)	0.67 _{Be} (1.05)	0.0 _{Ca} (0.71)	1.0 _{ra} (1.2247)	0.33 _B (0.98)	
III	1.0 _{Cb} (1.22)	2.0 _{Af} (1.58)	1.67 _{Bd} (1.77)	0.0 _{Da} (0.71)	0.0 _{Db} (0.71)	0.93 _f (1.20)	
IV	0.0 _{Cd} (0.71)	2.34 _{Ae} (1.95)	1.67 _{Bd} (1.77)	0.0 _{Ca} (0.71)	0.0 _{Ca} (0.71)	0.60 _e (1.17)	
V	1.0 _{Cb} (1.22)	3.0 _{Bd} (1.87)	4.0 _{Ac} (2.12)	0.0 _{Da} (0.71)	0.0 _{Db} (0.71)	1.60 _d (1.33)	
VI	1.67 _{Ca} (1.58)	4.0 _{Bc} (2.12)	4.34 _{Ab} (2.20)	0.0 _{Da} (0.71)	0.0 _{Db} (0.71)	2.00 _c (1.46)	
VII	1.0 _{Bb} (1.22)	5.0 _{Ab} (2.35)	5.0 _{Aa} (2.35)	0.0 _{Ca} (0.71)	0.0 _{Cb} (0.71)	2.2 _b (1.47)	
Adult	0.34 _{Cc} (0.88)	5.34 _{Aa} (2.41)	5.0 _{Ba} (2.35)	0.0 _{Da} (0.71)	0.0 _{Db} (0.71)	2.14 _a (1.41)	
Mean	0.71 _C (1.08)	2.95 _B (1.93)	3.34 _A (1.94)	0.0 _E (0.71)	0.11 _D (0.78)		

* Mean of three replications

Values in the parenthesis are $(\sqrt{x + 0.5})$ transformed values

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

4.3.6. Prey preference of spiders in mixed population of sucking pests

The prey preference of the six spiders viz., *O. javanus*, *P. viridana*, *C. drassodes*, *A. pulchella*, *L. decorata* and *Salticus* sp was studied by providing adult spiders with mixed population of sucking pests, and the results are given in the Table 12.

The maximum predation was observed in case of *O. javanus* (50.35%) which was statistically on par with lynx spider *P. viridana* (49.175%) where both preferred aphids (60 and 65.0% respectively) and leafhoppers (51.42% and 50.0%) respectively as major food.

The other two hunting spiders *C. drassodes* and *Salticus* sp preferred aphids (68.57% and 65.71%) followed by leafhoppers (51.42% and 60.0%) and whiteflies (42.85% and 20.0%).

The preference by two web spiders *A. puchella* and *L. decorata* has shown towards leafhoppers (71.30% and 68.57% respectively) and whiteflies (60.0% and 60.0% respectively), whereas aphids were preferred only to an extent of 12.85 and 8.57 percent (Table 12).

The over all result indicated that aphids and leafhoppers were preferred by all the spiders, and the preference was on par. Among the six spiders the prey preference of the two lynx spiders *O. javanus* (50.35%) and *P. viridana* (49.175%) was on par. Similarly there was no significant difference observed between the preferences by *C. drassodes* and *Salticus* sp (43.12% and 41.42%) and also for the two web spiders (38.53% and 36.785%) (Table 12).

Table 12. Prey preference of different spiders on mixed population of sucking pests

Spider species	Predation (%)*			Mean
	Aphids	Leaf hoppers	Whiteflies	
<i>O.javanus</i>	60.0 ^{Ab} (50.77)	51.42 ^{Bc} (48.80)	48.57 ^{Bb} (44.18)	50.35 ^a (45.20)
<i>P.viridana</i>	65.0 ^{Aab} (53.73)	50.0 ^{Bc} (45.00)	42.85 ^{Cb} (40.89)	49.18 ^a (42.44)
<i>Salticus</i> sp.	68.57 ^{Aa} (55.90)	51.42 ^{Bc} (45.82)	42.85 ^{Cd} (40.89)	43.21 ^b (40.26)
<i>C.drassodes</i>	65.71 ^{Aab} (54.16)	60.0 ^{Ab} (50.77)	20.0 ^{Bc} (26.57)	41.42 ^b (39.51)
<i>L.decorata</i>	8.57 ^{Cc} (17.02)	68.57 ^{Aab} (55.87)	60.0 ^{Ba} (50.77)	36.785 ^c (39.53)
<i>A.pulchella</i>	12.85 ^{Cc} (21.01)	71.30 ^{Aa} (50.15)	60.0 ^{Ba} (50.77)	38.53 ^{cb} (36.96)
Mean	46.78 ^A (42.10)	58.78 ^B (57.61)	45.71 ^A (42.34)	

Values in the parenthesis are arc sine transformed values

* Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

4.3.7. Inter - predation among spiders

Cannibalism among spiders in presence of alternate prey was studied using all the three species of hunting spiders viz., *O. javanus*, *P. viridana* and *C. drassodes* in different combinations as indicated in the Table 13.

It is evident from the observations that cannibalism was less (0.89 ± 0.76 to 2.86 ± 0.88) among the spiders in the presence of alternate prey offered as choice. Anyhow the spider *C. drassodes* was observed to have more cannibalistic behaviour on *P. viridana* and *O. javanus* (2.12 ± 0.79 and 2.09 ± 0.68) when compared with other two spiders *O. javanus* (1.12 ± 0.78 on *P. viridana* and 1.60 ± 0.93 on *C. drassodes*) and *P. viridana* (0.89 ± 0.76 and 1.02 ± 0.65 on *O. javanus* and *C. drassodes* respectively (Table 13).

4.3.8. Cross predation

The cross predation between spider species and *C. carnea* was studied, under laboratory condition.

The two spiders *O. javanus* and *C. drassodes* consumed 2.46 ± 1.36 and 3.15 ± 1.62 grubs of *Chrysoperla* respectively in 24 hours, whereas the *P. viridana* did not prefer *Chrysoperla* as prey. But when the egg sacs were offered as prey to fully grown grubs of *Chrysoperla* consumed 31 ± 12.2 the eggs of *O. javanus*, 27 ± 10.8 of *C. drassodes* and nil of *P. viridana* in the absence of mother, whereas no consumption was observed when mother was present. (Table 14).

4.4. Impact of cultural practices on spider population

When the impact of cultural practices like growing of resistant varieties, fertilizer and spacings on the spider population was studied (Table 15), the result indicated that the var MCU 5 at spacing 75 x 45 cm and fertilizer level

Table 13. Feeding preferences of spiders on other spiderlings in presence of alternate prey

Predator (Adult)	Prey insects offered	Prey consumed / 24 h mean \pm SD
<i>O. javanus</i>	5 nymphs of leafhoppers	1.15 \pm 0.82
	+	
	5 spiderlings of <i>P. viridana</i>	1.12 \pm 0.78
<i>O. javanus</i>	5 nymphs of leafhoppers	1.89 \pm 0.96
	+	
	5 spiderlings of <i>C. drassodes</i>	1.60 \pm 0.93
<i>C. drassodes</i>	5 nymphs of leafhoppers	2.96 \pm 0.92
	+	
	5 spiderlings of <i>P. viridana</i>	2.12 \pm 0.79
<i>C. drassodes</i>	5 nymphs of leafhoppers	2.86 \pm 0.88
	+	
	5 spiderlings of <i>O. javanus</i>	2.09 \pm 0.68
<i>P. viridana</i>	5 nymphs of leafhoppers	1.24 \pm 0.68
	+	
	5 spiderlings of <i>C. drassodes</i>	1.02 \pm 0.65
<i>P. viridana</i>	5 nymphs of leafhoppers	2.88 \pm 0.93
	+	
	5 spiderlings of <i>O. javanus</i>	0.89 \pm 0.76

Table 14. Cross predation between *C. carnea* and spiders

Predator (Adults)	Prey (n)	Prey	Prey consumed / 24h mean \pm SD
Spider			
<i>C. drassodes</i>	10	<i>Chrysoperla</i> grub	2.46 \pm 1.36
<i>P. viridana</i>	10	<i>Chrysoperla</i> grub	No consumption
<i>O. javanus</i>	10	<i>Chrysoperla</i> grub	3.15 \pm 1.62
<i>Chrysoperla</i> grub		<i>O. javanus</i>	
<i>Chrysoperla</i> grub.	1	Egg sac + mother	No consumption
<i>Chrysoperla</i> grub	1	Egg sac alone	31 \pm 12.2
		<i>P. viridana</i>	
	1	Egg sac + mother	No consumption
	1	Egg sac alone	No consumption
		<i>C. drassodes</i>	
	1	Egg sac + mother	No consumption
	1	Egg sac alone	27 \pm 10.8

40:20:20 kg NPK/ha was contributing for the increased population of spiders per plant (2.2/plant) and was statistically superior to all other combinations.

The number of spiders per plant are less (0.2 / plant) in the combinations of var TCH 1569 with spacing 75 x 30 cm and fertilizer level 40:20:20 and also with spacing 75 x 45 cm and fertilizer level 120:60:60 NPK/ha and var CNH 120 MB at spacing 75 x 45 and fertilizer level 40:20:20 NPK/ha (Table 15).

Toxicity studies

4.5. Persistent toxicity of insecticides on the mortality rate of different spiders

The persistent toxicity of six insecticides viz., chlorpyrifos, methyl demeton, endosulfan, monocrotophos, quinalphos and imidacloprid along with neem and *B.t.* was studied through five intervals (1, 3, 7, 10 and 15 days after treatment) for four spiders *O. javanus*, *P. viridana*, *C. drassodes* and *A. pulchella*. The results are given as per cent mortality for each chemical at different intervals. The experiments were restricted to four spiders due to non availability of sufficient populations in web spider groups.

4.5.1. *O. javanus*

Of the six chemical insecticides tested on spiders, the monocrotophos was observed to be more toxic causing highest mortality of 62.22 per cent, followed by methyl demeton (48.88%). Imidacloprid was safest of all causing only 31.1 per cent mortality followed by quinalphos (35.54%).

Between neem and *B.t.* there was no mortality in case of neem, whereas *B.t.* (28.89%) was statistically on par with imidacloprid, causing 28.89 per cent mortality (Table 16).

Table 15. Impact of cultural practices on population of spiders

V S F	No. of Spiders/plant
V ₁ S ₁ F ₁	1.2 ^d (1.32)
V ₁ S ₁ F ₂	1.2 ^d (1.32)
V ₁ S ₁ F ₃	1.2 ^d (1.32)
V ₁ S ₂ F ₁	2.2 ^a (1.55)
V ₁ S ₂ F ₂	1.6 ^b (1.33)
V ₁ S ₂ F ₃	1.0 ^e (0.82)
V ₂ S ₁ F ₁	1.4 ^c (1.15)
V ₂ S ₁ F ₂	0.8 ^f (1.26)
V ₂ S ₁ F ₃	0.2 ⁱ (0.92)
V ₂ S ₂ F ₁	0.6 ^g (1.02)
V ₂ S ₂ F ₂	0.4 ^h (0.91)
V ₂ S ₂ F ₃	0.2 ⁱ (0.71)
V ₃ S ₁ F ₁	0. ^{aj} (0.71)
V ₃ S ₁ F ₂	0.0 ^j (0.71)
V ₃ S ₁ F ₃	0.2 ⁱ (0.82)

Contd.

V S F	Spiders
V ₃ S ₂ F ₁	0.0 ^j (0.71)
V ₃ S ₂ F ₂	0.0 ^j (0.71)
V ₃ S ₂ F ₃	0.0 ^j (0.71)
V ₄ S ₁ F ₁	0.0 ^j (0.71)
V ₄ S ₁ F ₂	0.0 ^j (0.71)
V ₄ S ₁ F ₃	0.0 ^j (0.71)
V ₄ S ₂ F ₁	0.0 ^j (0.71)
V ₄ S ₂ F ₂	0.2 ⁱ (0.71)
V ₄ S ₂ F ₃	0.0 ^j (0.71)

V- Variety

V₁ - MCU 5

V₂ - TCH 1659

V₃ - CW ROCK

V₄ - CNH 120 MB

S - Spacing

S₁ - 75 x 45 cm

S₂ - 75 x 30 cm

F - Fertilizer level

F₁ - 40 : 20 : 20

F₂ - 80 : 40 : 40

F₃ - 120 : 60 : 60

* Mean of five replications

Values in the parenthesis are ($\sqrt{x + 0.5}$) transformed values

In a column, means followed by same alphabet (lower case) are not significantly different (P = 0.05) by DMRT.

Table 16. Persistent toxicity effect of insecticides on *O. javanus*

Chemical	Mortality (%)*					Mean
	Days after treatment					
	1	3	7	10	15	
Chlorpyrifos 25EC	77.80 (61.50)	55.57 (48.25)	44.44 (41.75)	11.10 (12.86)	0.0 (0.96)	37.78 ^{bc} (33.06)
Endosulfan 35EC	88.90 (75.28)	44.47 (41.75)	44.47 (41.75)	0.0 (0.96)	0.0 (0.96)	42.22 ^c (32.14)
Imidacloprid 200SL	88.90 (75.28)	33.30 (30.55)	22.20 (24.05)	11.10 (12.86)	0.0 (0.96)	31.10 ^b (28.74)
Methyl demeton 25EC	77.80 (61.50)	88.90 (49.10)	55.54 (25.33)	22.20 (24.05)	0.0 (0.96)	48.88 ^{cb} (32.19)
Monocrotophos 36EC	100.0 (89.05)	88.90 (49.10)	88.90 (38.34)	33.30 (35.25)	0.0 (0.96)	62.22 ^d (42.54)
Quinalphos 25EC	77.80 (61.50)	55.54 (48.25)	33.30 (35.25)	11.10 (12.86)	0.0 (0.96)	35.54 ^{bc} (31.76)
<i>B.t.</i>	77.80 (61.50)	44.44 (31.83)	22.20 (24.05)	0.0 (0.96)	0.0 (0.96)	28.89 ^b (23.86)
Neem oil 3%	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 ^a (0.96)
Mean	73.63 ^e (60.82)	51.39 ^d (37.47)	38.88 ^c (28.93)	11.075 ^b (12.59)	0.0 ^a (0.96)	

Values in the parenthesis are arc sine transformed values

* Mean of three replications

In a column and a row means followed by same alphabet (lower case) are not significantly different (P = 0.05) by DMRT.

4.5.2. *P. viridana*

All the synthetic chemical insecticides were toxic to spiders and the maximum per cent mortality of *P. viridana* was caused by methyl demeton (48.88%) followed by monocrotophos (46.66%), quinalphos (46.65%) and endosulfan (40.0%).

Imidacloprid and chlorphyriphos were recorded as safer chemicals causing 24.43 and 15.57 per cent mortality respectively, which were on par with *B.t.* (19.95%). No mortality was observed in neem.

The mortality per cent at 10th and 15th days after treatments was not significantly different (Table 17).

4.5.3. *C.drassodes*

The maximum mortality of *C.drassodes* was observed due to quinalphos (51.22%) followed by monocrotophos (51.114) which were statistically superior to the other chemicals namely, methyl demeton (42.23%), endosulfan (42.18%) which were on par with each other. The chlorpyriphos and imidacloprid were observed to cause reduced per cent mortality, 37.80 per cent and 35.55 per cent respectively and were on par with each other.

There was no mortality due to neem whereas *B.t.* recorded 19.94 per cent mortality. The mortality per cent at 1 day and 3 days after treatment as well as 10 days and 15 days after treatment was on par (Table 18).

4.5.4. *A.pulchella*

Chlorpyriphos was found to record minimum per cent mortality among all chemicals causing only 22.21 per cent mortality, which was followed by imidacloprid (33.32%). The maximum per cent mortality was caused by

Table 17. Persistent toxicity effect of insecticides on *P. viridana*

Chemical	Mortality (%)*					Mean
	1	3	7	10	15	
Chlorpyrifos 25EC	55.57 (41.51)	33.33 (37.12)	22.20 (24.05)	11.10 (12.78)	0.0 (0.96)	24.43 ^b (23.43)
Endosulfan 35EC	88.90 (75.28)	66.70 (54.76)	33.30 (35.25)	11.10 (12.856)	0.0 (0.9550)	40.00 ^c (35.82)
Imidacloprid 200SL	44.44 (41.75)	22.10 (24.05)	11.10 (12.86)	0.0 (0.96)	0.0 (0.96)	15.57 ^b (16.11)
Methyl demeton 25EC	77.80 (61.50)	88.90 (49.10)	33.30 (35.25)	33.30 (35.2452)	11.10 (12.8556)	48.88 ^c (38.79)
Monocrotophos 36EC	88.90 (75.28)	77.80 (46.08)	44.44 (41.75)	11.10 (12.86)	0.0 (0.96)	46.66 ^c (35.38)
Quinalphos 25EC	77.80 (61.50)	66.70 (54.76)	55.57 (48.25)	22.10 (24.05)	11.10 (12.86)	46.65 ^c (40.28)
<i>B.t.</i>	55.57 (48.75)	33.30 (35.25)	11.10 (12.86)	0.0 (0.96)	0.0 (0.96)	19.94 ^b (19.94)
Neem oil 3%	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 ^a (0.96)
Mean	63.91 ^c (53.44)	48.62 ^c (38.59)	31.97 ^{bc} (31.79)	23.60 ^{ab} (24.73)	6.93 ^a (8.27)	

Values in the parenthesis are arc sine transformed values

* Mean of three replications

In a column and a row means followed by same alphabet (lower case) are not significantly different (P = 0.05) by DMRT.

Table 18. Persistent toxicity effect of insecticides on *C. drassodes*

Chemical	Mortality (%)*					Mean
	Days after treatment					
	1	3	7	10	15	
Chlorpyrifos 25EC	66.70 (47.73)	55.57 (43.97)	33.30 (36.42)	22.20 (26.75)	11.00 (12.86)	37.80 ^c (33.54)
Endosulfan 35EC	88.90 (77.28)	55.57 (43.97)	44.47 (40.19)	22.20 (26.75)	0.0 (0.96)	42.188 ^{de} (37.83)
Imidacloprid 200SL	66.70 (54.76)	55.57 (48.25)	22.20 (24.05)	22.20 (24.05)	11.10 (12.86)	35.55 ^c (32.79)
Methyl demeton 25EC	55.57 (43.96)	66.90 (47.73)	44.47 (40.19)	44.44 (40.19)	0.0 (0.96)	42.23 ^{de} (34.61)
Monocrotophos 36EC	88.90 (77.28)	77.80 (61.50)	44.47 (40.19)	33.30 (36.42)	11.10 (12.86)	51.11 ^d (45.65)
Quinalphos 25EC	88.90 (77.28)	55.57 (38.34)	44.47 (48.25)	44.47 (41.75)	22.20 (24.05)	51.22 ^d (45.93)
<i>B.t.</i>	55.57 (48.25)	22.20 (24.05)	22.20 (24.05)	0.0 (0.96)	0.0 (0.96)	19.99 ^b (19.65)
Neem oil 3%	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 ^a (0.96)
Mean	63.91 ^c (53.44)	48.62 ^c (38.59)	31.97 ^{bc} (31.79)	23.60 ^{ab} (24.73)	6.93 ^a (8.27)	

Values in the parenthesis are arc sine transformed values

* Mean of three replications

In a column and a row means followed by same alphabet (lower case) are not significantly different (P = 0.05) by DMRT

Table 19. persistent toxicity effect of insecticides on *A. pulchella*

Chemical	Mortality (%)*					Mean
	1	3	7	10	15	
Chlorpyrifos 25EC	77.80 (61.50)	55.57 (48.25)	22.20 (24.05)	22.20 (24.05)	11.10 (12.86)	22.21 ^{bc} (34.14)
Endosulfan 35EC	88.90 (75.28)	77.80 (61.50)	55.57 (20.64)	44.47 (41.75)	22.20 (24.05)	55.78 ^d (42.41)
Imidacloprid 200SL	88.90 (75.28)	33.30 (35.25)	22.20 (24.05)	11.10 (12.86)	11.10 (12.86)	33.32 ^{cbd} (32.06)
Methyl demeton 25EC	88.90 (75.28)	88.90 (49.10)	55.57 (48.25)	33.30 (35.25)	11.10 (12.86)	55.55 ^d (49.38)
Monocrotophos 36EC	100.00 (89.05)	88.90 (72.28)	55.57 (48.25)	44.43 (41.75)	11.10 (12.86)	59.98 ^d (53.44)
Quinalphos 25EC	88.90 (75.28)	76.67 (60.56)	55.57 (41.75)	33.3 (30.56)	0.0 (0.96)	50.89 ^d (41.82)
<i>B.t.</i>	33.30 (35.25)	22.20 (24.05)	11.10 (12.86)	0.0 (0.96)	0.0 (0.96)	13.32 ^{ab} (14.42)
Neem oil 3%	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 (0.96)	0.0 ^a (0.96)
Mean	70.84 ^c (60.98)	55.42 ^d (47.64)	34.72 ^c (27.60)	23.60 ^b (23.51)	8.35 ^a (9.79)	

Values in the parenthesis are arc sine transformed values

* Mean of three replications

In a column and a row means followed by same alphabet (lower case) are not significantly different (P = 0.05) by DMRT

monocrotophos (59.98%) followed by endosulfan (55.78%), methyl demeton (55.55%) and quinalphos (50.88%) and were on par with each other.

Neem recorded nil mortality whereas *B.t.* caused 13.32 per cent mortality and both were on par with each other (Table 19).

4.6. Residual toxicity of insecticides on mortality percent

The residual toxicity of eight selected insecticides *viz.*, chlorpyrifos, methyl demeton, monocrotophos, endosulfan, quinalphos, neem and *B.t.* were tested against the three spiders *O. javanus*, *P. viridana* and *C.drassodes* by offering three types of prey insects (Aphids, leafhoppers, whiteflies). The results indicated that quinalphos (55.56 - 70.45%) and monocrotophos (55.51 - 63.02%) caused maximum residual toxicity.

4.6.1. *O. javanus*

Of the six chemicals tested, the quinalphos was observed to be more toxic causing highest mortality of 59.28 per cent, followed by endosulfan (55.62%) and monocrotophos (55.51%), which were statistically on par with each other. The residual toxic effect of neem and *B.t.* was less 8.0 per cent and 0.0 per cent respectively and both were on par.

The mortality rate was comparatively high when treated leafhoppers (44.47%) were offered as prey (Table 20).

4.6.2. *P. viridana*

Maximum per cent mortality (70.45%) was caused by quinalphos followed by monocrotophos (63.02%) which were on par but superior to other treatments. Minimum per cent mortality was caused by chlorpyrifos (22.20%) followed by imidacloprid (33.30%) which were statistically on par with each other. The residual toxicity was maximum when aphids were offered as prey (50.04%).

Table 20. Residual toxicity of insecticides to *O. jamvanus*

Chemical	Mortality (%)* after 24h			Mean
	Aphids	Leaf hoppers	Whiteflies	
Chlorpyrifos 25EC	11.10 ^{Aa} (12.86)	44.44 ^{Bbc} (40.19)	22.20 ^{Ab} (30.56)	25.91 ^b (25.88)
Endosulfan 36EC	55.57 ^{Bd} (45.91)	78.00 ^{Ce} (61.05)	33.30 ^{Ac} (30.56)	55.62 ^d (45.84)
Imidacloprid 200SL	33.30 ^{Ab} (35.25)	44.44 ^{Abc} (41.75)	33.30 ^{Ac} (30.56)	37.00 ^{bc} (35.85)
Methyl demeton 25EC	44.44 ^{Bc} (41.75)	55.57 ^{Bcd} (48.25)	33.30 ^{Ac} (30.56)	44.44 ^{cd} (41.75)
Monocrotophos 35EC	77.67 ^{Ced} (60.56)	55.57 ^{Bcd} (43.96)	33.30 ^{Ac} (36.42)	55.51 ^b (46.98)
Quinalphos 25EC	66.70 ^{Bd} (54.76)	66.70 ^{Bd} (54.76)	44.44 ^{Adc} (41.76)	59.28 ^d (50.42)
<i>B.t.</i>	33.30 ^{Bb} (35.25)	11.10 ^{Aa} (12.86)	0.0 ^{Aa} (0.96)	8.00 ^a (16.35)
Neem oil 3%	11.10 ^{Aa} (12.86)	0.0 ^{Aa} (0.96)	0.0 ^{Aa} (0.96)	3.70 ^a (4.92)
Mean	41.65 ^B (37.40)	44.48 ^B (37.97)	24.98 ^A (25.87)	

Values in the parenthesis are arc sine transformed values * Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

Table 21. Residual toxicity of insecticides to *P. viridana*

Chemical	Mortality (%)* after 24 h			Mean
	Aphids	Leaf hoppers	Whiteflies	
Chlorpyrifos 25 EC	33.30 ^{Bb} (35.25)	11.10 ^{Ab} (12.86)	22.20 ^{Aa} (24.05)	22.20 ^{ab} (24.05)
Endosulfan 35EC	66.70 ^{Bc} (54.76)	22.20 ^{Ab} (24.05)	33.30 ^{Ab} (35.25)	40.73 ^c (38.02)
Imidacloprid 200SL	44.44 ^{Bb} (37.06)	23.20 ^{Ab} (24.05)	33.30 ^{Bb} (35.25)	33.30 ^b (5.25)
Methyl demeton 25EC	44.44 ^{Bb} (41.75)	55.57 ^{Bc} (48.25)	22.20 ^{Aa} (24.05)	40.73 ^c (38.02)
Monocrotophos 36 EC	89.10 ^{Bd} (75.26)	55.57 ^{Ac} (48.25)	44.40 ^{Ac} (41.75)	63.02 ^d (55.10)
Quinalphos 25EC	89.10 ^{Bd} (21.91)	66.70 ^{Ad} (54.76)	55.57 ^{Ad} (48.25)	70.45 ^d (41.65)
<i>B.t.</i>	33.30 ^{Bb} (35.25)	22.20 ^{Ab} (24.05)	22.20 ^{Aa} (24.05)	18.50 ^{ab} (27.78)
Neem oil 3%	0.0 ^{Aa} (0.96)	0.0 ^{Aa} (0.96)	11.10 ^{Aa} (12.86)	3.70 ^a (4.92)
Mean	50.04 ^B (37.78)	31.91 ^A (29.65)	30.53 ^A (30.69)	

Values in the parenthesis are arc sine transformed values * Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

The mortality due to *B.t.* was 18.5 per cent whereas it was found to be only 3.7 per cent in neem (Table 21).

4.6.3. *C.drassodes*

The safest chemical was found to be chlorpyrifos causing 22.20 per cent mortality, followed by imidacloprid (37.02%). All the other chemicals were highly toxic and were statistically on par with each other.

B.t. caused 11.10 per cent mortality which was on par with chlorpyrifos, whereas neem caused only 3.7 per cent mortality and both were on par with each other (Table 22).

4.7. Residual toxicity effect of different insecticides on the predation rate of spiders

When the spiders were exposed to the six chemicals viz., chlorpyrifos, methyl demeton, monocrotophos, endosulfan, quinalphos and imidacloprid and also *B.t.* and neem, through the prey released on to sprayed plants, the result indicated that the reduced predation rate of spiders was because of residual toxicity.

4.7.1. *O. javanus*

When *O. javanus* was exposed to plants treated with different chemicals and offered with aphids and leafhoppers, the predation rate was found to be affected. Quinalphos was found to affect the predation rate to maximum extent (0.18) followed by chlorpyrifos (0.21). The predation rate was least affected by *B.t.* (0.90) imidacloprid (0.80) and monocrotophos (0.70) which were statistically on par with each other. The predation rate was not affected by neem. The maximum decrease in predation rate was observed when leafhoppers were

Table 22. Residual toxicity of insecticides to *C. drassodes*

Chemical	Mortality (%)* after 24 h			Mean
	Aphids	Leaf hoppers	Whiteflies	
Chlorpyrifos 25EC	33.30 ^{Bbc} (36.42)	11.10 ^{Aa} (17.08)	22.20 ^{ABbc} (26.75)	22.20 ^b (26.7479)
Endosulfan 35EC	55.57 ^{Bd} (43.77)	33.30 ^{Abc} (30.52)	44.47 ^{ABc} (42.53)	44.44 ^c (37.75)
Imidacloprid 200SL	44.47 ^{AcD} (35.06)	33.30 ^{Abc} (30.56)	33.30 ^{Abc} (30.56)	37.02 ^c (32.75)
Methyl demeton 25EC	44.47 ^{AcD} (41.75)	44.47 ^{Ac} (48.25)	66.70 ^{Be} (31.83)	51.88 ^d (40.61)
Monocrotophos 36EC	88.9 ^{Ce} (75.13)	33.30 ^{Abc} (36.42)	55.57 ^{Bd} (43.96)	59.25 ^d (51.8658)
Quinalphos 25EC	88.90 ^{Be} (75.22)	33.30 ^{Abc} (35.25)	44.44 ^{Ac} (41.75)	55.56 ^d (50.74)
<i>B.t.</i>	22.2 ^{Bb} (24.05)	11.1 ^{Aa} (12.86)	0.0 ^{Aa} (0.96)	11.1 ^{ab} (12.86)
Neem oil 3%	0.0 ^{Aa} (0.96)	0.0 ^{Aa} (0.96)	11.10 ^{Aab} (12.86)	3.70 ^a (4.92)
Mean	47.23 ^B (41.36)	24.98 ^A (26.48)	34.736 ^A (28.90)	

Values in the parenthesis are arc sine transformed values

* Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different ($P = 0.05$) by DMRT.

Table 23. Residual toxicity of insecticides on predation rate of *O. javanus*

Chemical	Aphids				Leafhoppers				Whiteflies			
	Days after treatment				Days after treatment				Days after treatment			
	1	5	10	Mean*	1	5	10	Mean*	1	5	10	Mean*
Chlorpyrifos 25EC	0.24	0.21	0.18	0.21 ^{Aa}	0.23	0.23	0.24	0.23 ^{Aa}	0.16	0.16	0.16	0.16 ^{Aa}
Endosulfan 35EC	0.71	0.70	0.71	0.70 ^{Ac}	0.69	0.71	0.69	0.69 ^{Ac}	0.50	0.50	0.50	0.50 ^{Ac}
Imidacloprid 200SL	0.80	0.80	0.80	0.80 ^{Af}	0.85	0.93	0.93	0.96 ^{Be}	0.85	0.7	0.71	0.78 ^{Af}
Methyl demeton 25EC	0.36	0.35	0.37	0.36 ^{Ab}	0.46	0.46	0.45	0.45 ^{Ab}	0.33	0.33	0.32	0.32 ^{Ab}
Monocrotophos 36EC	0.56	0.56	0.58	0.56 ^{Ab}	0.76	0.71	0.69	0.72 ^{Bd}	0.57	0.58	0.66	0.60 ^{Ad}
Quinalphos 25EC	0.18	0.18	0.18	0.18 ^{Ac}	0.23	0.22	0.21	0.22 ^{Aa}	0.21	0.21	0.21	0.21 ^{Ae}
<i>B.t</i>	0.86	0.93	0.93	0.90 ^{Ag}	0.93	0.95	0.97	0.95 ^{Ae}	0.83	0.88	0.94	0.88 ^{Ag}
Nem oil 3%	1.0	1.0	1.0	1.0 ^{Ah}	1.0	1.0	1.0	1.0 ^{Af}	1.0	1.0	1.0	1.0 ^{Ab}
Mean	0.63	0.63	0.64	0.64 ^A	0.68	0.69	0.68	0.68 ^B	0.60	0.60	0.61	0.60 ^C

*Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different ($P = 0.05$) by DMRT.

provided as prey,(0.68) except for methyl demeton where aphids as prey affected the predation rate to maximum extent (0.22) (Table 23).

4.7.2. *P. viridana*

The predation rate of *P. viridana* decreased to a maximum extent when the aphids on plants treated with quinalphos were offered as prey (0.17) followed by leafhoppers on plants treated with chlorpyriphos (0.18). The predation rate was least affected when the plants were treated with neem for all the insects as prey (0.93). When leafhoppers were offered as prey the predation rate values of chemicals, chlorpyriphos (0.18), monocrotophos (0.22) and quinalphos (0.22) were on par with each other. Similarly when whitefly was offered as prey the predation rate was affected to a maximum extent by chlorphyriphos (0.28) and methyl demeton (0.29) which were statistically on par with each other (Table 24) .

4.7.3. *C.drassodes*

The maximum reduction in the predation rate was found when the leafhoppers and aphids were offered as prey with the quinalphos (0.20) and chlorpyriphos (0.20) treatments, which were statistically on par followed by whiteflies as prey (0.29 and 0.29 respectively). These were followed by methyl demeton, monocrotophos and endosulfan. The predation rate was least affected by neem (0.89 - 0.90) followed by *B.t* (0.78 - 0.81) when different prey insects were offered (Table 25).

4.8. Determination of median lethal concentration values for different insecticides

The LC_{50} values, fiducial limits, Chi^2 values and slope for five insecticides are summarized in Table 26 for the two commonly available species.

Table 24. Residual toxicity of insecticides on predation rate on *P. viridana*

Chemical	Aphids			Leafhoppers			Whiteflies					
	Days after treatment			Days after treatment			Days after treatment					
	1	5	10	Mean*	1	5	10	Mean*	1	5	10	Mean*
Chlorpyrifos 25EC	0.23	0.28	0.32	0.28 ^{Aa}	0.17	0.16	0.21	0.18 ^{Ba}	0.29	0.29	0.27	0.28 ^{Ad}
Endosulfan 35EC	0.28	0.28	0.32	0.29 ^{Aa}	0.34	0.16	0.16	0.22 ^{Ba}	0.49	0.59	0.59	0.5 ^{bCb}
Imidacloprid 200SL	0.57	0.61	0.66	0.61 ^{Ab}	0.60	0.52	0.50	0.54 ^{Ba}	0.69	0.60	0.62	0.63 ^A
Methyl demeton 25EC	0.42	0.42	0.47	0.43 ^{Ab}	0.28	0.33	0.38	0.33 ^{Bb}	0.30	0.30	0.28	0.29 ^{Ca}
Monocrotophos 36EC	0.28	0.32	0.32	0.31 ^{Aa}	0.39	0.44	0.44	0.42 ^B	0.39	0.29	0.39	0.35 ^C
Quinalphos 25EC	0.18	0.14	0.18	0.17 ^{Ac}	0.21	0.23	0.21	0.22 ^{Ba}	0.49	0.59	0.49	0.52 ^{Cb}
<i>B.t</i>	0.61	0.66	0.71	0.66 ^{Ac}	0.73	0.66	0.66	0.68 ^A	0.89	0.89	0.88	0.88 ^B
Neem oil 3%	0.95	0.94	1.0	0.96 ^{Af}	0.94	0.83	0.88	0.88 ^B	0.92	0.96	0.92	0.93 ^C
Mean	0.50	0.51	0.55	0.53 ^A	0.52	0.48	0.49	0.496 ^B	0.60	0.61	0.60	0.603 ^C

*Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different (P = 0.05) by DMRT.

Table 25. Residual toxicity of insecticides on predation rate on *C. drossides*

Chemical	Aphids				Leafhoppers				Whiteflies				
	5		10		5		10		5		10		
	1	Mean*	1	Mean*	1	Mean*	1	Mean*	1	Mean*	1	Mean*	
Chlorpyrifos 25EC	0.20	0.20	0.20	0.20	0.27	0.27	0.27	0.27	0.29	0.29	0.29	0.29	0.29 ^{Ca}
Endosulfan 35EC	0.40	0.40	0.40	0.40	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54 ^{Bb}
Imidacloprid 200SL	0.60	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.60	0.60	0.60	0.59	0.59 ^C
Methyl demeton 25EC	0.22	0.22	0.22	0.22	0.30	0.30	0.30	0.30	0.54	0.54	0.54	0.54	0.54 ^{Cb}
Monocrotophos 36EC	0.59	0.59	0.59	0.59	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54 ^{Ab}
Quinalphos 25EC	0.20	0.20	0.20	0.20	0.27	0.27	0.27	0.27	0.29	0.29	0.29	0.29	0.29 ^{Ca}
<i>B.t</i>	0.81	0.81	0.81	0.81	0.78	0.78	0.78	0.78	0.80	0.80	0.80	0.80	0.80
Neem oil 3%	0.90	0.90	0.90	0.90	0.89	0.89	0.89	0.90	0.89	0.89	0.89	0.90	0.89 ^B
Mean	0.54	0.55	0.55	0.55	0.57	0.57	0.57	0.57	0.61	0.61	0.61	0.61	0.61 ^C

*Mean of three replications

In a column, means followed by same alphabet (lower case) and in a row means followed by same alphabet (upper case) are not significantly different ($P = 0.05$) by DMRT.

4.8.1. *O. javanus*

Among the insecticides tested, acephate was observed to be safest of all (0.021) followed by chlorpyrifos (0.016) whereas, monocrotophos (0.011), quinalphos (0.012) and endosulfan (0.016) were observed to be more toxic to this spider. (Table 26).

4.8.2. *P. viridana*

Among the five insecticides tested against the adults of *P. viridana*, acephate was safest of all (0.047) followed by chlorpyrifos (0.045), whereas the chemicals monocrotophos (0.041), quinalphos (0.041) and endosulfan (0.044) were observed to be more toxic. (Table 26).

Table 26. LC₅₀ values of certain insecticides for adults of *O. javanus* and *P. viridana*

Insecticide	Chi ² *	No. of insects	Slope 'b' ± S.E.	LC ₅₀	Fiducial limits
<i>O. javanus</i>					
Acephate	4.07	15	1.11 ± 0.22	0.02	0.01 - 0.05
Chlorpyrifos	3.42	15	1.06 ± 0.26	0.01	0.00 - 0.03
Endosulfan	4.73	15	0.88 ± 0.19	0.01	0.01 - 0.04
Monocrotophos	2.34	15	1.08 ± 0.27	0.01	0.00 - 0.03
Quinalphos	3.76	15	0.93 ± 0.25	0.01	0.00 - 0.03
<i>P. viridana</i>					
Acephate	1.00	15	0.91 ± 0.22	0.05	0.22 - 0.14
Chlorpyrifos	0.43	15	0.87 ± 0.19	0.05	0.02 - 0.15
Endosulfan	2.01	15	0.84 ± 0.21	0.44	0.02 - 0.15
Monocrotophos	2.76	15	0.74 ± 0.18	0.04	0.01 - 0.15
Quinalphos	1.07	15	0.07 ± 0.18	0.04	0.00 - 0.01



DISCUSSION

CHAPTER V

DISCUSSION

Spiders are one of the most abundant predators regulating insect populations in terrestrial agro ecosystems (Schaefer, 1974; Edwards *et al.*, 1976). Young and Edwards (1990) found the presence of rich spider fauna especially in cotton (>300 species), which feed heavily on sucking insects. Not only this but in ecotoxicological studies, spiders were acknowledged as sensitive bio indicators of pesticide side effects (Everts 1990).

From this view point studies were concentrated on the distribution, abundance, seasonal incidence, prey preferences of spiders of cotton ecosystem, standardisation of sampling technique, predatory potential, impact of cultural practices on spider population and the relative toxicity of recommended insecticides to spiders were also carried out.

5.1. Collection and identification of spiders under cotton ecosystems

Survey on spider fauna in different cotton ecosystems revealed a wide array of 28 species under 17 genera and 8 families. The abundance of the spider species in cotton ecosystem has been earlier documented by Young and Edwards (1990) who monitored the rich spider fauna especially in cotton (>300 species).

The spider under genera *Argiope*, *Bianor*, *Leucauge*, *Neoscona*, *Oxyopes*, *Pardosa*, *Peucetia*, *Salticus*, *Tetragnatha* and *Thomisus*, were reported in almost all the cotton ecosystems under survey.

The spider species *Araneus* sp., *Argiope* sp., *A. pulchella*, *Bianor* sp., *C. citricola*, *C. drassodes*, *C. viridamus*, *G. unguifera*, *L. decorata*, *Leucauge* sp., *N. elliptica*, *Neoscona* spp., *Olios* sp., *O. javanus*, *O. rufisternum* *P. paykulli*, *Pardosa* spp., *P. pseudoannulata*, *P. viridana*, *T. cherapunjens*, *T. pugilis*,

Tetragnatha sp., *V. preymandibularis* and *V. monostriata* were reported from the cotton fields of Tamil Nadu.

5.1.1. Host range and seasonal abundance

When the host range was tested, the studies indicated that the spiders in cotton ecosystem will prey upon almost all the insects present in the cotton ecosystem, including some other predators. The spiders preying on cotton pests was reported previously Dhulia and Yadav (1991). Breene *et al.* (1990) reported spiders preying upon cotton leafhoppers.

Most of the spider species were found to be abundant in the winter months (October to February) which provides congenial climate for the development and reproduction of spiders as evidenced by the correlation studies carried out in the present investigation, which showed one degree decrease in temperature will increase the spider population by 4.54.

5.1.2. Abundance of spiders in cotton agro ecosystems

Quantitative estimates of spiders in different cotton ecosystems revealed that the species richness was more in the cotton fields of Coimbatore than other three areas *viz.*, Kinathukadavu, Annur and Alanthurai. But in all the four cotton ecosystems, the species richness was found to be more than that of border weeds. This density variations between cotton field and border weeds can be attributed to the fact that in case of cultivated fields the food availability is plenty and continuous throughout the season. Similarly, Kamal *et al.* (1992) reported that the species richness was more in rice field than that of the weedy fallow.

5.1.4. Influence of pest abundance, population levels of other groups of predators

The multiple regression worked out between the population of spiders and the sucking pests revealed that the spider population was independent of the

population fluctuations of sucking pest. This is due to the fact that the spiders may possibly limit their ability to regulate a given prey since it fails to respond numerically to the increasing densities (Richert and Lockley, 1984). Another reason might be that the spiders prefer other spiders, followed by dipterans even in the presence of potential prey as reported by Nyffeler *et al.* (1987a). In contrary to the above findings, Breene *et al.* (1988) also reported that the leafhopper number decreased as the population of spiders number increased.

The multiple regression analysis between population of spiders and other predators indicated that there is no correlation between the existing spider population and population of other predators (coccinellids and chrysopids). The plausible reason for this might be that the competition between spiders and other predators was very meagre for the common prey as the spiders are polyphagous insectivores (Wise, 1993).

5.1.5. Influence of weather factors on population dynamics of spiders

For evaluating the influence of weather factors on spider population, the multiple regression analysis was worked out which revealed that the spider population was influenced by weather parameters such as minimum temperature and evening relative humidity. However, according to the findings of Kessler *et al.* (1984), the spiders in coastal plains aggregated during winter in tussocks of sedges to protect themselves against adverse meteorological conditions like reduced temperatures. The evening relative humidity was observed to be negatively correlated with spider population. The relative humidity was negatively correlated with the number of species reported by Hatley and Macmahon (1980).

5.1.3. Seasonal incidence of spider population

The studies conducted on the seasonal incidence of spiders revealed that the spider population increased gradually as the stage of crop advanced. However

during earlier stages of crop growth (September to October) the spider population fluctuated without showing any distinct trend, but after square formation it increased steadily. This may be due to the availability of prey and slow increase in the population of spider without any external interruptions.

This is in accordance with the findings of Nyffeler *et al.* (1987) where in early season the spider numbers tend to be very low.

5.2. Standardisation of an effective sampling technique

The four commonly used sampling techniques for collection of spiders in cotton ecosystem were compared to identify an effective method.

Among the four sampling methods compared *viz.*, net sweeping, counting the websites, pitfall trapping and whole plant sampling; the whole plant sampling method was found to be effective in yielding more number of spiders per plant whereas the net sweeping method yielded less number of spiders. However Bayot *et al.* (1990) reported that net sweeping was easy to adopt and fast to execute than other techniques in rice ecosystem. But in case of cotton, efficiency of net sweeping was limited during the later stages, because of profuse branching and boll formation. But Howell and Peinkowski (1971) and Wheeler (1973) reported that sampling of spiders of many systems was made difficult, because of plant architecture which limited the access to portions of plant and preclude use of some of more common sampling methods such as net sweeping.

Pitfall trapping was the another effective method which extracted comparatively more number of spiders per plant next to the whole plant sampling method. Graveson and Toft (1987) also reported that pitfall trapping was the predominant method of sampling the spider fauna in managed systems. According to Hengmoss *et al.* (1998) pitfall traps were able to collect largest number of beneficial arthropods, and it was more effective in capturing highly mobile,

surface dwelling arthropods. In contrary, Topping and Sunderland (1992) stated that pitfall data not necessarily represent real species compositions in the field. In addition it reflect only the activity density of species but not absolute densities. The least number of spiders per plant were collected in counting the web sites as it over looks hunting spiders from sampling.

5.3. Predatory potential of spiders on cotton pests

In the present investigation, the predatory potential studies were conducted for five predominant species of spiders occurring in cotton ecosystem. Among these three were hunting spiders viz., *O. javanus*, *P. viridana* and *C. drassodes* and two were web spiders viz., *A. pulchella* and *L. decorata*. The predation rate was tested on both sucking pests and caterpillar pests.

The results revealed that the *O. javanus* was able to consume more number of leafhoppers through all the instars where the adult was consuming more number of leafhoppers per day, whereas aphids were preferred next, followed by whiteflies. Among the lepidopreran pests it consumed more number of *H. armigera* larvae followed by larvae of *S. litura* per day.

The predatory potential studies on the spider *P. viridana* inferred that the adult *P. viridana* was capable of consuming aphids, leafhoppers, whiteflies, larvae of *H. armigera*, *S. litura* as food in order of preference. When the instar wise consumption of spider was considered it was in increasing manner.

The adult *C. drassodes* consumed aphids, leafhoppers and whiteflies, larvae of *H. armigera* and *S. litura*. The consumption rate of spider increased gradually from II instar to adult.

The studies on the predatory potential of web spiders revealed that the *A. pulchella* consumed majority of leafhoppers followed by whiteflies and aphids



larvae of *Helicoverpa* and *Spodoptera* respectively at the adult stage, whereas adult of *L. decorata* observed to consume more number of leafhoppers whiteflies followed by aphids, and larvae of *Helicoverpa*. This spider did not show any preference for *Spodoptera* larvae. For both of these spiders the predation rate followed an increasing trend as the instar of spider advanced.

The predatory potential studies conducted on different spiders at different stages inferred that the consumption rate of all spiders on a prey was increased slowly as the stage of the spider advanced. This was proved by consumption rate of later instar spiderlings which devoured more number of prey insects when compared to earlier instars. Also the consumption rate of adult was more when compared with the developing stages. Similar trend was noticed in Rice ecosystem by Chiu *et al.* (1974) in which fourth instar spiderlings *Oxyopes insecticeps* Boes consumed more of BPH when compared to the predation by their spiderlings on BPH. However this study has indicated high consumption rate of the adult spider than by the eighth and ninth instar spiderlings which might be due to the larger size of adult predators, which requires more amount of food compared to spiderlings. This type of possibility was also reported by several workers (Nyffeler and Benz, 1981; Nentwig, 1987 ; Wise, 1993). According to these reports the spiders feed predominantly on small size prey relative to their own size (Prey length < predator length) and optimal prey length ranges from 50 - 80 per cent of spider length.

When the consumption rate on sucking complex was compared with that of lepidopterans (caterpillars), all the spiders preferred mostly the sucking type of insects as major food source than lepidopterans. This observations holds true with the statement given by Turnbull (1960) which says that the lepidopterans and coleopterans often escape from fragile sheet webs and thus compose an insignificant fraction of the spiders diet. However at the adult stage the spiders

preferred the larvae of lepidopterans compared to the earlier stages. But there are several reports on the spiders feeding on lepidopteran caterpillars. Mansour *et al.* (1980) reported that *Chiracanthium mildei* (Clubionidae) was observed feeding on *Spodoptera littoralis* (Boisd). Similar report was made by Dhulia and Yadav (1991) where *Clubiona* sp. was feeding on *H. armigera* and *S. litura*. Rao *et al.* (1981) reported the *O. salticus* consuming second instar of *Heliothis* and first and fourth instars of *S. litura*.

5.3.1. Prey preference of spiders in mixed population of sucking pests

The prey preference studies conducted for the six predominant spider species of cotton (four hunting and two web spiders) revealed that the hunting spiders showed similarity in their prey preferences. These hunting spiders preferred leafhoppers, aphids, as major food followed by whiteflies. This was in agreement with the findings of Alderweireldet (1994) who reported that the aphididae can make 55 per cent of spiders prey. Nyffeler *et al.* (1987a) also reported that *P. viridana* prey on leafhoppers.

Similar trend of prey preference was also observed in the two web spiders *viz.*, *A. pulchella* and *L. decorata* tested. Both the spiders preferred more of leafhoppers followed by whiteflies. Dhulia and Yadav (1991) also observed the feeding of whiteflies by *A. pulchella* in cotton ecosystem.

The differences in prey preferences can be attributed to the habitat of spiders, where the *O. javanus* move all over the plant and search for the prey whereas *P. viridana* waits on the surface of leaf in cryptic manner and feeds on prey whatever is encountered. The other spider *C. drassodes* rolls the leaf and forms a dense web where aphid infestation is more, while the *Salticus* sp., were present near the twigs infested with aphids. The web spiders can consume only those insects got trapped in the web.

5.3.2. Cross predation between spiders

The predation of spiders on other spiders was investigated under laboratory conditions, which inferred that the adult non web spiders were feeding on other spiders, especially in the absence of the alternative prey. This results can be supported by the findings of Jackson (1977) who reported that the jumping spiders frequently eat other spiders. Similar report was given by Nyffeler and Breene (1990); Nyffeler *et al.* (1992), where higher levels of cannibalism was observed in hunting spiders which may be crucial for survival under conditions of food limitations. Nirmala (1990) also reported similar trend for *L. pseudoannulata* and *T. javana*.

5.3.3. Cross predation between spiders and other predators

The predation of spiders on other predators was investigated under laboratory conditions. These studies revealed that the adult hunting spiders were feeding on fully grown grubs of *Chrysoperla* especially when the alternate prey was absent. Where as *P. viridana* does not show any preference. This result can be supported with the findings of Nyffeler *et al.* (1987) who reported that *O. salticus* includes *Chrysoperla* as its prey in the field upto 42 per cent. Agnew and Smith (1989), Guillebeau and All (1989) also indicated that the striped lynx spider predate on *Chrysoperla*. Similar report was given by Dinter (1998). According to him the larvae of *Chrysoperla* was highly acceptable by erigonids.

Also the fully grown grubs of *Chrysoperla* were observed to feed on spider eggs in the absence of mother spider. The *Chrysoperla* grub consumed eggs of *O. javanus* and *C. drassodes*. Similar report was given by Ganeshkumar (1994) where *Cyrtorhinus lividipennis* (Reuter) consumed eggs of *O. javanus* in the absence of mother spider.

5.4. Impact of cultural practices on spider population

The impact of different cultural practices such as growing of resistant varieties, fertilizer levels and spacing on spider population was investigated. The results indicated that all these three practices were found to influence the population density of spiders. Among the varieties MCU 5, TCH 1569, CNH - 120 MB and CW ROCK at two spacings (75 x 30 and 75 x 45 cm) and three fertilizer levels tested (40 : 20 : 20, 80 : 40 : 40 and 120 : 60 : 60), the variety MCU 5 at spacing 75 x 45 cm and fertilizer level 40 : 20 : 20 was observed to support more number of spiders per plant. This can be supported by finding of Dekeer *et al.* (1989) where day active spiders preferred short vegetation as the spiders are quick hunters with excellent vision, dense foliage may obstruct their vision and impair rapid jumping movements used to capture prey.

5.5. Toxicity of different insecticides to spiders

Pot culture experiments were conducted with the insecticides *viz.*, chlorpyrifos, methyl demeton, endosulfan, monocrotophos, quinalphos, imidacloprid, *B.t* and neem, recommended for cotton, to assess the contact toxicity, residual toxicity its effect on predation rates of the four spider species (*O. javanus*, *P. viridana*, *C. drassodes* and *A. pulchella*). The residual toxicity studies were restricted to the first three species only. Whereas the LC₅₀ was restricted to first two species only, which was conducted under laboratory conditions.

The results of these experiments for contact toxicity at five different intervals revealed that of all the chemical insecticides used monocrotophos caused maximum mortality of the spiders followed by methyl demeton. The toxicity of monocrotophos against the spiders was previously reported by Saxena *et al.* (1989) and Vanden berg *et al.* (1998) who claimed that the monocrotophos adversely affected the spiders after first and second sprays. The toxicity of methyl demeton

was against the finding of Easterbrook (1997) where insignificant reductions in numbers of spiders was observed due to this chemical. Other chemicals such as endosulfan and quinalphos were also observed to be toxic. These observations can be supported by the experimental results obtained by Ganesh Kumar and Velusamy (1996) who reported toxicity of quinalphos against *T. javana*. High persistency of monocrotophos and quinalphos was previously reported by Nirmala (1990) against wolf spider. Toxicity of endosulfan was also reported by Vandenberg *et al.* (1990) who observed reduction in spider population followed by its application.

The other two chemical insecticides *viz.*, chlorpyrifos and imidacloprid were observed to be considerably safe. The results can be supported by the findings of Curtis and Horne (1995) who reported that chlorpyrifos is not having any effect on lycosids. Similar report was also given by Easterbrook (1997), stating that no significant reduction in numbers of spider was observed followed by the application of chlorpyrifos. However the safety of chlorpyrifos to spiders was not in concordance with the reports of Thang *et al.*, (1987); and Nirmala (1990). But the safety of the chemical imidacloprid was in concordance with the observations made by Lixin and Liang (1995) where imidacloprid used for control of leafhoppers had no significant effect on spiders. Guifen *et al.* (1996) observed that the spider prey ratio was 1:0.23 indicating the safety of imidacloprid to spider.

When neem and *B.t* were observed for contact toxicity, the toxicity of neem was nil for all the spiders at all the intervals, whereas *B.t*. toxicity ranged from 13.32 to 28.89. Kareem *et al.* (1988, 1988a, 1988b) reported the safety of neem oil for rice spiders. The safety of neem against spiders was similar to the observations of Dash *et al.* (1996) where the natural enemy population was greatest in NO 3 % sprays. Raguraman and Rajasekaran (1996) also reported that a better

recolonisation of predatory wolf spider was observed in neem treatments.. The reason for safety of neem might be the quick degradation property.

In all the treatments the persistent toxicity decreased with the time interval. Similar type of observations were also made by Nirmala (1990) and Ganesh Kumar (1994).

5.6. Effect of residual toxicity of insecticides on mortality per cent

Among the chemicals, quinalphos and monocrotophos were observed to be more toxic, when treated prey was offered to spiders whereas imidacloprid and chlorpyrifos were observed to be safe. The *B.1* was also observed to be safe and neem was safest of all. Kiritani and Kawahara (1973), Chiu and Cheng (1976) and Thang *et al.* (1985) also observed significant mortality in predators not only from direct toxicity but also from ingestion of prey that had taken up the insecticide.

The residual toxicity of chlorpyrifos was observed to be less. The reason might be that it is rapidly detoxified in the animal body. And the higher residual toxicity of monocrotophos observed might be due to the systemic nature of this chemical.

The mortality percentage due to the residual toxicity was less when compared with that of persistent toxicity ,the plausible reason might be that in case of residual toxicity since the spiders were provided only with treated prey the spiders did not have chance of experiencing contact effect, as well as insecticides were probably converted to less toxic metabolites in body before being ingested by the predator.

Among the treated prey offered, leafhoppers caused maximum mortality for *O. javanus* whereas for *P. viridana* and *C. drassodes*, treated aphids as prey

caused maximum mortality. This was in concordance with the prey preference of the respective spiders

5.7. Effect of residual toxicity on predation rate

The effect of residual toxicity of monocrotophos and quinalphos on the predation rate was observed to be a maximum extent, when sucking pests were given as prey.

The minimum effect on predation rate was observed in case of chlorpyriphos and imidacloprid respectively.

The residual toxic effect of monocrotophos, and quinalphos on *L. psuedoannulata* and on *O. javanus* was reported before by Ganesh kumar (1994) where for chlorpyriphos the effect was less. The *B.t.* and neem observed to affect the predation rate to a minimum extent.

5.8. LC₅₀ values of certain insecticides for *O. javanus* and *P. viridana*

Studies on determination of median lethal concentration values for different insecticides to the spiders *O. javanus* and *P. viridana* showed that acephate was the safest chemicals followed by chlorpyriphos whereas the other three chemicals monocrotophos, quinalphos and endosulfan were proved to be toxic.

The safety of acephate and chlopyriphos as well as the toxicity of monocrotophos for the spider *O. javanus* was previously reported by Ganesh Kumar (1994).

The present studies were focused on identification, sampling and predatory potential of spiders and impact of cultural practices and insecticides, on spiders. Even though the investigations have proved spiders as potential predators on cotton pests, this area was not exploited so far hence the future research can be concentrated on

1. Development of appropriate mass culturing techniques for field release of spiders.
2. Studies on conservation of spiders at field level can be carried out, since they are sensitive to some cultural practices.
3. Interactions with other natural enemies should be studied as they are generalist predators.
4. Studies on impact of other pesticides such as herbicides and fungicides can be carried out.



SUMMARY

CHAPTER VI

SUMMARY

Investigations on identification of the spider species existing in cotton ecosystem, host range, their abundance and seasonal influence, standardisation of an effective sampling technique, predatory potential, prey preferences, impact of cultural practices and relative toxicity of various insecticides to spiders revealed the following.

- * The survey conducted in 4 directions of Coimbatore yielded in 24 species of spiders from cotton fields and border weeds of Coimbatore, 19 from Annur, 19 from Alanthurai and 13 from Kinathukadavu. The species richness in all the places was more in cultivated fields than that of the border weeds.
- * Of the different spiders, the spiders under genera *Argiope*, *Bianor*, *Leucauge*, *Neoscona*, *Oxyopes*, *Pardosa*, *Peucetia*, *Salticus*, *Tetragnatha* and *Thomisus* were observed in almost all the places.
- * The survey revealed the occurrence of *Araneus* sp., *Argiope* sp., *Clubiona drassodes*, *Clubiona viridanus*, *Cryptophora citricola*, *Gasteracantha unguifera*, *Leucauge decorata*, *Leucauge* sp., *Neoscona ellipitica*, *Neoscona* sp., *Olios* sp., *Oxyopes javanus*, *Oxyopes rufisternum*, *Pardosa* spp., *Pardosa pseudoannulata*, *Peucetia viridana*, *Plexipus paykulli*, *Salticus* sp., *Tetragnatha* sp., *Thomisus pugilis*, *Vicaria preymandibularis* and *Vicaria monostriata* which are being reported for the first time from cotton ecosystem of Tamil Nadu, India.
- * The host range of the identified spiders includes homopterans, hemipterans, lepidopterans, dipterans, coleopterans, hymenopterans and some other predatory insects.

- * The spider population was not influenced by the fluctuations of pest and other predatory population. Whereas the weather factors like minimum temperature and evening relative humidity were observed to have an impact.
- * Studies on seasonal incidence of spiders indicated that the population density of the spiders increases as the crop stage advances.
- * Among the four sampling techniques tested, the whole plant sampling technique was the most efficient one for the collection of spiders followed by pitfall trapping and net sweeping.
- * The predatory potential studies on spiders revealed that as the stage of spider advanced, the consumption rate also increased for all the spiders. The sucking pests were consumed by all the instars whereas caterpillars were fed only by late instar and adult spiders.
- * All the hunting spiders preferred the prey insects in the order of leafhoppers > aphids > whiteflies > where as web spiders preferred the prey insects in the order of leafhoppers > whiteflies > aphids.
- * The interpredation studies of spiders revealed that hunting spiders will feed on young ones of other spiders.
- * The cross predation studies indicated that the spiders were capable of feeding on *Chrysoperla* grubs whereas the *Chrysoperla* grubs were feeding on spider egg masses.
- * Among the cultural practices, variety, wider spacing and lower fertilizer levels were found to have influence on the spider population density per plant.

- * Persistent toxicity studies showed that monocrotophos, methyl demeton were toxic to spiders, chlorpyrifos and imidacloprid were proved to be safe, whereas *B.t.* and neem were safer among all.
- * Quinalphos and monocrotophos caused maximum mortality of spiders due to residual toxicity followed by other chemicals when different prey insects were offered. *B.t.* and neem oil were showing least residual effect on spiders.
- * The predation rate of the spiders was affected to a maximum extent when treated with monocrotophos and quinalphos, whereas *B.t.* and neem oil were having negligible effect.



REFERENCES

REFERENCES

- Abbot, W.S. 1925. Method for computing the effectiveness of an insecticide. *J. Econ. Entomol.*, **18**: 265-267.
- Agnew, C.W. and J.W. Smith. 1989. Ecology of spiders (Araneae) in a peanut agro ecosystem. *Eviron. Entomol.*, **18**(1): 30-42.
- Alderweireldt, M. 1994. Habitat manipulations increasing spider densities in agro ecosystems. Possibilities for biological control. *J. Appl. Ent.*, **118**: 10-16.
- Anderson, J.F. 1974. Responses to starvation in the spiders *Lycosa lenta* (Henz) and *Filistata hibernalis* (Henz). *Ecology*, **55**: 341-576.
- Baldev Parashad. 1985. Significance of spiders in relation to Agriculture. In "Non insect pests and predators" pp 40-49 (Eds.) R.H. Bhanotar, Shashiverma, S.I. Farooqi. All India Scientific Writers Society, Pashum Vihar. New Delhi.
- *Barberi, R. 1997. New strategies of defence against *Lobesia botrana*. *Informatore - Agrario*, **53**(25): 71-74.
- Barbour, J.D. and R.L. Brandenberg. 1995. Impact of type and timing of southern corn root worm treatments on predaceous arthropods in pea nut. *J. Entomol. Sci.*, **30**: 447-462.
- Barnes, B.M. and R.D. Barnes. 1954. The ecology of the spiders of maritime drift lines. *Ecology*, **35**: 25-35.
- Barnes, R.D. and B.M. Barnes. 1955. The spider population of the abstract broomsedge community of the south western piedmont. *Ecology*, **36**: 658-666.
- *Barrion, A.T. and J.A. Litsinger. 1981. The spider fauna of Philippine dry land and wet land rice agro ecosystem. IRRI Saturday seminar. April, 4 1981 Los Banos, Philippines, 32 p.
- Bayot, R.G., B.F. Cayabyab, E.A. Benigno, M.W. Ebuenga and E.P. Penalba. 1990. Monitoring populations of the brown planthopper, *Nilaparvata lugens* (Stal), the green leafhopper, *Nephotettix virescens* (Distant) and spiders in rice at maquiapo, Guagua, Pampanga. *Philipp. Ent.*, **8**(2): 779-786.

Bilising, S.W. 1920. Quantitative studies in the food of spiders *Ohio. J. Sci.*, **20**: 215-260.

Bishop, L. and S.E. Riechert. 1990. Spider colonization of agro ecosystems mode and source. *Environ. Entomol.*, **19**(6): 1738-1745.

*Bonnet, P. 1960. La mue. L'automie regeneration chez les araignees avec une etude des Dolomedes d' Europe. *Bull. Soc. Hist. Nat. Toulouse*, **81**: 185-250.

Braman, S.K. and A.F. Pandley. 1993. Relative and seasonal abundance of beneficial arthropods in centipede grass as influenced by management practices. *J. Econ. Entomol.*, **86**(2): 494-504.

Breene, R.G. 1991. Effects of an arsenical herbicide on beneficial arthropods on Texas cotton. Progress Report - Texas Agricultural Experiment Station. No. PR. 4816. 4p.

Breene, R.G., A.W. Hartstack, W.L. Sterling and M. Nyffeler. 1989. Natural control of the cotton fleahopper *Pseudatomoniscelis seriatus* (Reuter) (Hemiptera : Miridae), in Texase. *J. Appl. Ent.*, **108**: 298-305.

Breene, R.G., W.L. Sterling and D.A. Dean. 1988. Predators of the cotton fleahopper on cotton.(Hemiptera : Miridae) *South West Entomol.*, **14**: 159-166.

Breene, R.G., W.L. Sterling and M. Nyffeler. 1990. Efficacy of spider and ant predators on the cotton fleahopper (Hemiptera : Miridae). *Entomophaga*, **35**: 393-401.

Chamberlin, R.V. and W. Ivie. 1945. On some Nearctic mygalomorph spiders. *Ann. Entomol. Soc. Am.*, **38**: 549-558.

Chant, D.A. 1956. Predaceous spiders in orchards in South Eastern England. *J. Hort. Sci.*, **31**: 35-46.

Chen, B.H. and S.C. Chiu. 1979. The annual occurrence of *Lycosa* and *Oedothorax* and their response to insecticides. *J. Agric. Res. China*, **28**: 285-290.

Cherret, J.M. 1964. The distribution of spiders on the moor House Nature Reserve, West Morland. *J. Anim. Ecol.*, **35**: 27-28.

- Chiu, S.C. and S.J. Cheng. 1976. Toxicity of some insecticides commonly used for rice insect control to the predators of rice hoppers. *Plant Prot. Bull.* (Taiwan), **18**: 254-260.
- Chiu, S.C., Y.I. Chu and Y.H. Long. 1974. The life history and some bionomic notes on a spider *Oedothorax insecticeps* Boes, (Micryphantidae : Araneae). *Plant Prot. Bull., Taiwan*, **16**: 153-161.
- *Choudary, M.M.A. and S. Alam. 1979. Effects of diazinon spray on rice pests and their natural enemies. *Bangladesh J. Zool.*, **7**: 15-20.
- Clark, E.W. and P.A. Glick. 1961. Some predators and scavengers feeding upon pink bollworm moths. *J. Econ. Entomol.*, **54**(4): 815-816.
- *Coddington, J.A., S.F. Larcher and J.C. Cokendolpher. 1990. The systematic status of Arachnida, exclusive of Acarina, in North America North of Mexico (Arachnida : Amblypygi, Araneae, Opiliones, Palpigradi, Pseudoscorpiones, Solifugae, Uropygi). In : Diversity and Dynamics of North American Insect and Arachnid Fauna, eds. M. Koztarab, C.W. Schaeffer, pp. 5-20. Va polytech. Inst. Blackburg, Virginia.
- Cole, J.F., E.D. Pilling, R. Boykin and J.R. Ruberson. 1997. Effects of Karate R insecticide on beneficial arthropods in Bollgard R cotton. *Proceedings Beltwide cotton conference*, New Orleans. LA, USA, January 6-10, 1997: 1118-1120.
- Collatz, K.G. and T. Mommsch. 1975. Physiological conditions and variations of body constituents during the moulting cycle of the spiders. *Tegnaria atrica* (Agelidae) *Comp. Biochem. Physiol.*, (A), **52**: 465-476.
- Coppel, H.C. 1960. Empty cocoons of the introduced sawfly *Diprion similis* as habitat niches for arthropods. *Ann. Entomol. Soc. Am.*, **53**: 847-848.
- Costello, M.J. and K.M. Daane. 1997. Comparison of sampling methods used to estimate spider (Araneae) species abundance and composition in grape vineyards. *Environ. Entomol.*, **26**(2): 142-149.
- Costello, M.J. and K.M. Daane. 1998. Influence of ground cover on spider populations in a table grape vineyard. *Ecological Entomology*, **23**: 33-40.

Coung, N.L., P.T. Ben, L.T. Phoung, L.M. Chau and M.B. Cohen. 1997. Effect of host plant resistance and insecticide on brown planthopper *Nilaparvata lugens* (Stal.) and predator population development in the Mekong Delta, Vietnam. *Crop Protection*, 6(8): 707.

Culin, J.D. and Yeargan, K.V. 1983. The effects of selected insecticides on spiders in Alfalfa. *J. Kans. Entomol. Soc.*, 52(2): 151-158.

Curtis, J.E. and P.A. Horne. 1995. Effect of chlorpyrifos and cypermethrin applications on non-target invertebrates in a conservation - tillage crop. *J. Aust. Entomol. Soc.*, 34(3): 229-231.

*Dabrowska Port, E., J. Luczack and K. Tarwind. 1968. The predation of spiders on forest mosquitoes in field experiment. *J. Med. Entomol.*, 5: 252-256.

Dash, A.N., B. Senapathi and P.R. Mishra. 1996. Efficacy of neem derivatives in combination with synthetic insecticides against population of brown and white backed planthoppers and their natural enemies in rice. *J. Insect. Sci.*, 9: 137-142.

Dean, D.A., W.L. Sterling and N.V. Horner. 1982. Spiders in eastern Texas cotton fields. *J. Arachnol.*, 10: 251-260.

Dean, D.A., W.L. Sterling, M. Nyffeler and R.G. Breene. 1987. Foraging by selected spider predators on cotton fleahopper and other prey. *South West Entomol.*, 12: 263-270.

*Deevey, G.B. 1949. The developmental history of *Latrodectus mactans* (Fabr.) at different rates of feeding. *Amer. Midl. Nat.*, 42: 189-219.

Dekeer, R., M. Alderweireldt, K. Dechleer, H. Segers, K. Desender and J.P. Maelfait. 1989. Horizontal distribution of the spider fauna of intensive grazed pastures under the influence of diurnal activity and grass height. *J. Appl. Ent.*, 107: 455-473.

Dhulia, F.K. and D.N. Yadav. 1991. Occurrence of some predatory spiders on hybrid cotton in Anand (Gujarat). *J. Biol. Control*, 5(1): 48-49.

*Dietz, L.L., J.W. Vanduyne, J.R. Bradley, R.L. Rabb, W.M. Brooks, and R.E. Stinner. 1976. A guide to the identification and biology of soybean arthropods in North Carolina. Tech. Bull. North. Carolina Agric. Exp. Stn. No. 238.

- Dinter, A. 1998. Intraguild predation between erigonid spiders, lacewing larvae and carabids. *J. Appl. Ent.*, **122**: 163-167.
- Dinter, A. and H.M. Poehling. 1992. Spider populations in winter wheat fields and the side - effects of insecticides. *Aspects of Applied Biology*, **31**: 77-85.
- Dorris, P.F. 1969. Spiders collected from mud dauber nests in Mississippi. *J. Kans. Entomol. Soc.*, **1**: 10-11.
- *Duffy, E. 1968. An ecological survey of the spider fauna of sand dunes. *J. Anim. Ecol.*, **37**: 641-674.
- Duncan, D.B. 1951. A significance test for difference between ranked treatments in an analysis of variance. *Va. J. Sci.*, **2**: 171-189.
- Easterbrook, M.A. 1997. A field assessment of the effects of insecticides on the beneficial fauna of strawberry. *Crop Protection*, **16**(2): 147-152.
- Easterbrook, M.A. 1998. The beneficial fauna of strawberry fields in South - East England. *J. Hort. Sci. Biotech.*, **73**: 137-144.
- *Edwards, C.A., C.G. Bultler and T.R. Lofty. 1976. The invertebrate fauna of the park grass plots ii. surface fauna. Rep. *Rothamst. Exp. Stn.* Part 2: 63-89.
- Everts, J.W. 1990. Sensitive indicators of side effects of pesticides on the epical fauna of arableland-Doctoraastv., Landbow Univ., Wageningen.
- Fabellar, C.T. and E.A. Heinrichs. 1984. Toxicity of insecticides to predators of rice brown planthoppers, *Nilaparvata lugens* (Stal.) (Homoptera : Delphacidae). *Environ. Entomol.*, **13**: 832-837.
- Ferrer, E.R. and B.M. Shephard. 1988. Sampling methods for estimating population densities of planthoppers and predators in direct - seeded and transplanted rice. *J. Agric. Entomol.*, **5**: 199-204.
- Finney, D.J. 1962. Probit Analysis : A statistical Treatment of the Sigmoid Response Curve. Cambridge University Press, London. 318p.
- Forster, R.R. 1967. The spider of New Zealand. Part 1, *Otago Mus. Bull.*, **1**: 1-124.
- Ganesh Kumar, M. 1994. Prey predatory interactions in the rice ecosystem with special reference to spiders. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore, 204p.

- Ganesh Kumar, M. and R. Velusamy. 1996. Safety of insecticides to spiders in rice fields. *Madras Agric. J.*, **83**(6): 371-375.
- Gardner, B.T. 1965. Observations on three species of *Phidippus* jumping spiders (Araneae : Salticidae). *Psyche*, **72**: 133-147.
- Gluck, E. and S. Ingrisch. 1990. The effect of biodynamic and conventional agriculture management on erigoninae and lycosidae spiders. *J. Appl. Entomol.*, **110**: 136-148.
- Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for Agricultural Research. John Wiley and Sons, New York. 680 p.
- Gravena, S. and H.F. Da Cunha. 1991. Predation of cotton leafworm first instar larvae, *Alabama argillaceae* (Lep : Noctuidae). *Entomophaga*, **36**(4): 481-491.
- Gravena, S. and W.L. Sterling. 1983. Natural predation on the cotton leafworm (Lepidoptera : Noctuidae). *J. Econ. Entomol.*, **76**: 779-784.
- *Gravesen, E. and S. Toft. 1987. Grass fields as reservoirs for polyphagous predators (Arthropoda) of aphids (Homopt: Aphididae). *Z. Angew. Entomol.*, **104**: 461-473.
- Greenstone, M.H. 1978. Numerical response to prey availability of *Pardosa ramulosa* (Mc cook) (Araneae : Lycosidae) and its relationship to the role of spiders in the balance of nature symp. *Zool. Soc. Lond.*, **42**: 183-193.
- Greenstone, M.H. 1982. Ballooning frequency and habitat predictability in two wolf spider species. *The Florida Entomologist*, **65**: 83-89.
- Guifen, Z., L.V. Chuantao, G.F. Zhang and C.T. Lu. 1996. Trials on control of planthoppers with imidacloprid in fields. *Plant Protection*, **22**(2): 48-49.
- Guillebeau, L.P. and J.N. All. 1989. *Geocoris* sp. (Hemiptera : Lygaeidae) and the striped lynx spider (Araneae : Oxyopidae): cross predation and prey preferences. *J. Econ. Entomol.*, **82**(4): 1106-1110.
- Gupta, M., P. Rao and A.D. Pawar. 1986. Survey of the predatory spider fauna from rice agro ecosystem. *Indian J. Plant Prot.*, **14**(2): 19-21.

- Hatley, C.L. and J.A. Macmahon. 1980. Spider community organization. Seasonal variation and the role of vegetation architecture. *Environ. Entomol.*, **9**: 632-639.
- Heneidy, A.H. and B. Sekamate. 1996. Comparative population densities of certain predatory species in two cotton field ecosystems in Uganda. *Ann. Agril. Sci.*, **34**(3): 1189-1199.
- Hengmoss, T., F. Baxendale and T. Riordan. 1998. Beneficial arthropods associated with buffalograss. *J. Econ. Entomol.*, **91**(5): 1167-1172.
- Horner, N.V. 1972. *Metaphidippus galathea* as a possible biological control agent. *J. Kans. Ent. Soc.*, **45**: 324-327.
- Howell, J.O. and R.L. Pienkowski. 1971. Spider populations in alfalfa, with notes on spider prey and effect of harvest. *J. Econ. Entomol.*, **64**: 163-168.
- Jackson, R.R. 1977. Prey of the jumping spider *Phidippus johnsoni* (Araneae : salticidae). *J. Arachnol.*, **5**: 145-149.
- Jenings, D.T. and M.W. House weart. 1978. Spider preys on spruce budworm egg mass. *Entomol. News*, **89**: 183-186.
- Jones, S.E. 1941. Influence of temperature and humidity on the life of the spider *Agelena naevia* Walckner. *Ann. Entomol. Soc. Am.*, **34**: 557-571.
- Judd, W.W. 1970. Invertebrates from an abandoned muskrat house at London, Ontario. *Can. J. Zool.*, **48**: 402-403.
- Kamal, N.Q., A. Begum and V. Biswas. 1992. Studies on the abundance of spiders in rice ecosystem. *J. Insect. Sci.*, **5**(1): 30-32.
- Kareem, A.A., M.E.M. Boncodin and R.C. Saxena. 1988a. Neem seed kernel or neem cake powder and carbofuran granule mixture for controlling green leafhopper (GLH), and rice tungro virus (RTV). *IRRN.*, **13**(3): 35.
- Kareem, A.A., R.C. Saxena and E.L. Palanginan. 1988b. Effect of neem seed bitters (NSB) and neem seed kernel extract (NSKE) on the pests of mung bean following rice. *IRRN.*, **13**(6): 41-42.
- Kareem, A.A., R.C. Saxena and R.T. Malayba. 1988c. Effect of sequential neem treatment on green leafhopper (GLH) rice tungro virus (RTV) and predatory mirids and spiders in rice. *IRRN.*, **13**(6): 37.

- *Kaston, B.J. 1978. How to know the spiders. M.C. Brown, Dubuque, Iowa: 272 p. 3rd ed.
- *Kaston, B.J. 1981. Spiders of Connecticut. *Bull. Conn. Geol. Nat. Hist. Surv.*, 70: 1-1020.
- *Kessler, A., J. Vermeulen and W.C. Wapenaar, 1984. Partitioning of the space in tussocks of the sedge, carex distance during winter, by a spider community, *J. Zool. London*, 202: 259-269.
- Kiritani, K. and S. Kawahara. 1973. Food chain toxicity of granular formulations of insecticides to a predator *Lycosa pseudoannulata* of *Nephotettix cincticeps*. *Botyukagaku*, 38: 69-75.
- Kushakul, V., R. Pattarasudhi and P.H. Patirupanusorn. 1979. Effect of granular insecticides on stem borers and their parasites and predators. *IRRN.*, 4: 16-17.
- Leigh, T.F. and R.E. Hunter. 1969. Predaceous spiders in California cotton. *Calif. Agric.*, 23: 4-5.
- Lengwiler, V. and G. Benz. 1994. Effects of selected pesticides on web building behaviour of *Larinioides scolopetarius* (Clerck) (Araneae : Araneidae). *J. Appl. Ent.*, 117: 99-108.
- Levi, H.W. 1981. The American orb-weaver genera *Dolichognatha* and *Tetragnatha* (Araneae : Araneidae, Tetragnathinae). *Bull. Mus. Comp. Zool.*, 149: 271-318.
- Levi, H.W. 1983. The orb-weaver genera *Argiope*, *Gea* and *Neogea* from the Western Pacific region (Araneae ; *Argiopinae*, *Araneidae*). *Bull. Mus. Comp. Zool.*, 150(5): 247-338.
- *Levi, H.W. 1991. The neotropical and Mexican species of the orb-weaver genera *Araneus*, *Dubiepieira* and *Aculepeira* (Araneae : Araneidae). *Bull. Mus. Comp. Zool.*, 152(5): 167-315.
- *Lewis, W.J. , P.B. Haney and S. Phatak. 1996. Continued studies of insect population dynamics in crimson clover and refugia cotton systems Part I: Sweep and Whole plant sampling. 1996. *Proceedings of Beltwide cotton conferences*, Nashville, TN. USA. January 9-12, 2, 1108-1114.

- Lixin, M. and T. Liang. 1995. An evaluation of the effect of imidacloprid on rice planthopper and its natural enemies. *Plant Protection*, **21**: 42-44.
- Lockley, T.C., J.W. Smith, W.P. Scott and C.R. Parencia. 1981. Relationship of populations of striped lynx spider, *Oxyopes salticus* Hentz., and *Heliothis* species larvae in selected cotton fields. *Amer. Arach.*, **23**: 13.
- Lowries, D.C. 1948. The ecological succession of spiders of the Chicago area dunes. *Ecology*, **29**: 334-351.
- *Malt, S.F.W., Sander and G. Schaller. 1990. Contribution to the feeding ecology of selected Araneidae in Xerophil grass lands with particular reference to *Argiope brunnichii* (Scop) *Zoologische jahrbucher abteilung fur systematik, Okologie Und Geographie der Tiere*, **117**: 237-260.
- Mangan, R.L. and R.A. Byers. 1989. Effects of minimum tillage practices on spider activity in old field swards. *Environ. Entomol.*, **18**(6): 945-952.
- Mansour, F., D. Rosen and A. Shulov. 1980. Biology of the spider *Chiracanthium mildei* (Arachnida : Clubionidae). *Entomophaga*, **25**(3): 237-248.
- Mansour, F.U. Heimbach and A. Wehling. 1992. Effects of pesticide residues on ground dwelling lycosid and micryphantid in laboratory tests. *Phytoparasitica.*, **20**(3): 195-202.
- Mc Carty, M.J., M. Shepard and S.G. Turnipseed. 1980. Identification of predaceous arthropods in soybeans by using autoradiography. *Environ. Entomol.*, **9**: 199-203.
- Mc Daniel, S.G. and W.L. Sterling. 1982. Predation of *Heliothis virescens* (F.) eggs on cotton in East Texas. *Environ. Entomol.*, **11**: 60-66.
- Mc Daniel, S.G., W.L. Sterling and D.A. Dean. 1981. Predators of tobacco budworm larvae in Texas cotton. *Southwest Ent.*, **6**:102-108.
- Mitter, C., B. Farrel and B. Weigmann. 1988. The phylogenetic study of adaptive zone; has phytophagy promoted insect diversification? *Am. Nat.*, **132**(1): 107-28.
- Morril, W.L. 1975. Plastic pitfall trap. *Environ. Entomol.*, **4**: 596.

- *Moulder, B.C. and D.E. Reichle. 1972. Significance of spider predation in the energy dynamics of forest - floor arthropod communities. *Ecol. Monogr.*, **42**: 473-493.
- Muralidharan, C.M. and M.S. Chari. 1992. Spider fauna active in cotton fields at Anand. *Gujarat Plant. Prot. Bullt. Faridabad*, **44**(3): 26-27.
- Murray and R.J. Lloyd. 1997. The effect of spinosad (Tracer) on arthropod pest and beneficial populations in Australian cotton. *Proceedings of Beltwide cotton conferences*, New Orleans, LA., USA, Jan. 6-10, 2: 1087-1091.
- Muthukrishnan, N. and M. Balasubramanian. 1995. Rope dispenser form of gossypure and insecticides on predators in cotton ecosystem. *Madras Agric. J.*, **82**(2): 87-89.
- Myint, M.M., H.R. Rapusas and E.A. Heinrichs. 1986. Integration of varietal resistance and predation for the management of *Nephotettix virescens* (Homoptera : Cicadellidae) population on rice. *Crop Prot.*, **5**: 259-265.
- Nagata, K., G. Shinjo, H. Okuda and M. Yoshida. 1997. Efficacy of several insecticides to red back widow spiders *Latrodectus hasseltii* collected in Osaka and Mie Pre fectures, Japan. *Medical Entomology and Zoology*, **48**(2): 135-139.
- *Namakura, K. 1972. The ingestion in wolf spiders. II. the expression of degree of hunger and the amount of ingestion in relation to spiders hunger. *Popul. Ecol. Kyto. Uni.*, **14**: 82-96.
- Nentwig, W. 1987. The prey of spiders. Pp. 249-263. In: *Ecophysiology of spiders* Ed. by W. Netwig springer, Berlin.
- Nentwig, W. 1988. Augmentation of beneficial arthropods by strip-management 1. Succession of predaceous arthropods and long term changes in the ratio of phytophagous to predaceous arthropods in a meadow. *Oecologia*, **76**: 567-606.
- Nirmala, R. 1990. Studies on predatory spiders of rice pests. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore. 183p.
- Nuessley, G.S. 1986. Mortality of *Heliothis zea* eggs, affected by predator species, oviposition sites and rain and wind dislodgement. Ph.D. diss., Texas A & M Univ., College station.

- *Nyffeler, M. 1982. The ecological importance of spiders in forest ecosystem, a literature review. *Anz., Schaedlingskd pflanzenschutz umweltschutz*, **55**: 134-137.
- *Nyffeler, M. 1983. Eine Notiz Zur Okologischen Bedeutung der Radnetzspinnen all. Blattlaus pradatoren in Garten. *Mitt. Schweiz. Ent. Ges.*, **56**: 200.
- *Nyffeler, M. and G. Benz. 1981. Field studies on the feeding ecology of spiders. Observations in the region on Zurich (Switzerland) *Anz., Schaedlingskd pflanzenschutz umweltschutz*, **54**: 33-39.
- Nyffeler, M. and G. Benz. 1987. Spiders in natural pest control. A review. *J. Appl. Ent.*, **103**: 321-339.
- Nyffeler, M., D.A. Dean and W.L. Sterling. 1986. Feeding habits of the spider *Cyclosa turbinata* (Walckenaer) and *Lycosa rabiata* walckenaer. *South west Entoml.*, **11**: 195-201.
- Nyffeler, M., D.A. Dean and W.L. Sterling. 1987. Evaluation of the importance of the striped lynx spider, as a predator in Texas Cotton. *Environ. Entomol.*, **16**(5): 1114-1123.
- Nyffeler, M., D.A. Dean and W.L. Sterling. 1987a. Predation by Green lynx spider *Peucetia viridans* (Araneae : Oxyopidae) inhabiting cotton and wooly croton plants in East Texas. *Environ. Entomol.*, **16**(1): 355-359.
- Nyffeler, M., D.A. Dean and W.L. Sterling. 1992. Diets, feeding specialization and predatory role of two lynx spiders *Oxyopes salticus* and *Peucetia viridans* (Araneae : Oxyopidae) in a Texas cotton agroecosystem. *Environ. Entomol.*, **21**(6): 1457-1465.
- Nyffeler, M., R.G. Breene. 1990. Evidence of low daily food consumption by wolf spiders in meadow land and comparison with other curosial hunters. *J. Appl. Ent.*, **110**: 73-81.
- Nyffeler, M., R.G. Breene and D.A. Dean. 1990. Spiders as predators of arthropod eggs. *J. Appl. Ent.*, **109**: 490-501.
- Nyffeler, M., W.L. Sterling and D.A. Dean 1994. How spiders make a living. *Environ. Entomol.*, **23**(6): 1357-1367.
- Nyffeler, M., W.L. Sterling and D.A. Dean. 1994. Insectivorous activities of spiders in United States field crops. *J. Appl. Ent.*, **118**: 113-128.

Palanichamy, S. 1980. Ecophysiological studies on a chosen spider *Crytophora cicatrosa* (Araneae : Araneidae) Ph.D. Thesis, Madurai Kamaraj University, Madurai. 137p.

Palanichamy, S. 1983. Influence of spatial heterogeneity and prey density on predatory behaviour of the tropical spiders *Crytophora cicatrosa* (Stoliczka) and *Marpissa calcutaensis* (Tikader) (Araneae : Araneidae) *Proc. Indian. Acad. Sci. (Anim, Sci)* **92**: 369-374.

*Parker, S.P. ed. 1982. Synopsis and classification of living organisms vol. 2.. Mc. Graw. Hill. New York.

Pasquet, A. and R. Leborgne. 1990. Prey capture efficiency and prey selection from insects intercepted by trap in four orb-weaving spider species. *Acta Oecologia*, **11**: 512-513.

Peck, W.B. and W.H. Whitcomb. 1968. Feeding spiders on artificial diet. *Entomol. News.*, **79**: 233-236.

Peck, W.B. and W.H. Whitcomb. 1970. Studies on the biology of a spider, *Chiracanthium inculsum* (Hentz), *Bull. Ark. Exp. Stn.*, **753**: 1-76.

Pekar, S., J. Kazda and K. Veverka. 1997. Effect of an organophosphate insecticide combined with a liquid fertilizer (VAN) on some pests (Aphidoidea : Chrysomelidae) and beneficial arthropods (Araneae : Opiliones) in winter wheat stands. *Scientia Agriculture Bohemica*, **28**(4): 271-281.

Pekar, S. and P.A.Seldon. 1998. Effect of selective insecticides on beneficial spider community of pear orchard in the Czech Republic. Proceedings of the 17th European Colloquim of arachnology, Edinburgh, 337-342.

Perfect, T.J., A.G. Cook and E.R. Ferrer. 1983. Populations sampling of planthoppers, leafhoppers (Hemiptera : Delphacidae and Cicadellidae) and their predators in flooded rice. *Bull. Ent., Res.*, **73**: 345-355.

Plagens, M.J. 1983. Populations of *Misumenops* (Araneida : Thomisidae) in two Arizona cotton fields. *Environ. Entomol.*, **12**(1): 572-575.

Platnik, N.I. 1989. Advances in spider Taxonomy, 1981-1987. Manchester, Univ. Press. Manchester, UK.

Pointing, P.J. 1965. Some factors influencing the orientation of the spider *Frontinella communis* (Hentz) in its web (Araneae : Linyphiidae). *Can Ent.*, **97**: 69-78.

- Punzo, F. 1997. Effects of azadirachtin on mortality, growth and immunological function in the wolf spider *Schizocosa episima* (Araneae : Lycosidae). *Bull. Environ. Contam. Toxicol.*, **58**(3): 415-421.
- Rajenderan, R. 1987. Studies on the predatory spiders in rice ecosystem. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore. 160p.
- *Raman, K. and S. Uthamasamy., 1983. Insecticide toxicity to natural brown planthopper enemies. *IRRN.*, **8**: 20.
- Ranjit Lal. 1995. In the spiders parlour. *The Hindu*, Sunday, March 5.
- *Rao, V.N., P. Israel and K.S. Behera. 1981. Spiders in rice fields and their egg parasitoids. *Int. Rice. Comm. Newsl.*, **35**: 40-42.
- Reguraman, S. and B. Rajasekaran. 1996. Effect of neem products on insect pests of rice and the predatory spider. *Madras Agric. J.*, **83**(8): 510-515.
- Reissing, W.H., E.A. Heinrichs and S.L. Valencia. 1982. Effects of insecticides on *Nilaparvata lugens* and its predators, spiders *Microvelia atrolineata* and *Cyrtorhinus lividipennis*. *Environ. Entomol.*, **11**: 193-199.
- *Richman, D.B., W.F. Buren and W.H. Whitcomb. 1983. Predatory arthropods attacking the eggs of *Diaprepes abbreviatus* L. (Coleoptera : Curculionidae) in Puerto Rico and Florida. *J. Ga. Entomol. Soc.*, **18**: 335-342.
- Riechert, S.E. and L. Bishop. 1990. Prey control by an assemblage of generalist predators. Spiders in garden tent systems. *Ecology*, **71**: 1441-50.
- Riechert, S.E. and T. Lockley. 1984. Spiders as biological control agents. *Ann. Rev. Entomol.*, **29**: 299-230.
- Roach, S.H. and A.R. Hopkins. 1981. Reduction in arthropod predator populations in cotton fields treated with insecticides for *Heliothis* spp. *J. Econ. Entomol.*, **74**: 454-457.
- Room, P.M. 1979. Parasites and Predators of *Heliothis* spp (Lepidoptera : Noctuidae) in cotton in the Namoi valley, New South Wales. *J. Aust. Entomol. Soc.*, **18**: 223-228.
- *Roth, V. 1985. Spider Genera of North America : Am. Arachnol. Soc., Gainesville, Fla 38p.

- Rovner, J.S. and S.J. Knost. 1974. Post immobilisation wrapping of prey by lycosid spiders of the herbaceous stratum. *Psyche.*, **81**: 398-415.
- Samiayyan, K. 1996. Spiders of South India. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore. 521p.
- Samu, F. and F. Vollarath. 1992. Spider orbweb bioassay for pesticide side effects. *Entomol. Exp. Appl.*, **62**: 117-124.
- Saxena, R.C., A.A. Kareem, E.L. Palaniginam and M.T. Malayba. 1989. Systemic and foliar application of neem seed bitters (NSB) to control green leafhopper (GLH) and rice tungro virus (RTV) disease. *IRRN.*, **14**: 31.
- *Saxena, R.C., P.B. Epino, Tucheng - Wen and B.C. Puma. 1983. Neem, chinaberry and custard apple; antifeedant and insecticidal effect of seed oils on leaf and planthopper pests of rice In : *Proc. 2nd International Neem Conference, Raviscbholzhausen.* pp. 403-412.
- *Schaefer, M. 1974. Experimental studies on the importance of interspecies competition between three wolf spider species (Araneida : Lycosidae) in a salt marsh. *Zool. Jb. Abt. Syst.*, **101**: 213-235.
- Schuster, M.F., M.J. Lukefahr and F.G. Maxwell. 1976. Impact of nectariless cotton on plant bugs and natural enemies. *J. Econ. Entomol.*, **69**: 400-402.
- *Sivasubramaniam, W., S.W. Wratten and A.J. Popay. 1995. Effects of insecticides on the abundance of arthropod predators in carrots in Canterbury, New Zealand. *Proceedings of the forty eight New Zealand Plant Protection Conference.* 302-307.
- *Skinner, R.B. 1974. The relative and seasonal abundance of spiders from the herb - shrub stratum of cotton fields and the influence of peripheral habitat on spiders populations. M.Sc. Thesis, Auburn Univ., Auburn, Alabama.
- Specht, H.B. and C.D. Dondale. 1960. Spider populations in New Jersey apple orchards. *J. Econ. Entomol.*, **53**: 810-814.
- Spiller, A.D. 1986. Interspecific competition between spiders and its relevance to biological control by general predators. *Environ. Entomol.*, **15**: 177-181.

- Stam, P.A., D.F. Clower, J.B. Graves and P.E. Schilling. 1977. Effects of certain herbicides on some insects and spiders found in Louisiana cotton fields. *J. Econ. Entomol.*, 17(3): 477-480.
- *Thang, M.H., O. Mochida and B.M. Rejesus. 1985. Selectivity of eight insecticides to the brown planthopper, *Nilaparvata lugens* (Stal) (Homoptera : Delphacidae) and its predator, the wolf spider *Lycosa pseudoannulata* Boes et strand (Araneae : Lycosidae). IRRI Saturday seminar, March 15, 1985, Los Banos, Philippines, 36 p.
- Thang, M.H., O. Mochida, B.M. Rejesus and R.P. Robles. 1987. Selectivity of eight insecticides to the brown planthopper *Nilaparvata lugens* (Stal) (Homoptera : Delphacidae) and its predator, the wolf spider, *Lycosa pseudoannulata* Boes et. Str. (Araneae : Lycosidae). *Philipp. Ent.*, 7(1): 51-66.
- Thomas, C.F.G. and J.W. Everts. 1990. Modelling the diffusion component of dispersal during recovery of a population of linyphiid spiders from exposure to an insecticide. *Functional Ecology*, 4(3): 357-368.
- *Tidaker, B.K. and A. Bal. 1981. Studies on some orb-weaving spiders of the genera *Neoscona* (Simon) and *Araneus clerek* of the family Araneidae (= Argiopidae) from India, *Rec. Zool. Surv. India. Occ. Pap.*, 24: 1-60.
- Tikader, B.K. 1960. On some new species of spider (Arachnida) of the family Thomisidae from India. *J. Bombay Nat. Hist. Soc.*, 57(1): 173-183.
- Tikader, B.K. 1962. Studies on some Indian spiders (Araneae : Arachnida). *J. Linn. Soc. London Zool.*, 44: 561-584.
- Tikader, B.K. 1963. Studies on interesting South Indian crab spiders (Family : Thomisidae). *Proc. Indian. Acad. Sci. Bangalore*, 58(5): 249-262.
- Tikader, B.K. 1965. On some new species of spiders of the family Thomisidae from India. *Proc. Indian. Acad. Sci., Bangalore*, 61(5): 277-289.
- Tikader, B.K. 1967. Studies on some salticidae spider from Sikkim Himalaya, India. *Proc. Ind. Acad. Sci.*, 66(4): 17-22.
- Tikader, B.K. 1969. Spider fauna of India : Catalogue and Bibliography. Part I. *J. Bombay nat. Hist., Soc.*, 66(1): 81-91.

- 17
- Tikader, B.K. 1970. Spider fauna of India : Catalogue and Bibliography. Part III. *Bombay nat. Hist. Soc.*, **67**(2): 212-221.
- Tikader, B.K. 1970. Spider fauna of Sikkim. *Rec. Zool. Surv. India*, **64**(1-4): 1-84.
- Tikader, B.K. 1977. Key to Indian spiders. *J. Bombay nat. Hist. Soc.*, **73**(2): 356-370.
- Tikader, B.K. 1980. The fauna of India : Araneae Vol I. Calcutta : Zoological Survey of India, 433 p.
- Tikader, B.K. 1982. The fauna of Indian Spiders : Araneae. Vol. I, II part I. family : Araneidae (= Argiopidae) and part 2. Family : Gnaphosidae. pp 536. Published by the Director. Zoological Survey of India, Calcutta 12.
- Tikader, B.K. 1987. Hand book of Indian spiders pub. The Director, Zoological Survey of India, Calcutta p 251.
- TNAU. 1992. Annual Report by DBT.
- Toft, S. and A.P. Jensen. 1998. No negative sublethal effects of two insecticides on prey capture and development of a spider. *Pesticide Science*, **52**(3): 223-228.
- Topping, C.J. and K.D. Sunderland. 1992. Limitations to the use of pitfall traps in ecological studies exemplified by a study of spiders in a field of winter wheat. *J. Appl. Ecol.*, **29**: 485-491.
- *Turnbull, A.L. 1960. The prey of the spider *Linyphia triangularis* (Clerck) (Araneidae, Linyphiidae). *Can. J. Zool.*, **44**: 557-583.
- Turnbull, A.L. 1962. Quantitative studies on the food of *Linyphia triangularis* Clerk (Araneae : Linyphiidae). *Can. Entomol.*, **94**: 110-124.
- Turnbull, A.L. and C.F. Nicholos. 1966. A quick trap for area sampling in grassland communities. *J. Econ. Entomol.*, **59**: 1100-1104.
- Turnbull, A.L. 1973. Ecology of the true spiders (Araneomorphae). *Ann. Rev. Entomol.*, **18**: 305-348.
- Utez, G.W. 1975. Temporal and spatial variation in species diversity of wandering spiders (Araneae) in deciduous forest litter. *Environ. Entomol.*, **4**: 719-24.
- *Van hook, R.I. 1971. Energy and nutrient dynamics of spider and arthropoeran populations in grassland ecosystem. *Ecol. Mongr.*, **41**: 1-26.

Vanden berg, A.M., A.S. Dippenaar and H.J. Schoonbee. 1990. The effect of two pesticides on spiders in South African cotton fields. *Phytophylactica*, 22(4): 435-441.

Vanden berg, H., K. Hassan and M. Marzuki. 1998. Evaluation of pesticide effects on arthropod predator populations in soybean in farmers fields. *Biocontrol Sci. and Tech.*, 8(1): 125-137.

Viestola, E.H. 1998. Effects of perennial grass strips on spiders (Araneae) in cereal fields and impact on pesticide side effects. *J. Appl. Ent.*, 122: 575-583.

Vijayalakshmi, K. and Preston Ahimaz. 1993. Spiders : An introduction. Madras Cre - A Publications. 112p.

*Volkmar, C. and A. Schutzel. 1997. Spider populations on a typical field site in central Germany and special influences of various plant protection intensities. *Archives of phytopathology and plant protection*, 30(6): 533-546.

*Volkmar, C. and T. Wetzel. 1993. Occurrence of insect pests and predatory spiders (Araneae) in cereal fields and the side effects on them of chemical pesticides. *Nachrichtenblatt - des - Deutschen - p flanzensehu - tzdicnstes.* 45: 233-239.

*Weideman, W.H. 1978. Uber die Bedeutung Von Insekten im Okosystem Laubwald. *Mitt. Dtsch. Ges. Allg. Agnew. Ent.*, 1: 196-204.

Wheeler, A.G., 1973. Studies on the arthropod fauna of alfalfa. V. spiders (Aranidae). *Can. Ent.*, 105: 425-432.

Whitcomb, W.H., M. Exline and M. Hite. 1963. Comparison of spider populations of ground stratum in Arkansas pasture and adjacent cultivated field. *Arkansas Acad. Sci. Proc.*, 17: 1-6.

Whitford, F.W., B. Showers and G.B. Edwards. 1987. Insecticide tolerance of ground and foliage dwelling spiders (Araneae) in European corn borer. (Lepidoptera : Pyralidae) actionsites. *Environ. Entomol.*, 16: 779-785.

*Wise, D.H., 1993. Spiders in ecological webs. Cambridge Univ. Press, Cambridge, UK.

Young, O.P. 1989. Predation by *Pisaurina mira* (Araneae : Pisauridae) of *Lygus lineolaris* (Heteroptera : Miridae) and other arthropods. *J. Arachnol.*, **17**(1): 43-48.

Young, O.P. and G.B. Edwards. 1990. Spiders in United States field crops and their potential effect on crop pests. *J. Arachnol.*, **18**: 1-27.

*Zhao, X.M., J.C. Qi and R.P. Yan. 1989. Preliminary report on biological characters of *Pardosa astrigera* (Araneae : Lycosidae) and its use in the control of cotton aphid. *Natural Enemies of Insects*, **3**: 110-115.

* Originals not seen

