CHAPTER 2

REVIEW OF LITERATURE

The work on natural enemies especially spiders have gained considerable attention recently. Since spiders are numerically abundant and the diversity of the spiders in agroecosystems is higher than any of the parasitoids found in the field. The habitat occupied by the spiders is also diverse, in that some of the spiders are found in the lower strata (ground) while the others are found in the aerial parts of the plant. The mode of the attack of the spiders on the feeding of the insect prey is also varied; some of the spiders build webs for capturing the prey while others actively hunt for the prey. Due the above mentioned characteristics spiders are considered to be an important component of the biological control of the insect pests.

The history of the arachonological studies in India started with the late 19th century with the pioneering work of the taxonomists like Blackwall (1864 , 1867), Stolickza (1869) , Thorell (1877) , Cambridge (1892 , 1897) ; Simon (1897 a, b) ; Pocock (1895, 1900a b, 1901) and Sheriff (1919, 1927, 1928). The first seventy years of the work was undertaken on the preserved specimens and it was Graveyly (1915, 1921 a,b , 1922,1931,1935 a,b) who was the first in India to study spiders in Wild. At the same time Narayan (1915) from St John College Agra described 7 species of spiders. Dayal (1935) described another 45 species of spiders from Lahore.

The major contributors to the Indian Arachnology were made by Pocock and Tikader for bringing to the notice of spider studies to the spider researchers in India. Pocock described 112 species from India (1895, 1900, and 1901). He described 37 new species of spiders belonging to Mygalomorphae to which Graveyly added another 15 new species. Tikader streamlined and popularized the studies in India. Tikader (1987) published the first comprehensive account of the spiders which included 1067 species of spiders from 249 genera and 43 families. Platnick (2005) described over 39000 species of spiders from 3600 genera and 110 families.

The history of the arachonological studies in the rest of the world mainly was restricted to the Chinese some 4000 years back when they identified the importance of the spiders in the paddy field. They also devised ways to conserve them in the field. In the 20th century the work on spiders was mainly concentrated in the United States, Kaston (1978) gave an illustrated account of the spiders of United States. The work on spiders in West European countries and Asian countries like Japan and Korea were also working on spiders. In the Western Europe Germany was the country which realized the importance of the spiders very early and the work till this date in Germany is higher than the other European countries. The studied on spiders till 1980s were mainly towards taxonomic identification and documentation of the spiders in various agroecosystems. It was in the late 1980s that the work on spider biology and ecology received much recognisition with the work of

Richert and Lockley (1984). Today the work on spiders in the world is being carried out in various parts of the world. In Japan (Kiritani,1972 , 1975 ; Sasaba , 1972 ,1973; and Kenmore et al 1984); Korea(Heong et al 1991), Philippines (Sigsgaard,2000; Barrion and Litsinger,1995 ; Barrrion et al ,1999) and China the population dynamics and the behavioural ecology spiders in various ecosystems have been worked out with respect to the implication in biological control of the insect pests. Sigsgaard (2000) had worked on the population dynamics of the Lycoids in the paddy agroecosystem. Kiritani et al (1972) have shown that spiders have a significant impact on the leaf hopper densities in Paddy. Okuma et al (1978) have shown similar results in Korea; Barrion et al (1999), Schoenly et al (1998), Pimentel et al (1992), showed that diversity of the spiders to be very high and was comparable to several of the natural ecosystems. Work on spiders in Israel has been carried out by Mansour and his co workers in, Citrus orchards and Cotton agroecosystems. In Europe the work on spiders has been done on the Winter wheat fields by Nyffeler and Benz (1987), Dean et al (1987) ; Dinter (2002), Nentwig (1980). Cheverton (1986) found out the impact of beetles and spiders in Aphids in the Barley crop. Richert and Bishop (1990) provided insights into the impact of the spiders in the biological control of insect pests.

Extensive work on the cereal fields and in soybean agroecosystems have been carried out in United States by several workers notable among them are Sunderland et al (1987); Greenstone (1978) ; Richert and Lockley (1984) ;

Wise (1975) . Oraze and Grigarick (1989) have studied the paddy fields in California. During the 1985 – 2000, the workers in India were far behind in realizing the potential of spiders in biological control. The work on the spiders was mainly done in the Eastern India, and is mainly on the taxonomy of the spiders (Tikader 1980, 1982, 1987) and In the Western India (Patel, 1986; Siliwal, 2000). The prime focus was mainly on the taxonomy of the spiders found in various natural and agricultural habitats. The work pertaining to the spider ecology and its incorporation in the biological control of the insect pests was given focus.

The work was concentrated to the several selected pockets within South East Asia primarily focusing on spiders n Paddy Agroecosystem. In Israel spiders in Cotton agroecosystem and Citrus orchards have been studied extensively. European continent is focused in Winter Wheat crop (Harwood et al 2001) ; Apple orchards (Pekar, 1999 ; Bogya and Mols, 1996; Nentwig,1982 ; Nyffeler and Benz, 1987).In the Northern United states with the work primarily concentrated on Apple and Citrus orchards (Milickzy et al, 2000); Riparian Habitats (Rypstra et al, 1999) ; Wheat fields (Symondson et al, 2002) ; and Soybean (Culin and Yeargan,1983). In India 1442 species of spiders belonging to 361 genera and 59 families being identified (Siliwal, 2005). In the New era the focus on the community structure of the spiders incorporating the dynamics of spider assemblages; Biocontrol studies of spiders in Field and Laboratory have gained much focus. Agroecosystems offers as ideal model environment for understanding the interactions between the predator – prey interaction and also the factors influencing the spider assemblages. Agroecosystems provide a relatively uniform habitat, thus the factors influencing the assemblages can be deciphered with much ease as compared to the other natural ecosystems.

2.1 Work on Community structure of spiders in Agroecosystems and Orchards

The community structure of spiders in the Agricultural crops and Orchards have been worked out by several scientists in United States and Europe and there are ample evidences to show that spiders do have a significant impact on the insect pests' populations.

In Paddy agroecosystem Sigsgaard and Villareal (1999) have shown that *Atypena formosana* was efficient in reducing the population of Brown plant hopper and Green leaf hopper densities. Sebastian et al (2001) have shown that in the laboratory *Pardosa birmanica* which is a dominant spider in Cotton Agroecosystem feeds on a variety of insect pests like *Aphis craccivora, Amsacta biguttula, Tricentrous bicolour and Helicoverpa armigera* are known to be predated by *Pardosa birmanica.* Sebastian (2005) has shown that paddy fields of Central Kerala harbors a rich diversity of the spider fauna, 92 species of spiders belonging to 16 families have been reported. *Tetragnatha mandibulata* was the dominant spider in the paddy field and the web builders showed an overall dominance in terms of density and diversity in the paddy field.

There are other scattered reports on the spiders in the Maize crop in India. Singh et al (1975) have reported 7 families of spiders belonging to Oxyopidae, Clubionidae and Lycosidae being the dominant spiders. The members of the family Clubionidae, *Chieracanthium sp* and *Clubiona* sp have been reported as efficient predators of Maize stem borer. Sharma and Swarup (1979) have reported 10 species of spiders from 5 families, Oxyopidae, Lycosidae, Clubionidae, Araneidae and Salticidae from Maize crop. They reported that Endosulphan (1%) had no effect on the *Oxyopes pandae, Chieracanthium sp and Araneus sinhagdensis.* Siliwal (2000) has reported 52 species of spiders from 13 families in Pigeonpea, 82 species from 18 families in Banana and 48 species from 11 families in Cotton agroecosystems. The work on Broccoli agroecosystem by Hook and Johnson (2002) have shown that intercropping with non host food plants reduced the pest densities and promoted the assemblages of the natural enemies. They also showed that the Mulching the broccoli fields promoted the assemblages of spiders. Non arthropod predators have been shown to be an important component of the biological control of the insect pests in agricultural fields Hook and Johnson (2003).

The importance of the spiders in Orchards crops like Apple and Pear has been studied extensively by Milickzy and Calkins (2002), they reported 11 species of spiders (hunting spiders) feeding on the egg masses of Torticidae. The most effective predator of eggs was *Oxyopes sp* and *Chieracanthium inclusum* while *Chieracanthium melidei* has been shown to be the larval predator. They have also shown that the web builder *Dictyna coloradensis* selectively preferred the areas not treated with pesticides.

2.2 Factors affecting the spider assemblages in agroecosystems and other habitats

The spider assemblages and composition of the spiders in crop fields have shown to be affected by a multitude of factors. Of the abiotic factors the microclimatic humidity and the availability of water in the near vicinity have been shown to have a positive influence on the assemblages of the spiders. According to Lowrie (1948) the changes in the physical factors like Temperature , Exposure to wind , Humidity and Soil moisture compared with the diversity of the prey species decides the spider diversity. According to Markens (1997) Soil Humidity is known to be positively correlated with the distribution of the spiders. The effect of Moisture on the web placement of the orb weavers has been studied by Cherrett (1964); Gillespie (1987); Markezich (1987). Temperature on the other hand has been a determinant on female wolf spiders (Norgaard, 1951; Edgar, 1971; Knonk and Richert, 1979). Dondale and Binns (1977) have shown that a cumulative temperature and rainfall are the determinants of the spider communities. Ruchton, et al, (1987) showed that wetness as the determinants of spider assemblages in grassland.

Other factors that affect the spider assemblage are the disturbance caused to the use of pesticide spray in the fields and the farm management practices which causes the physical disturbance in the field. These disturbances reduce the diversity of the spiders as well as the predatory efficacy of the spiders. Andrew et al (2005) in the Potato agroecosystem have shown that in the conventional fields receiving pesticide input (broad spectrum insecticides) the spiders diversity was much lower than in the organically managed fields. Ragini (1999) have shown that a positive correlation exists between spider assemblages and the organic manure (Azolla) input in the fields. Siliwal et al (2003) had shown that in undisturbed Riparian ecosystems the population of the web builders was higher as compared to the other habitats. Laboratory experiments by Singh et al (2001) have shown that chemicals like Dimethoate produces avoidance behaviour in lady bird beetles. Singh et al (2004) have also shown that the predatory efficacy of the lady bird beetles decreased drastically as a result of the pesticide spray. The beetles also showed a decreased preference towards the prey which had pesticide residues on their body.

According to Culin and Yeargan (1983) the disturbance in the Soybean agroecosystems results in the non equilibrium system which affects the diversity of the spiders and they also state that vegetation structures is not the important determinant of the spider assemblages. The influence of the abiotic factors has been studied in lesser detail as compared to the biotic factors like the prey densities, Crop architecture and the floral diversity in the agroecosystems. Hooks and Johnson (2002) have shown that crops like Brocilli which have grown in shade (Mulched) promoted the spider assemblages as compared to the Non Mulched Broccoli fields.Ishijima et al (2004)have shown that untilled paddy crop had more spider density (Lycosidae) than tilled paddy field. Langellotto and Denno (2004) have shown that structural complexities of the habitat and Plant architecture significantly increased the spider diversity. Roland et al (2005) have shown that the combination of prey availability and the structural complexities of the flora promote spider assemblages in forests. Greenstone (1984) has shown that a positive correlation between the structural diversity of the plant tips and web building spiders. Duffey (1978) showed plant diversity in the habitat to be the major determinant on the density of the Ergonid spider *Erigone atra.* Rypstra (1986) has shown that the proportion of the actively foraging web building spiders is directly proportional to the total amount of the vegetation strata. The impact of the vegetation structure on the assemblages of the wandering spiders have been studied by Uetz (1991), inferring that the habitat structure also influences the distribution of the spiders.

The plant architectural features influencing the distribution of the web building spiders have shown that in the grasslands the diversity of the flora, presence of shrubs and the depressions present on the ground determines the composition of the web building spiders (Richert, Reeder and Allen 1973). The impact of the leaf litter on the ground dwelling spiders (Lycosidae)have been shown by Uetz 1991 , Edgar 1971 ; Lowrie 1948 ; Jocque 1973 ; to have a positive correlation with the leaf litter. Rypstra (1983) had shown that the web builders in response to the web site availability and the prey abundance, showed a differential preference; the Orb web builders relocated their webs to an area which had more amount of the prey. The Orb web builders also changed the orientation of the webs in response to the presence of sunlight; against the direction of the wind, so that the web becomes invisible and while sheet web builders preferred the web sites quality more to the availability of the prey for web building. These spiders failed to relocate their webs in response to the increase in the prey density else where. From the above experiments it is seen that habitat structure and the properties of leaf litter are important determinants of the spider composition in each habitat.

2.3 Feeding preferences and its implication on the biological control of insect pests

Spiders are known to be generalist, polyphagous predators which feed on a variety of insect prey and hence are thought to be less important as biocontrol agents (Richert and Lockley, 1984). Yet recent studies have indicated that spiders show some degree of specialization or monophagy by which they are assumed to be selective in their preferences towards their prey. The differences in their differential feeding habits are attributed to their microhabitat preferences and temporal variation in their activity.

It is known that some of the spiders are diurnal using visual cues and vibratory cues to hunt their prey examples Salticidae and Web building spiders. There are other spiders like Clubionidae, which usually hunt their prey at night. The insect prey active during the active periods of the spiders form the major diet and hence it is seen that the nocturnal spiders feed on moths and other nocturnal insects. The diurnal spiders feed on insects active during daytime (Marc et al, 1999; Richert and Lawrence, 1997; Marc and Canard, 1997). The diurnal or temporal differences coupled with the microhabitat preferences also provide differences in the feeding by the spiders. For example Family Lycosidae which includes ground dwelling hunting spiders feed on the insect present in the soil and sub soil surfaces more often as compared to those found on the plants. In the case of foliage dwelling spiders like the Clubionids and Oxyopids, the insects feeding on the leaves and stems form a major portion of the prey consumed by the spiders. In the case of web building spiders like Tetragnatha mandibulata and *Cytrophora cicatrosa* the prey is constituted from several orders of the insecta and these spiders are usually found in the vicinity of the water or moisture (Bell et al, 1999). The flower dwelling spiders like those belonging to the family Thomisidae, pollinating insects constitute a major portion of the diet since the niche of the pollinating insects and Thomisids are same (Marc and

Canard, 1987). Hence it is seen that the spider's microhabitat preferences and the periods of activity determines the composition of the prey in its diet. However if the nocturnal prey are made available to a diurnal spider it may or may not feed depending on a set of factors as described below (1) whether the spider has a method to catch the prey (Predatory behaviour of the spider) (2) the size of the prey.

It is known from the laboratory experiments that the hunting spiders usually prefer to catch the prey whose size is between 50 – 80% of their own body length (Nentwig, 1982) while the web building spiders catch comparatively larger prey (Nyffeler et al, 1994; Marc et al, 1999) this size dependent preference is due to the risk a particular spider takes while attacking a particular prey. It is seen that in the case of Castor Semilooper (*Achoea janata)* larvae on attacking wriggles violently to escape from the predator. As a result of this behaviour of the larvae, semilooper larvae are not the preferred prey of hunting spiders.

In hunting spiders, the predatory behaviour also decides the type and composition of the prey for each species of spider. For example several species of jumping spiders belonging to Family Salticidae are behaviorally adapted to feed on ants (Jackson and Pollard, 1996), while other genera of Salticidae like *Portia* show feeding preferences to other spider than to insects. Salticids of the genera *Phiddipus* shows preferences towards lepidopteran larvae and dipteran flies (Jackson and Pollard, 1996). The underwater spiders (*Argyrontidae*) foraging under water feed on aquatic insects larvae including the mosquito larvae (Nyffeler et al, 1994). Lynx spiders (Family: Oxyopidae) show preference for dipterans, small hoppers whose body size is between 1-3mm (Nyffeler et al, 1994). Clubionidae are known to be highly specialized for feeding on lepidopteran larvae. *Chieracanthium meildei* is known to be a dominant predator of torticidae larvae in the Orchards (Mansour et al, 1980a). They are important in regulating the densities of the *Spodoptera exuigua* larvae in Cotton agroecosystems, and also in Apple and Pear orchards. (Mansour et al, 1980b).

However the preferences of the prey are less commonly observed in the web building spiders. Since the web traps a diverse array of the insects and it is seen that the preference of web building spiders towards prey is very less. However in some cases like *Argiope argentata* seemed to prefer 62% of the stingless bees (Craig and Bernard, 1990). Some of the web builders seem to exclude the coleopteran from their webs by excluding them out of web (Nyffeler, 1994).

In the spider *Micrathena sagittata* (Araneidae) the larger sized prey are captured on the upper reaches of the Orb web were attacked more frequently than the ones present towards the bottom. Thus it is seen in this case that there is a size dependent preference towards the prey in the case of certain web building spiders. Studies done by other scientists have suggested that the prey preferences in both hunting spiders as well as web building spiders is dependent on the nutritional requirements of the predatory and the food quality of the prey. Mayntz et al (2005) have shown that the spider foraging in a nutrient specific manner occurred in the hunting spiders, showing that the spiders show a differential preference of the diet with respect to the amino acid composition of the prey. This type if nutrient specific foraging has been studied in detail in the carabid beetles and aphids of various species as prey models (Bilde and Toft, 1998; Bilde and Toft, 1997).

Prey switching by the predator as a function of the quality of the prey has been reported in the spider *Schizocoza* (Lycosidae) to Aphids reared on different diets (Toft and Wise, 1999). The laboratory experiments show that in certain spiders and beetles, the differential prey preference is as a result of the quality of the prey and the need for intake of balanced diet. Apart from the nutritional requirements other factors like Predatory behaviour, Active periods of the predator, and Microhabitat location of the predator are also important in determining the prey preference. Hence it is seen that the hunting and web building spiders show a differential preferences towards some of the prey which is dependent on the size of the prey, whether the period of activity of the prey coincides with the predator's activity, the prey specific predatory behavior and the Niche overlap of the insect and spiders. In the case of web builders, the larger sized prey is preferred to others and the soft bodied insects are preferred to the hard bodied ones. But in the state of food scarcity or non availability of the larger prey, the spiders tend to feed on the smaller prey without showing any preference. Thus preference towards different prey is on the basis of size, large web builders like the Tetragnathidae and Araneidae are effective in trapping large grasshoppers and adult moths more than any other insects, however it may be noted that the web provides additional advantages in trapping several species of smaller insects which are not usually fed and hence this non specific trapping helps in the overall reduction of the pest densities.

Criteria for prey selection

(a) Size of the prey: in the case of hunting spiders the prey smaller than the size of the predator is preferred while in the web building spiders it is seen that the larger sized prey are preferred.

(b) Predatory Behavior: in the hunting spiders the predatory behaviour of the spider is much pronounced and it dictates the kind of prey. For example in the case of jumping spiders of the genus Portia show strong preference towards the spiders as compared to the other prey. While in *Phiddipus* , *Salticus* , *Rhene* and *Myrmarachnae* genera of the family Salticidae , prefer mobile insect prey primarily comprising of small hoppers and Flies (Tarsitano and Jackson, 1992) while in other jumping spiders like *Habrocestum pulex* , ants are preferred to other insect prey (Jackson and Willey, 1994). *Myrmarachne* (ant like spiders) show differential feeding efficiency with the females consuming more than the male spiders.

The salticid genera found in the agroecosystems are primarily the ones which are insectivorous. The foliage dwelling hunting spiders like the Oxyopidae and Clubionidae , forage on a variety of insect prey (Young and Edwards, 1990) have shown that *Oxyopes salticus* feeds on a variety of prey usually smaller than their own body size. These preferences of Oxyopids to small prey sizes have been important in regulating the population of Aphids and Hoppers. The Clubionidae usually have been shown to prefer lepidopteran larvae. The ground dwelling lycosids in the paddy fields have been reported to regulate the buildup of insect pests in the start of the cropping season (Sigsgaard, 2000). Lang and Klarenberg (1997) have shown that *Pisaura mirabilis* (Pisauridae) was found to feed on the insect prey which was larger as compared to the others.

2.4 Predatory Potential of the spiders in Agroecosystems

It is believed that spiders and beetles being generalist predators are more efficient in regulating insect pest densities as against the specialists (Symondson et al, 2002). Scientists argue that the generalist predators can sustain themselves on alternate prey during the lean periods in agroecosystems and are hence present in much higher densities in the next copping season. Being polyphagous predators their capacity to regulate the population of insect pests on a wide variety of crops is also seen to their advantage. Spiders use of variety of hunting techniques as some of the spiders use their webs for catching flying and highly mobile insects like grasshoppers , beetles and wasps , moths and butterflies (Young and Edwards,1990). They are inefficient in regulating the population of the caterpillars, sucking insects like the bugs, Aphids and Jassids, leaf beetles (Young and Edwards, 1990). While the hunting spiders use visual and vibratory cues to hunt insects, they are important in regulating the population of the slow moving as well as the fast moving insect whose body size is usually smaller than the size of the predators themselves (Nentwig, 1982).Occasionally the hunting spiders do feed on preys which are larger than their own body size.

Apart from the insect pests , spiders are known to feed on beneficial insects like predatory bugs , lady bird beetles , lace wing adults , lace wing larvae and pollinating insects , and also on other spiders. This feeding on the predatory insects and spiders by the spiders is termed as Intraguild Predation. As a result of Intraguild predation the population of the predator's decreases and at the same time the population of the herbivorous insect's increases, stating that intraguild predation dampens biological control (Morin, 1999). There are several studies conducted in laboratories and controlled field experiments which point out that intraguild predation in Agroecosystems. Finke and Denno (2002) have shown that the predator diversity reduces the predatory pressure on the insect pests in the crops, thus leading to a decreased primary productivity. Another study involving the tritrophic interaction between Spiders, Lacewing Larvae and Aphids showed that initially there was a reduction in the population of the predators, by the feeding of the spiders on the lacewing larvae but in the later stages of the experiments a combined action of both spiders and lacewing larvae led to a significant decrease in the density of aphids (Dinter, 2002). The tritrophic interaction involving the Lacewing larvae, Ladybird beetles (*Coccinella septumpunctata*) and Aphids showed that the intraguild predation was very less and the population of the aphids reduced significantly (Chang, 1996). Chang (1996) found that the reason for the above was the result of both the predators occupying different guilds in order to reduce competition. The controlled field experiments also show that there is some degree of intraguild predation occurring naturally in the field. In an experiment involving artificially increased densities of wolf spiders in controlled field trials, the population of crickets (prey) increased; this increase in the cricket population was either due to cannibalism in the predators or by the predators showing preferences for other predator (Fagan and Hurd 1991). Roach (1987) found that in prey choice tests, *Phiddipus audax* preferred *Geochoric punctipes* to other herbivore prey which was offered. Agnew and Smith (1989) have shown that *Oxyopes salticus* frequently feeds on *Geocoris punctipes.* They conclude that spiders when present in high densities dampen the predatory pressure on herbivores.

Though all the above experiments state that intraguild predation in potentially simple ecosystems like the agroecosystems are much pronounced in the laboratory conditions, but in the uncontrolled field conditions the intraguild predation is assumed to be lower than expected. In the field a diverse type of prey are available to the spiders and thus the choice of the prey which are harmless to the predator seems to the ideal one for foraging. In a habitat which has a high density of the predators as a result of competition there is emigration to the adjoining fields which again leads to a decrease in intraguild predation. As a result of competition the predator may tend to occupy different niches or it may lead to a change in the foraging activity, all these will lead to decreased competition and resulting in partitioning of the resource (Prey) so that a greater combined effect of the predator might be there on the insect prey.

Though most of the studies conducted states that intraguild predation is a common occurrence in the agroecosystems leading to a decrease in the biocontrol potential. Despite this most of the studies state that as a result of a combination of predators the pest densities decreased significantly (Agnew and Smith 1989; Nyffeler et al 1992). Thus it seems that intraguild predation is present in agroecosystems but at a lower level than found in the laboratory condition. Intraguild predation in the nature is seen as an adaptation towards surviving during the lean periods when the prey density is low and thus maintaining a stable population even in the lean periods (Nentwig, 1988).The above stated experiments do not take into consideration about the prey spectrum found in the field which might form the alternative food of the spider and other entomophagous predators. For stating intraguild predation a comprehensive set of experiment involving various permutation and combination of the predators needs to be done for accurately accessing the intraguild predation in the field. Apart from the above the right combination of the predators from various species and at various densities has to be done for proper assessment of impact that a combination of the insect predators may have on insect pests in the field.

2.5 Functional and Numerical responses in spiders

An ideal biocontrol agent is one which can bring down the population of insect pests to a lower level under varying densities of the insect pests. The property to increase the prey intake with the increase in prey densities and decrease its potential at lower densities of the prey is the properties which would make any biocontrol agent effective in the field. Insect pests possess a very short life cycle as compared to spiders and can show a quick increase in their densities with respect to the food availability. The spiders in response to the increase in the prey densities can regulate the insect population by two ways; firstly they can either increase the food intake which is termed as Functional response or may increase in numbers in order to reduce the pest densities which is termed as Numerical response. A combination of the functional response and Numerical response is called as Total response and it is the total response of any predator which determines its efficiency in controlling any insect prey.

A functional response is defined as "*Change in rate at which an individual predator captures the prey as prey density changes*". Holling (1959; 1965; 1966) described three types of functional response curves; these are Type I, Type II and Type III. These curves are based on the feeding intensity of the predators. Of these three responses the Type III response is the most preferred response of the predator in terms of regulation of the insect pests in the fields. The Type III functional response shows a sigmoid curve, as the rate of prey capture increases at an accelerating rate over a range of prey densities before effects of predator satiation or increased handling time causes the rate of prey capture to increase at a decreasing rate (Holling, 1959). This type of Type III response in invertebrate predators is very rare, and spiders having low metabolic rates (Richert and Lockley, 1984; Wise, 1981), are expected to rarely exhibit a Type III response. There are certain exceptions as stated from several studies. Studied conducted by Nakamura (1977) showed that the Lycosids feeding on leafhoppers exhibited Type III response. Haynes and Sisojevic (1966) observed Type III response in Crab spider, concluding that this response is as a result of increased prey activity than due to any other factor. Richert (1979) showed a wasteful or superfluous killing in some of he spiders when exposed to higher prey densities. The functional responses in the predator comes from a change in its foraging behaviour by selectively preferring to feed on one type of prey and discarding the other a phenomenon termed as Prey – switching . This is a behavioural change which arises as a result of learning. The two studies (Nakamura 1977; Haynes and Sisojevic 1966) done above state that the behavioural change in the predation did not occur, instead the response was due to increased activity of the prey.

Type II responses are more common in invertebrate predators which some times even exhibit a weak type III response. Furuta (1977) showed that *Oxyopes seratus and Oxyopes badies* feeding on third instar gypsy moth declined after reaching a Type III response. Provencher and Coderre (1987) uncovered considerable variation n feeding in web builders (Tetragnathidae) and In Clubionidae at varying aphid densities. Dobel (1987) had showed that *Pardosa* fed on plant hoppers showed Type II and III response. He concluded that prey above certain densities could not find refuge in the plants and were the ones which were adequately predated upon.

Predator switching is a contributory to Type III response (Murdoch 1977) early studies show that preference of one prey to another did not arise as a result learning but was genetically determined(Richert and Luckzak , 1982) for *agelenopsis aperata* . *Linyphia triangularis* (Turnbull, 1960) concluded that prey switching is a rare phenomenon in spiders.

Predator satiation is another reason why there is a decline in the rate of prey capture at higher prey densities. (Richert 1974) showed that web builders tend to accumulate more prey than they can feed for example *Agelenopsis aperata* shows wasteful killing, which is the result of the prey getting trapped in the webs. We find that the wasteful killing is a common occurrence in the web building spiders and these spiders can exhibit a Type III response in the field as these spiders do not feed on all the prey which is trapped in their webs. Givens (1978) has shown that the amount of energy intake by the predator decreases with increase in the prey capture sequence. Smith and Wellington (1986) showed that *Araenus diadematus* showed type II response at higher densities of the prey. According to Wise (1993) a strong Type III response in the Invertebrate predators is a very rare phenomenon and is observed only in the laboratory studies. In the field the increase in the prey densities will lead to a predator satiation and thus the Type III responses are very rare in the field conditions. More over the size of the prey determines the type of response. for example in a Spider –Aphid system , we might expect to find a Type III response as the size of the aphid is smaller, while in another system involving a Spider – 3rd Instar spodoptera larvae the chances of finding a Type III response is very rare. Thus the Kind of Prey, Nutritional status of the predators, prey densities all together determines the functional responses of the predator. It is seen that the web builders can be expected to show Type III responses as a result of increased prey activity, leading to the trapping of the insect in their webs. Dabrowsky-prot and Luckzak (1968) showed that the Tetragnathid spider displayed a Type III response for mosquitoes.

A spider showing a Type II functional response can be an ideal biocontrol agent is it shows a strong numerical response. The numerical response is defined as "*The change in the population density of the predator as a function of changing prey density*". There are two types of numerical responses, namely aggregative numerical response and Reproductive numerical response. A Total response involving both Functional and Numerical response is required to accurately access the potential of any predator as a biocontrol agent. Study involving only Numerical or Functional response by no means can predict about the regulation of the prey densities in laboratory or in the feild. Dabrosky-Prot et al, (1973) found a correlation between web builders and the prey density in an ecotone between a forest and a grassland ecosystem. Morse and Fritz (1982) showed that *Misumena vatia* changes its residence site in the milkweed umbels in response to change in prey density. Cherrett, (1964); Schaefer, (1972); Nentwig, (1982) showed that the density of the spiders is positively correlated with the increase in the density of the invertebrate prey. Kronk and Richert, (1979) showed that *Lycosa santrita* after maturing move to open habitat from grassland, as open habitats have more prey densities. Edgar (1971) also showed that *Lycosa lugubris* moves to an area having high densities. thus two of the two numerical responses, the aggregative numerical response is much pronounced in spiders, the reproductive response in spiders is a rare possibility as the life cycle of the spider is very long and thus an immediate effect on the insect pests is not possible however on a log term basis reproductive numerical response may contribute to the stability of the pest population in the field.

2.6 OBJECTIVES

With this information on the spider assemblages, species composition, seasonal dynamics, feeding ecology and prey preference studies the study was conducted keeping the following objectives in mind.

- To Know the Composition of Spider Assemblages in Paddy, Pigeonpea, and Castor Agroecosystems and to identify the key factor affecting the spider assemblages in the field.
- To find out the Seasonal dynamics of the spider families and its correlation with the stage of the crop?
- To Identify the Habitat specific Spiders found in the three crops and to determine the numerically dominant spider species in the crops.
- To assess and compare the species diversity measures of the spiders in the three crops.
- To Evaluate the feeding potential of *Oxyopes shweta* (Lynx spider) on varying densities of the prey (Functional Response) and feeding potential of *Oxyopes shweta* present at varying densities.
- To know the Predatory behavior and Prey preference of *Oxyopes shweta* in two prey system with Choice and No Choice setups.