# POPULATION FLUCTUATION OF SPIDERS IN KUTTANAD RICE AGROECOSYSTEM

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Chapter 2

POPULATION FLUCTUATION OF SPIDERS
IN KUTTANAD RICE AGROECOSYSTEM

2.1. Introduction

Spiders are obligate carnivores and hold the unique position of being the only large class of arthropods which are entirely predatory in nature. Predation contributes significantly towards preventing excessive increase of insect populations. Under normal field conditions, if one species of a predator is absent, the other may take its place. An increase in the population of spiders contributed significantly to prey limitation (Provencher & Riechert, 1994). However, if there has been a wide spread and continued catastrophe, such as drought or misuse of insecticides, this is no longer possible, and reproduction of insect and pest species may continue unabated until starvation or disease intervenes. Unless corrective measures are taken, the prolonged absence of predators in any agroecosystem may be reflected at harvest time in marked reduction in the crop yield. Native arthropod predators inhabiting the crop fields are playing a substantial role in suppressing a variety of insect pests (Gravena & Sterling, 1983). It is generally accepted that predaceous arthropods voluntarily enter the crop field at no cost to the producer; and when sufficient numbers are present, can maintain the pest at a level where these pests are unable to cause unacceptable losses. The importance of spiders in regulating insect population has been tacitly assumed by many arachnologists and entomologists despite a dearth of supporting quantitative evidences (Riechert & Lockley, 1984). Spiders form one of the most ubiquitous groups of predaceous organisms in the animal kingdom. Spiders are highly abundant in agricultural fields and if they can be conserved or augmented can regulate many insect pests. As a group, they are highly resilient in agroecosystems, long lived and readily seek out new fields after harvest. Information on the occurrence of spiders throughout the growing season and their abundance in the field are important and inevitable components of biological control and pest management in any agroecosystem.

Obviously, all these arachnological characteristics have led field ecologists to consider the spiders as a potentially excellent group for limiting pests and acting as bioindicators. The present chapter gives an idea of population fluctuation of spider community and the factors affecting the succession. The mechanisms that regulate the biological...
cycles allow synchronisation of the periods in which juveniles and adults are present with periods of abundant potential prey. The possible use of some spiders in biological control requires knowledge of these mechanisms of cycle regulation, especially for spider rearing and production. Maintenance of a high density and diversity of spiders is important in integrated pest control (Marc & Canard, 1997). One must also take into account these regulatory mechanisms as well as spider biology in order to minimize the mortality induced by different cultural practices such as insecticide spraying, mowing, plowing, etc. and for effective management of areas adjacent to agroecosystems. Since more than half of the predatory fauna in agroecosystems are spiders (Ferguson et al., 1984; Young & Edwards, 1990), and it is known that changes in spider density can impact pest populations (Mansour et al., 1983; Nyfeller et al., 1994), it would seem logical that the spider community would be a key component of integrated pest management strategies even though significant control of prey populations by assemblages of spiders has been suggested repeatedly (Agnew & Smith, 1989).

2.2. Review of Literature

Spiders are common components of agricultural ecosystems wherever found (Young & Edwards, 1990). Because spiders often attain high population densities in the crop systems, there exists the potential for insect pest population suppression (Riechert, 1999; Sunderland & Greenstone, 1999). For this reason, there has long been interest in the population dynamics of spiders in agricultural ecosystems (Breene et al., 1993; Draney, 1997; Greenstone & Sunderland, 1999), and the ways in which crop management practices impact spider population fluctuation in the field (Bishop & Riechert, 1990; Balfour & Rypstra, 1998; Rypstra et al., 1999). Studies revealed that there are many factors affect the population density of spiders in ecosystems.

Some of the earliest studies of spider habitat selection and community structure focused on the importance of architectural features of the environment. Clear relationships have been revealed between the physical complexity of the environment and spider population density both across successional gradients (Hurd & Fagan, 1992) and across geographical regions (Greenstone, 1984; Rypstra, 1986). Surveys as well as manipulative studies have demonstrated that spiders respond to the diversity and complexity of the vegetation (Robinson, 1981; Greenstone, 1984; Gunnarsson, 1990; Halaj et al., 1998) and that cursorial spider, in particular, respond to the depth and complexity of the litter layer (Bultman & Uetz, 1984; Hurd & Fagan, 1992).

The literature on the responses of individual species of spiders and the community as a whole to habitat structure and complexity was
comprehensively reviewed in the early 1990’s (Uetz, 1991; Wise, 1993). The studies of Strong et al. (1984) and Andow & Prokym (1990) analyzed the effect of plant diversity and plant composition on spider abundance by changing foraging efficiency and the nutritional quality of the herbivore prey (Price et al., 1980). Critical experiments regarding the importance of habitat manipulations to spiders were conducted in a mixed vegetable garden (Riechert, 1990; Riechert & Bishop, 1990).

The composition and structure of spider communities, relative abundance and number dynamics of spiders occurring in the crop fields were analysed by Luczak (1980). Kayashima (1960) made initial attempts to increase the spider population to enhance pest control by reduced insecticidal applications. Studies have revealed that specific plant associations harbor distinct spider faunas (Elliot, 1930; Kajak, 1960; Duffey, 1962; Almquist, 1982). Comparative studies have shown that spider community composition changes with vegetative succession (Wissinger, 1997). Changes in family and species composition with ecological succession have been reported by Gibson (1947). Wissinger (1997) have also noted a general increase in species diversity through early and mid succession and a subsequent decrease in spider diversity in the climax community. This trend in diversity has been suggested for community development in general (Odum, 1997). Norgaard (1941); Almquist (1982) and Vogel (1972) demonstrated the importance of microclimatic conditions in effecting observed spider distributions.

Early research in spider community ecology documented the fact that early successional habitats had lower spider species diversity when compared to later serial stages nearby (Uetz et al., 1999). Wissinger (1997) found that this relatively low spider species diversity was functionally linked to the relative structural simplicity of the vegetation. The study on crop associated spiders revealed that those species found in the surrounding agricultural landscape and not species invading from local natural ecosystems (Duelli et al., 1990; Bishop & Riechert, 1990). Wise (1993) studied how competition might explain the patterns of space use exhibited by lycosids in agroecosystems in Germany.


Seasonal fluctuations in rice field spiders in Korea have been analyzed by many workers (Kim et al., 1990; Kim, 1992; Song & Lee, 1994; Kim & Kim, 1995; Yang et al., 1998; Im & Kim, 1999). Lee et al. (1997) suggested that the different time taken by different spider species to immigrate from levees into paddy fields is the cause of the low initial population densities, in spite of the abundance of prey. However, Kim (1998) showed that the immigration rate of overwintering spiders from levees into paddy fields was low.

Studies conducted in Europe revealed that the relative abundance of linyphiids rises with increasing intensity of agricultural management, whereas the relative abundance of hunting spiders decreases (Gluck & Ingrisch, 1990; Basedow, 1998; Ratschker & Roth, 2000). This is also supported by the experimental work of Kajak (1978), who demonstrated a shift to higher dominance of linyphiids associated with increased inputs of fertilizers. Similarly, Downie et al. (1998) monitored the arachnofauna in fifty agricultural grassland sites in Scotland and found that sites subject to disturbance from a high management intensity were dominated by Linyphiidae, but more stable sites had a higher proportion of non-linyphiid families.

Studies on the ecology of wandering spiders have been performed mainly in temperate regions and mostly with spiders of the family Lycosidae (Greenstone, 1980; Suwa, 1986; Wise, 1993). Numerous workers have detailed the strong relationship between vegetation structure and the composition of spider communities; and it is
often argued that this is the most important parameter involved in web site selection (Wise, 1993). As density and specific diversity of spiders do not correspond to the general vegetal quality of hedges, there are indications from species which show the habitat quality. The dominant species did not vary among hedges of different quality (Ysnel et al., 1996).

2.3. Materials and Methods

The sampling was done fortnightly to study the population fluctuation of resident spider community in the crop. The abundance of spiders in the rice agroecosystem was estimated every fortnight during the study by hand picking and standard sweeping methods of sampling. The water logged condition of the area made the use of pitfall traps impossible. A cropping composed of 7 fortnights and visits were made in every fortnight. In each site, specimens from 4 quadrates were collected per visit. As a result, spiders of 28 quadrates were collected from each site per season. Eight sites were selected for the study. Thus, a total of 224 quadrates were sampled during one season in the entire Kuttanad rice agroecosystem. The study was conducted in five different cropping seasons, 3 kharif crops and 2 rabi crops. Thus, spiders from a total of 1120 quadrates were collected during the entire study period. All life stages including spiderlings were collected to study the time of the production of new generation during the crop growth. The details of methodology are already described in the previous chapter.

2.4. Results

General trend of population during the crop growth:

The population of spiders in the Kuttanad rice agroecosystem showed a gradual increase in the first 3 fortnights followed by a slight decrease during the 4th fortnight (Tab. 2.1). Thereafter it continued to grow up to 6th fortnight attaining a peak in the growth of population followed by a decrease. The maximum value of average number of individuals was 42.52 with a total population of 5443 individuals. However, the average number of individuals during the entire cropping was 19.76 with a total of 17717 individuals.

The number of species obtained during the sampling showed a gradual increase in the number as the growth of the plant advanced and a maximum of 86 species was collected in the 6th fortnight. Shannon index also showed a gradual increase except in the 4th fortnight with an average of 3.41 during the entire growth (Fig. 2.1). But Simpson index expressed an irregularity and the highest value was recorded in the 1st fortnight and the lowest in the 6th fortnight with an average Simpson index of 0.45.
The Richness index showed the same tendency as the number of individuals, and reached its peak in the 6th fortnight. The Evenness index showed more similarity in the first 4 fortnights than the last 3 fortnights.

In the 1st fortnight (15th day), a total of 180 individuals were collected comprising 15 species of 6 families. Tetragnathidae and Linyphiidae were the dominant families in this collection. These two families constituted 50% of the total collection in the first fortnight. The Shannon diversity index, $H'$ was 2.54 and Simpson diversity index, $\lambda$ was 0.95. The Margalef richness index, $R$ was 2.75 and Evenness index, $E$ was 0.92. No males were collected in this fortnight. A: J ratio was 12.46.

In the 2nd fortnight (30th day), a total of 546 individuals belonging to 19 species were collected. The mean number of spiders increased in this session to 4.26. Families Tetragnathidae and Linyphiidae were dominant during this fortnight too. Four other families were also recorded in this fortnight. The different indices were, $H'$-2.68, $\lambda$ -0.76, R-2.95 and E-0.89. M: F was 6.33 and A: J ratio 23.81.

In the 3rd fortnight (45th day), 1535 individuals of 31 species were collected. Tetragnathidae, Linyphiidae and Lycosidae were the dominant spider families. These families constituted 70% of the total collection in this session. Spiders of the family Corinnidae appeared for the first time in this fortnight. Spiders of 8 families were reported in this fortnight. Different indices were, $H'$-2.99, $\lambda$ -0.57, R-4.16 and E-0.86; M: F was 7 and A: J ratio 6.11.

Fourth fortnight (60th day) collection was as follows, total spiders-1542, species-38, families-12. Linyphiidae and Tetragnathidae were the dominant spider families in this session. Different indices were, $H'$-2.96, $\lambda$ -0.66, R-5.11 and E-0.81; M: F-2.38, A: J ratio 2.21. Only a slight increase in the total number of spiders was observed in this collection.

In the fifth fortnight (75th day), spiders of 17 families were reported. This constitutes 3595 spiders of 64 species. Families Pholcidae and Pisauridae appeared for the first time in the field. Different indices were $H'$-3.27, $\lambda$ -0.49, R-7.74 and E-0.78; M: F-2.62, A: J ratio 2.25.

In the sixth fortnight (90th day), a total of 5433 spiders of 86 species were collected. Spiders of the family Tetragnathidae dominated in this stage (25.51% of total of this stage). Araneidae and Linyphiidae were the other dominant families. Different indices were $H'$-3.56, $\lambda$ -0.37, R-9.92 and E-0.79; M: F-2.21 and A: J ratio-1.77. In the last fortnight (105th day) spiders of 19 families were reported. Three families, Lycosidae, Linyphiidae and Tetragnathidae constitute 63% of the total collection. Different indices were $H'$-3.38, $\lambda$ -0.46, R-8.62 and E-0.78; M: F-2.15 and A: J ratio-1.98.
Table 2. 1. N, S, H’, λ, R, E, A: J ratio and M: F ratio during the each fortnight

<table>
<thead>
<tr>
<th>Fortnight</th>
<th>N</th>
<th>S</th>
<th>H’</th>
<th>λ</th>
<th>R</th>
<th>E</th>
<th>M:F</th>
<th>A:J</th>
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<td>0180</td>
<td>15</td>
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<td>0.00</td>
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<td>2</td>
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<td>19</td>
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<td>0.76</td>
<td>2.95</td>
<td>0.89</td>
<td>6.33</td>
<td>23.81</td>
</tr>
<tr>
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<td>1535</td>
<td>31</td>
<td>2.99</td>
<td>0.57</td>
<td>4.16</td>
<td>0.86</td>
<td>7.00</td>
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<td>4</td>
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<td>64</td>
<td>3.27</td>
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<td>0.78</td>
<td>2.62</td>
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<tr>
<td>6</td>
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<td>86</td>
<td>3.56</td>
<td>0.37</td>
<td>9.92</td>
<td>0.79</td>
<td>2.21</td>
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<tr>
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<td>4886</td>
<td>74</td>
<td>3.38</td>
<td>0.46</td>
<td>8.62</td>
<td>0.78</td>
<td>2.15</td>
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</tr>
<tr>
<td>Total</td>
<td>17717</td>
<td>99</td>
<td>3.41</td>
<td>0.45</td>
<td>9.51</td>
<td>0.75</td>
<td>2.38</td>
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Figure 2. 1. Changes in different indices during the crop growth stages
Effect of season on different population parameters during the crop growth:

1. Effect of season on number of individuals during the crop growth:

   The number of individuals collected during Kharif season was higher than Rabi season (Fig. 2.2). This trend continued throughout all fortnights with the highest difference in the total number recording in the 6th fortnight. In both seasons, the total number of spiders increased up to the initial three fortnights followed by stabilization in population up to the 4th fortnight. After this stage, the resident spider community exhibited an explosive growth up to 6th fortnight. This period indicates the flowering stage of rice plants. Thereafter the population showed signs of decline as shown in Fig. 2.2. This result indicates that the number of individuals in the rice agroecosystem was influenced by season. The statistical analysis also revealed that there was significant variation in the total number of spiders collected between two seasons.

![Fig. 2.2: Fluctuation in no. of individuals](image)

2. Effect of season on number of species during the crop growth:

   The number of species collected during the study in two different seasons exhibited the same trend as number of individuals (Fig. 2.3). The number of species collected during the crop growth showed a gradual increase in both seasons up to 6th fortnight and then decreased. From Fig. 2.3, it is clear that the number of species collected during the two seasons was different. The statistical analysis also supported the observation that there was significant variation between these two seasons in the case of number of species.
3. Effect of season on different indices of spider community during the crop growth:

There was significant difference in Shannon, Richness and Evenness indices between two seasons as shown in Figs. 2.4 to 2.7. However, Simpson index was not significantly different in two seasons. In both seasons, Richness and Shannon indices increased as the crop growth advanced whereas Simpson and Evenness indices showed a decline. In the case of Richness index, the rate of increase was more in Kharif season compared to Rabi season and the same trend was observed for Shannon index. During Kharif, highest Richness index was 9.88 and the lowest 4.63 with an average 7.61±0.40. However, in Rabi season, the indices were 7.75, 4.40 and 5.80±0.27 respectively. Richness index exhibited significant difference between two seasons (F1, 30=13.70, P=0.01) in the ANOVA. The highest Shannon index of the Kharif season was 3.55 and the lowest 2.95 with an average of 3.31±0.04. In the Rabi season, these indices were 3.34 and 3.02 with an average of 3.19±0.02. One way ANOVA showed that Shannon index had significant variation (F1, 30=7.41, P=0.01) between two seasons.

In the case of Simpson index, the highest of Kharif season was 0.61 and the lowest 0.37 with an average of 0.46±0.01. In the Rabi season, it was 0.56 and 0.37 and 0.47±0.01 respectively. This showed no significant difference between two seasons (F1, 30=0.6, P=0.01). The average Evenness index of Kharif season was 0.85±0.05 with a maximum of 0.90 and a minimum of 0.81. In the Rabi season, it was 0.88±0.06, 0.91 and 0.83 respectively. This index exhibited marked
difference between the two seasons throughout the crop growth. The ANOVA result also showed a significant difference ($F_{1, 30}=18.03$, $P=0.01$) between two seasons.

**Fig. 2.4. Fluctuation of Shannon index**

![Fluctuation of Shannon index](image1)

**Fig. 2.5. Fluctuation of Simpson index**

![Fluctuation of Simpson index](image2)
4. Effect of season on male - female ratio of spider community during the crop growth:

The male-female ratio is an important indicator of the population structure of the community. This ratio is expressed as the proportion of number of females to one male. Since spider community is a female dominant one, there is no chance for more number of males than females. In the first fortnight of both seasons, there were no mature males in the filed, so the ratio is expressed as 0. In the 2\textsuperscript{nd} fortnight, the ratio was 5.86 and 6.21 in Kharif and Rabi season respectively. In the 3\textsuperscript{rd} fortnight, this ratio slightly increased and attained the peak. A decline occurred in the
4th fortnight and this condition almost continued up to the harvest. An increase in the ratio indicates the less number of males collected during the study. From Fig. 2.8, it is evident that the least number of males were collected in the 3rd fortnight and the number of males increased as the crop growth advanced.

5. Effect of season on adult - juvenile ratio of spider community during the crop growth:

The adult-juvenile ratio is also an important indicator of the population structure of the community. This ratio is expressed as the proportion of number of juveniles to one adult. Spider community is generally a juvenile dominant one. So there is no chance for more number of adults than juveniles in the rice agroecosystem. In the first fortnight, both seasons expressed minimal difference in the adult-juvenile ratio of 10.55 and 14.88 in Kharif and Rabi seasons respectively. In the 2nd fortnight, this ratio increased and recorded the highest ratio of this agroecosystem. This ratio then declined and in the 3rd fortnight recorded the lowest value. This ratio continued the decline and from 4th to 7th fortnight the trend continued at an almost same level. An increase in the ratio indicates the lesser number of adults collected during the study. As Fig. 2.9 indicates, the 3rd fortnight recorded the least number of adults and then the number of adults increased as the crop growth advanced. It is imperative that the first 3 fortnights indicate the growth phase of the population and the last 4 fortnights indicate the maturation phase of the population.
Changes in cumulative number of species during the crop growth:

The cumulative number of species exhibited almost the same trend in both seasons. Compared to Kharif, the number was slightly less in Rabi season. From Fig. 2.10, it is apparent that the species composition did not change in the field during the first 3 fortnights. Following this, Kharif season recorded an increase in the occurrence of more species in the field up to the 4th fortnight. In Rabi season, new species did not appear in the field in the fourth fortnight compared to the previous fortnight. Then up to 6th fortnight, the cumulative number of species increased in both seasons, with more number of species appearing in Kharif season. The maximum difference in the cumulative number of species collected between two seasons was in the 6th fortnight. After this stage, the cumulative number decreased gradually towards the 7th fortnight.
Changes in mean number of spiders during the crop growth:
The mean number of spiders collected during the crop growth exhibited a continuous increase up to the harvest (2.11) with a stable stage during the 3rd and 4th fortnights. After 4th fortnight, the population growth curve exhibited a sharp rise and the mean number of spiders attained a peak in 6th fortnight. After this stage, the population showed signs of decline.
Population fluctuation of number of individuals of dominant families:

The population fluctuation of individuals of 8 dominant families is shown in Fig. 2.12. It is evident that different families exhibited different trends in population growth. In general, first peak of the population occurred in the 3rd fortnight. After this stage, a slight decline occurred in the population growth curve of some families while some others exhibited a plateau. After the 4th fortnight, the population exhibited an exponential growth and attained the peak in the 6th fortnight. After this stage, number of individuals of some families decreased while some others increased further. The individuals of the family Tetragnathidae continued the growth up to 3rd fortnight, slightly decreased up to 4th fortnight, and then grew exponentially and became the most dominant family of this agroecosystem by the 6th fortnight. This state was followed by a decline and finished as 3rd dominant family at the final stage of the crop growth. Members of the family Araneidae also showed the same trend in population fluctuation. Members of the family Lycosidae, Theridiidae, Linyphiidae, Oxyopidae and Thomisidae expressed a continuous growth up to the final stage of the crop growth, i.e., there was no population decline after 6th fortnight. From this, it can be inferred that population of orb-web building spiders suddenly fell after the peak, while ground dwellers and hunters continued the growth. Individuals of the family Tetragnathidae, the dominant spider family during the study, reached the peak in the 6th fortnight and then it decreased suddenly and recorded the third position in the final sampling along with family Araneidae. Spiders of the family Lycosidae and Linyphiidae continued the population growth and attained the first two ranks respectively with maximum numbers in the final sampling. Spiders of the family Theridiidae and Oxyopidae showed the same tendency in population fluctuation. However, salticids showed a slight decrease in population at the final stage. Miscellaneous group of spiders showed a continuous increase in the number with the crop growth.
Fig. 2.12. Population fluctuation in no. of individuals of dominant families during the crop growth

Population fluctuation of number of species of dominant families:

The population fluctuation of species of 8 dominant families is expressed in Fig. 2.13 and different families expressed different trends. In general, there were two peaks (in 3rd and 6th fortnight) during the crop growth and maximum peak was in the 6th fortnight. In contrast to Fig. 2.12, family Salticidae expressed the maximum number of species in the final stage of the crop growth. In the first two fortnights, this family was represented by only 2 species and 4 species in the next two fortnights. After this, the number of species increased and almost doubled in the 6th fortnight than the previous fortnight. Tetragnathidae was the next species rich family in the final stage of the crop growth. This family showed an increase in the number of species from 4th to 6th fortnight. In the final stage, the number of species reduced as in the case of number of individuals. Family Araneidae was the next species dominant family in the final stage. This family also exhibited the same trend as that of tetragnathids. In contrast to other families, family Lycosidae exhibited a plateau from 5th to 7th fortnight. Reduction or addition occurred in the number of species in all others families except Linyphiidae. This family exhibited a stable stage from 3rd to 7th fortnight with 4 species.
2.5. Discussion

Effect of the crop growth on spider population:

The study revealed that the abundance of spider community changed with season and the crop growth. The difference in population with season may be influenced by the changes in structural diversity of the habitat or spider phenology. The changes in the population density of web-builders and non-web builders differed between them. The density of web builders gradually increased and then decreased at the time of harvest. However, hunters showed a trend of continuous increase in population density towards harvest. Increase in the population density of the spiders is presumed to be brought about mainly by the propagation from nearby lands. Hereupon, seasonal changes in the propagation of the spiders were estimated from the A: J ratio (the ratio of the number of adults to the total number of juveniles collected). The juvenile ratio reaches at the peak on the 2nd fortnight of sampling. This indicates the migration of the juveniles or reproduction of females in the field.

However, when spiders were divided into vertical strata, there was a significant effect on the structural complexity. The web building and plant wandering spiders rely on vegetation for some part of their lives, either for finding food, building retreats or for web building. The
structure of the vegetation is therefore expected to influence the population density of spiders found in the habitat. There were many more plant wanderers and web builders sampled than ground dwellers. This again indicates that structural diversity of the vegetation may, in some way, influence the spider density. Studies have demonstrated that a correlation exists between the structural complexity of the vegetation and population density (Andow, 1991). Diversity generally increases when a greater variety of habitat types are present which leads to high population density (Hawksworth & Kalin Arryo, 1995). Uetz (1991) suggests that structurally more complex shrubs can support a more diverse spider community. Downie et al. (1999) and New (1999) demonstrated that spiders are extremely sensitive to small changes in the habitat structure; including habitat complexity, litter depth and microclimate characteristics. Thus the physical structure of the environment has an important influence on the habitat preferences of spider species, especially web-building species (Uetz, 1991; Hurd & Fagan, 1992).

Spiders are sensitive to changes in vegetation structure, where a highly variable structure provides web-spinners with increased web-site opportunities. Availability of structural support for webs and a suitable micro-climate are the most important factors in web site selection (Samu et al., 1996). Vegetation structure can influence not only wandering spider prey recognition (Rovner, 1980) but also mate detection (Uetz & Stratton, 1992).

The density and diversity of the spider community has been closely tied to the structural complexity of the local environment. Web-building spiders are directly linked to the configuration of the vegetation because of specific web attachment requirements. Correlative data support a tight relationship between spider density and habitat structure. Most of the available data show that agricultural practices which enhance the structural complexity of the environment (such as intercropping, mulching, and conservation tillage practices) enhance the density and diversity of the spider community. Some studies uncovered a strong link between habitat complexity, spider abundance and plant productivity; but others have not, and the mechanisms by which spiders could exert a top-down effect are not clear. Scheidler (1990) stated that for some spiders the plant architecture may play the dominant role, while for other spider species special structures like leaves or buds are most important. Frank & Nentwig (1995) also recorded a more diverse spider fauna in areas covered with richly structured vegetation.

Spiders are generalist predators that may be of great importance in reducing, and even preventing, outbreaks of insect pests in agriculture (Riechert & Lockley, 1984; Sunderland et al., 1986). Hence it might be profitable to create and sustain high densities of spiders in fields. However, agricultural cultivations kill spiders and destroy their habitats.
Population fluctuation

(Thomas & Jepson, 1997; Topping & Sunderland, 1998). Furthermore, fields vary in their suitability as habitats for spiders over the growing season of the crop (Dinter, 1996). Therefore the ability to disperse well is vital for the persistence and survival of spiders in agricultural habitats (Weyman, 1993). Recolonization of the fields is normally by aerial dispersal rather than by cursorial movements (Bishop & Riechert, 1990), but this varies among species (Thomas et al., 1990). Several studies have suggested that spider dispersal and re-colonization of fields are significant aspects of spider population dynamics in agroecosystems (Bishop & Riechert, 1990; Nyffeler & Breene, 1990; Dinter, 1996; Thomas & Jepson, 1997; Topping & Sunderland, 1998). Surveys as well as manipulative studies have demonstrated that spiders respond to the diversity and complexity of the vegetation (Rypstra, 1986; Greenstone, 1984; Gunnarsson, 1990; Halaj et al., 1998). After a vacuum state at the beginning, spiders began to migrate gradually and increased in number. While some spiders maintained this level until harvest others declined in population. This increase in curve, however, slightly differs from Hammamura (1969) and resembles a logistic curve in that it maintains a high density level after a sharp increase in the 6th fortnight. The reason that spider population in the paddy field showed a level transition during the crop growth can be explained from the changes in the density of the 8 classified spider groups.

Effect of prey density on spider population:

An increase in the spider population tends to depend on the amount of its prey, and if the density of prey becomes higher, spiders are expected to increase proportionally to some extent. The preys of the spider have a pretty wide variety and they even prey on one another (Kiritani et al., 1972). It is evident that an increase in the population of spiders tends to depend on the amount of preys available. It has already been pointed out by Kobayashi (1961) that the values of correlation coefficients between the population density of insect pests and that of spiders tend to increase from negative to positive form as the crop growth advanced. However, the amount of preys alone does not affect the density of spiders. The other important factors noticed to be affecting it are the number of individuals surviving after hibernation and other cultural practices related to agriculture.

It is a well known that that the density of the spider population inhabiting the paddy field shows a so called numerical response to the prey density and is indicated by a saturation type curve (Kawahara et al., 1969). On the other hand, it has already been clarified that there is a negative correlation between density of plant and leaf hopper and that of spiders (Kobayashi, 1961). As described above, two factors namely, numerical response and a predatory effect interact between the density of
the spiders and that of their prey. Hence, what is observed in the paddy field may be considered an integrated aspect of these two. The mechanism underlying the numerical response is directly related to the functional response of the predator in that with increased availability of food, the stenophagous predator will respond with greater consumption, thus linearly affecting survival and fecundity. Increased prey numbers would, therefore, induce a chain of responses in the associated predator, evidenced initially in increased food consumption, followed by increased survival, faster development, and greater fecundity. The subsequent young ones produced by well-fed parents may also be more viable.

A large number of spiders belonging to the families Lycosidae and Linyphiidae were collected in the final stage of crop growth. Among these, wolf spiders (Lycosidae) were dominant, accounting to 40-60% of all the spiders captured during this stage. This indicated that density of these spiders increased during this time. Field sampling in the flowering stage of rice indicated that the density of wolf spiders had reached up to 25 times than the average wolf spider density in the rice fields.

Differences in habitat use can change a spider’s diet (Brown, 1981) effected by change in the availability of prey (Olive, 1982) and/or web characteristics (Greenstone, 1984). Two habitat features that influence important web characteristics are the type and height of plant used for web attachment (Pasquet, 1984). If sturdy plants such as trees and shrubs support larger stronger webs, then larger, more powerful prey items (e.g., Orthoptera) can be captured compared to webs on slender plants such as grasses (McReynolds & Polis, 1987). If the flying insects (e.g., Hymenoptera) are at greater heights in vegetation where there is more open space for flight, then increasing the height of plant used for web attachment (thus increasing web height) can increase encounters with the web by flying insects (McReynolds & Polis, 1987). For habitat selection to be effective, different habitats or microhabitats must differ in effect on individual fitness, and the individual must be able to select the higher quality habitat based on some environmental cue or cues (Orians & Wittenberger, 1991). However, temporal and spatial variations in habitat quality make it difficult to find and choose a high quality site (Orians & Wittenberger, 1991), and the risk of movement from a web site increases the expediency of remaining in a lower quality site (Vollrath, 1985).

**Effect of season on spider population:**

There was an overall significant difference in the diversity, evenness and richness between the two seasons. The above results indicated that the interaction of season on spider composition was significant for Shannon, Richness and Evenness indices, but was non-significant for Simpson index. There are many environmental factors like
seasonality, spatial heterogeneity, competition, predation, habitat type, environmental stability, productivity, etc., that affect species diversity (Rosenzweig, 1995). The final stage of the crop growth appears to be more complex and has high diversity. The results indicate that the two seasons have different species composition. Additionally, there are many factors that determine the species composition. This may be related to the changes in the vegetational structure of the habitat (Uetz, 1991).

It might be expected that climatic changes through seasons would influence the abundance of spiders (Kato et al., 1995). In the tropics, a continuum of species with extended seasonal ranges has been found (Basset, 1991), that would give rise to variable samples at different times of the year. Most spiders are limited to a certain extent by environmental conditions. In general, different species have varying humidity and temperature preferences and are limited to those seasons which offer a microclimate within the range of their physiological tolerances. The population fluctuation also is influenced by migration of spiders since aerial dispersal and colonization of neighbouring habitats are common phenomena among spiders (Bishop, 1990; Bishop & Riechert, 1990; Greenstone, 1982 & 1999). It is apparent that some of the seasonal differences in the quantity of spiders may be due to temporal changes in prey density and diversity (Warren et al., 1987). Because spiders respond to increases in prey density (Riechert & Gillespie, 1986), pest insect population levels may explain some of the observed differences in spider abundance between two seasons.

The changes noted in spider association with specific crop stage at different sampling times were related to the flowering state of the crop (Riechert, 1973). Study of the movements of marked individuals and web location character indicated that attractants such as flowers and availability of insect pests are important determinants of web location quality and resultant reproductive success of spiders (Riechert, 1973). A multiple regression analysis of prey density versus various conditions of the physical environment and habitat features revealed the presence of a significant relationship between high insect density and the presence of flowering herbs and shrubs in the vicinity of the web (Riechert, 1973). Good growth conditions in Kharif season, possibly due to high temperature or food availability (De Keer & Maelfait, 1987; Beck & Connor, 1992) might be responsible for the observed differences. Whatever the cause, seasonality may facilitate the coexistence of species either by maintaining the species under a level in which their interactions would influence coexistence or by differentiation in seasonal peaks of activity or abundance.