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SPIDERS : NATURAL BIOLOGICAL CONTROL AGENTS AGAINST INSECT PESTS IN PHILIPPINE RICE FIELDS

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ABSTRACT

Spiders are economically significant arthropod predators, their most important use is in agriculture and forestry where they serve as natural biological control agents against insect pests. Of the 35,000 described species all over the world, the checklisted Philippine spiders is just 1.47%, consisting of 517 species, 225 genera belonging to 38 families grouped into two infraorders (Mygalomorphae and Araneomorphae) of suborder Opisthothelae. In Philippine rice fields, the teemingly rich spider fauna consist of 337 species under 28 families while the surrounding habitats have 70 species in 50 genera under 19 families. The Philippine spider record is the highest in the entire Asian tropical rice fields.

An ecological study of Philippine irrigated rice field reveals that 3,098 spiders belonging to 42 species are largely grouped into two functional guilds, namely, the web builders and the hunters. Among the web builders, the most diverse are the comb-footed spiders (Theridiidae); long-jawed spiders(Tetragnathidae); garden spiders (Araneidae) and the dwarf spiders (Linyphiidae).

The diverse hunters, on the other hand, are the jumping spiders (Salticidae); crab spiders (Thomisidae) and the wolf spiders (Lycosidae). In irrigated rice fields, spiders are visible on the rice canopy and above water environments during or immediately after transplanting in both wet and dry seasons. Wide array of insect preys of spiders include collembolans, dipterans, moths and butterflies, rice bugs, leafhoppers and planthoppers. Entire prey spectrum consisted of 198 species belonging to 91 families in14 orders of Class Insecta. Predation rates of spiders are known only in 14 taxa comprising of four hunters and 10 web builders. The hunters are Lycosidae (3 species, 2 genera) and Oxyopidae (one species), while the web builders are Araneidae (2 species), Linyphiidae (1 species),Theridiidae (1 species) and Tetragnathidae (6 species). A community assemblage of these 14 taxa at anyone time consumes 65 leafhoppers, 72 planthoppers, 26 rice stem borer and leaffolder moths, 51 rice whorl maggot flies and 146 collembolans in a day. In turn, spiders serve as hosts of 15 hymenopteran parasites, two pathogens, a nematode as well as prey to bull frogs, toads, birds, ants, and wasps. Natural enemies of spiders limit their effective and efficient use in the natural biological control of rice insect pests.

To conserve spiders and optimize their innate potentials in the regulation of rice insect pests, the following provisions are recommended: (1) maintain refuge areas with diverse plants and landscapes, (2) maintain files of rice straw around rice fields, (3) avoid burning habitats surrounding rice fields, (4) avoid overgrazing rice bunds and surrounding grassy habitats, (5) avoid using herbicides on grasses around rice fields and (6) use judiciously selective insecticides against rice insect pests.

INTRODUCTION

Spiders are insect relatives belonging to the Class Arachnida under Order Araneae of Phylum Arthropoda. The name Arachnida emanated from the spider myth story of the Greek maiden, **Arachne** who was very famous as a skilled weaver that she dared and challenged the goddess **Athena** to a weaving contest. Athena acquiesced to the challenge and wove a majestic tapestry of the gods but her work was superbly outclassed by Arachne's masterpiece, a weave portraying the gods' amorous adventures. Athena accepted the defeat but in raving fury destroyed her opponent's work. The maiden hanged herself in disgust. Feeling pity, the goddess loosened the rope tied around Arachne's neck, made the rope into a cobweb and turned the maiden into a spider so she could spin and weave forever.

Worldwide, spiders are disliked by many people yet these animals are basically part of the folklore in many cultures. Spiders are used by witch doctors to prognosticate the future of a person in Bali, Indonesia (Stone, 1984). In China, spiders are highly protected and sacred as these are regarded as the apostles of Confucius possessing great wisdom while in Japan, the Spider God is perceived as a great military strategist (Stone, 1984). In the Philippines, the egg cocoon of the banana spider, *Heteropoda venatoria* L., is a source of luck providing winning numbers for the local number game "jueteng" according to a number of village folks in Southern Tagalog Region (Barrion, unpublished data). This is similar to the money spiders, the small black dwarf spider in the family Linyphiidae in the British Isles. Among children, having these money spiders in their clothes mean good luck is coming in the form of monetary gain. To others, spiders are mysterious and powerful creatures that play a benevolent and potent role particularly to the lives of American Indians. The orb web is a symbol of heaven, the corners of the foundation lines with four directions provide thunder and from the spirals of the orb come the mystery and power of the Great Spirit (Gertsch, 1979). Unknown to many, spiders have a lot of uses. These diverse creatures provide medicine for the cure of malaria and arthritis, good source of silk threads (Bristowe, 1958), and a great gastronomic delight (Preston-Mafham, 1984).

The most important use of spiders is in agriculture and forestry where these small animals act as "little murderers" in regulating insect pest populations below damaging levels. Spiders are marvelous ecological tools posting as natural biological control agents against insect pests that operate more effectively when in species assemblages and communities than by single taxon. This paper aims to provide a concise overview of the taxonomy and ecology (viz. diversity, population dynamics and movements, prey and predation efficiency, natural enemies, and conservation practices) of Philippine spiders in rice fields and its surrounding habitats. Knowledge derived from these objectives is of paramount importance in optimizing spider-control strategies against rice insect pests.

CURRENT KNOWLEDGE ON PHILIPPINE ARANEOLOGY

At present, about 35,000 species of spiders are described from all over the world (Preston-Mafham, 1984; Okuma *et al.*, 1993) and some 30,000 unresearched species await discovery (IEW,1989). Of the named taxa, 85.7% are the true spiders or Araneomorpbae (Griswold *et al.*, 1999).

The Philippine spider fauna is a minuscule (1.47%) of the total described taxa as shown in the checklist of Pbilippine spiders recently prepared to provide baseline information for the biodiversity conservation efforts by the members of the National Biodiversity Strategy and Action Plan (NBSAP) (Barrion *et al.*, 2000). It consisted of 517 species, 225 genera belonging to 38 families grouped into two infraorders of suborder Opisthothelae. Infraorder Mygalomorphae is represented by three families while 35 families comprise Infraorder Araneomorphae. Within Araneomorpbae are two sections, namely, Cribellatae represented by three families and Ecribellatae with 32 families. Ecribellatae split into two divisions, the Haplogynae with 6 families and Entelegynae with 26 families. Two branches, Dionycha or two-clawed (11 families) and Trionycha or three-clawed spiders (15 families) formed Division Entelegynae. Of all the spider families, the jumping spiders or the Salticidae are the best known with 141 species.

In tropical rice agroecosystems, these animal taxa represent a dominantly large guild of invertebrate generalist predators inhabiting rice plant canopy, stem, tiller and the mud-water environment (Heong *et al.*, 1991; Okuma *et al.*, 1993; Barrion *et al.*, 1994; Arida and Barrion, 1995; Barrion and Litsinger, 1995; Inthavong *et al.*, 1996). Spiders also are in non-rice habitats adjacent to or around rice fields in South and Southeast Asia (Yasumatsu, 1975; Barrion and Litsinger, 1995; Chen & Lou, 1996; Li, 1996; Barrion, 1999a &b). In all tbese habitats, the prey of spiders are mostly herbivores consisting of rice insect pests such as leaf- and planthoppers, stemborers, leaffolders, crickets and grasshoppers.

The Philippine rice fields have a teemingly rich spider fauna comprising of 337 species under 28 families (Barrion & Litsinger, 1995) while the surrounding areas that serve as refuge for spiders yielded 70 species in 50 genera under 19 families (Barrion, 1999 a & b). The spider record for the Philippines is the highest in the entire tropical rice agroecosystems in Asia in terms of number of species, genera, and families.

Yet overall, the current knowledge on the systematics of Philippine spiders is very bleak and limited only to the fauna of our rice fields and its surrounding areas. The current record based on the available specimens at hand or those kept in museums abroad is unrealistic considering the many islands in the Philippines. It does not reflect the true species richness of spiders lingering in the six biogeographic zones or regions of the Philippines, namely, Palawan, Mindanao, Luzon, Mindoro, Negros-Panay and Sulu Archipelago. There is right now an urgent need to conduct a rigorous collection effort in the remaining forest cover of the six biogeographic zones before everything is lost to the rampaging forest denudation throughout the country. Proof to this urgency, are the illegal logging activities surprisingly happening in some of our forest national parks. Nonetheless this gargantuan vision if ever accomplished will generate countless number of specimens. Moreso, new genera and species of spiders are likely to be collected for the first time and would require new descriptions to make the names available. However, full success will only be achieved in the premise that more taxonomic manpower and resources are available and that more collaborative linkages will be established between and among research institutions, museums, colleges, and universities locally and internationally in the future.

ECOLOGY OF SPIDERS IN PHILIPPINE RICE FIELDS

A. Diversity-In irrigated rice fields sampled for two cropping seasons—dry (January to April) and wet (September to November), collection of spiders produced 3,098 individuals. It comprises 42 species belonging to 35 genera and 13 families. On the other hand, the total year-round collection from the non-rice habitats varies by location. In three sites in San Juan, Batangas, the grand total collection is 8,870 spiders with 3,829 individuals (39 species, 33 genera & 14 families) in the broadleaf (*Malachra* spp.) and 5041 in the tall grasses of *Saccharum spontaneum* L. (2,880 individuals, 50 species, 38 genera & 15 families) and *Paspalum conjugatum* Berg (2,161 individuals, 37 species, 28 genera & 13 families). The grand total collection was much higher in Candelaria, Quezon yielding 26,177 spiders in five non-rice habitats, namely, irrigation canal [Ic] (6,966 individuals, 47 species, 37 genera & 16 families), edge of the bund [E_0B_1] (6,488 individuals, 62 species, 47 genera & 19 families), coconut [Co] (5,833 individuals, 48 species, 39 genera & 18 families), banana [Ba_1] (3,739 individuals, 51 species, 42 genera & 19 families) and mixture of banana and coconut [Ba_{11}] (3,151 individuals, 55 species, 47 genera & 19 families). Species richness ranged from 10.4-24 (mean=15.21±4.94) spiders per 0.7 m^2 mylar enclosure in irrigated rice field and its surrounding areas.

In summer, irrigated rice field and their surrounding areas yielded a total of 74 taxa, 53 genera belonging to 20 families of spiders. The number of families was higher in banana and edge of the bund > coconut > irrigation canal than in irrigated rice field, *Paspalum* and other habitats.

Diversity in plant types and their landscapes is presumed to have supported the higher number of spider individuals in Candelaria, Quezon compared to that of San Juan, Batangas. It must be noted that the latter is dominated by grasses and short broadleaf plants subjected frequently to perturbations, such as animal grazing and burning. These two factors contributed to low spider diversity due to loss of suitable foundation web sites for the weavers, and low prey density in overgrazed and burned habitats for the hunting spiders.

In terms of feeding guilds or mode of life following Hatley and Macmahon (1980), Philippine riceland spiders are largely grouped into two, namely, the web builders and the hunters. In all but coconut habitat, the web builders are the most dominant (Table 1). Species-wise, there is no significant difference between the web builders (39 species) and the hunters (41species). However, the hunters are significantly more diverse than the web builders in terms of families with values of 14 and 6 families, respectively. Among the web builders, the most diverse are families representing the comb-footed spiders, Theridiidae (12 species); long-jawed spiders, Tetragnathidae (10 species); garden spiders, Araneidae (8 species) and the dwarf spiders, Linyphiidae (7 species). On the other hand, among the hunters, the jumping spiders, Salticidae (9 species); crab spiders, Thomisidae (8 species) and the wolf spiders, Lycosidae (6 species) represent the most diverse group.

Table 1. Guild structure and composition of spider communities in irrigated rice field and its surrounding habitats.

Habitat	Guild composition (%)	
	Web builders	Hunters
Irrigated rice field (Ir)	71.9	28.1
Paspalum conjugatum (Pc)	60.9	39.1
Saccharum spontaneum (Ss)	64.4	35.6
Malachra spp. (Ms)	60.6	39.4
Irrigation canal (Ic)	53.75	46.25
Edge of bund (Eb)	55.32	44.68
Coconut (Co)	36.46	63.54
Banana (Ba1)	73.63	26.37
Banana + coconut (Ba2)	66.28	33.72

B. Population Dynamics and Movements-At anytime of the day, spiders are always associated to rice agroecosystem due to the abundance and richness of prey in this habitat. In irrigated rice field, spiders are visible on the rice canopy and above water environments during or immediately after transplanting in both wet season (September to November) and dry season (February to April). The population peaks occur in October for the wet season and in March for the dry season both coinciding to the maximum tillering stage of the rice plant. During harvest and fallow periods, some spiders still remain in the rice fields but in low densities. Generally, these are hard to find because the spiders hide by staying underneath soil cracks and root systems of the stubbles. Most often, the spiders are easier to find in surrounding areas after harvest. These nearby habitats surrounding rice fields serve as refuge areas for these predators. Here, they are provided their nutritional requirements for survival and reproduction as surrounding habitats are house to a wide array of preys, namely: the collembolans, fruit flies and other dipterans, moths and butterflies, leafhoppers and planthoppers, etc. The peaks of abundance of spiders in non-rice habitats are in August, September and December. The lowest population was in November and during summer months of April to June when grass cover is minimal, stunted and almost burned due to drought (Fig. 1).

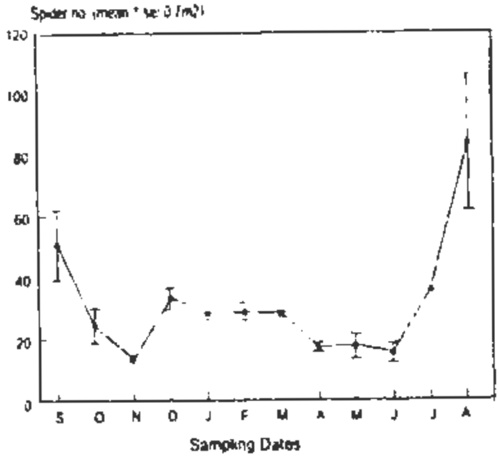

Figure 1. Seasonal Population Trends of Orb-Weavers and Hunting Spiders

In terms of movements, spiders do switch habitats for shelter and search for their nutritional requirements. Transparent mylar films thinly coated with tangle foot on both sides and placed vertically around rice field or specific habitat as enclosure strongly demonstrated that during land preparation, spiders emigrate and immigrate. Fallow fields when plowed increase spider migration into newly transplanted rice fields. One day after transplanting (1 DT), spider density in the rice field increased nine folds compared to rice field with surrounding unplowed fallows. The increase in spider density is extended further at 20 DT and 40 DT with 6.7 and 5.4 folds increase, respectively (Table 3). These movements of spiders that comprise 78-89% of the wolf spiders, *Pardosa pseudoannulata* (Boesenberg & Strand) and *P. irriensis* Barrion & Litsinger and the dwarf spider, *Atypena formosana* (Oi) regulated leafhopper and planthopper densities to 18.2±6.7/m^2 at 20 DT and 15.4±4.3/m^2 at 40DT. This result can be one management option in spider manipulation to combat insect pest problems in the rice fields.

Table 3. Effect of plowing surrounding uncultivated areas on spider population in irrigated rice fields.

Type of practice	DT	Density per square meter	
		Spiders	GLH, BPH, WBPH
	1	35.8	60.8
Plowed	20	22.8	18.2
	40	17.4	15.4
	1	4	23.4
Unplowed	20	3.4	60.8
	40	3.2	178.8

* Ave. of 5 reps. of spider and hopper densities per square meter. DT= days after transplanting.

C. Prey and Predation Rates-Spiders have a variety of prey. In rice agroecosystems, Barrion (1981) documented the prey records of 48 taxa of riceland spiders in their natural habitat while in farmers' fields in the different cropping systems sites throughout the Philippines from 1977 to 1981. Among the spider group observed are the 10 most prevalent taxa that are key biological control agents against rice insect pests (Barrion and Litsinger, 1984).

Most of the spider preys are soft-bodied phytophage insects notably common in the rice ecosystems viz. chironomids, collembolans, leaffolders, leafhoppers, planthoppers, ricebugs, stemborers, and whorl maggots. In year 2000, the prey breadth of five common web building spiders, namely, *Atypena formosana* (Oi) [Family Linyphiidae], *Tetragnatha virescens* Okuma [Family Tetragnathidae], *Wendilgarda liliwensis* Barrion & Litsinger [Family Theridiosomatidae], *Araneus inustus* (L. Koch) and *Argiope catenulata* (Doleschall) [Family Araneidae] was presented for the first time. The entire prey spectrum consisted of 198 species belonging to 91 families in 14 orders, all belonging to Class Insecta. Of these, 48.9% (98 species) are rice insect herbivores. A small portion of preys caught in the webs are beneficial species (Barrion, 2000). Araneophagy was not observed among the five web building spiders. Some preliminary observations are available for the spiders with hunting behaviour but a more rigorous documentation is still needed at this point to make conclusive statements. For instance, Li *et al.* (1997) reported flies to be one prey component for the jumping spiders. In *Scytodes* , the spitting spider [Family Scytodidae], 120 records of its feeding were observed in the field. Insects accounted for 19% (n=23) of all the preys and the other 81% (n=97) were spiders. Among the scytodid preys are leafhoppers, planthoppers, moths, lacewing, crickets and preying mantis (Li *et al.*, 1999).

Knowledge of prey quality is important in the utilization of spiders in natural biological control and spider management. In rice field spiders such as *Pardosa pseudoannulata* and *Atypena formosana*, mixed diet of fruitflies, leafhoppers and planthoppers and collembola provided the nutritional requirements for their survival. These spiders may live on collembola or fruitflies alone but mixed diet is essential to optimize fecundity. Similarly, pollen feeding in rice by the orb web spider *Argiope catenulata* (Doleschall) has been found to increase female spider fecundity

The insect predation rates of spiders are known only to a limited number of taxa. Table 4 shows the daily consumption rates of 14 riceland spiders (10 web builders and 4 hunters) in caged experiments using collembola (Symphypleona:Sminthuridae) and six key rice insect pests, such as green leafhoppers (Hemiptera:Cicadellidae), brown and whitebacked planthoppers (Hemiptera:Delphacidae), yellow stemborer and rice leaffolder (Lepidoptera:Pyralidae), and the rice whorl maggot (Diptera:Ephydridae). Individual predation rates are good. For instance, *Pardosa* spp. consumed 23 3^{rd}-4^{th} instar nymphs of green leafhoppers, 29 4^{th} instar nymphs of brown planthopper and 27 3^{rd}-4^{th} instar nymphs of whitebacked planthoppers. This is remarkable for this predator because its "wasteful killing" behaviour inflicted high mortality to the developing sucking pests that otherwise are transformed to full adults and produce another generation of pests. On the flood water, these wolf spiders consumed daily about 27 rice whorl maggot adults and 36 collembolans. The sit and wait web builders, on the other hand, contributed a relatively small share in regulating insect pest population. However, the community of spiders in the rice field and its surrounding areas are likely to exert more pressure and control against the rice insect pests. Singleton species predation are less effective in insect pest control unless this is mass reared and released at high densities. Gavarra and Raros (1975) demonstrated this phenomenon in the third generation of brown planthopper nymphs using *Pardosa pseudoannulata* (Boesenberg & Strand), thereby prevented the rice "hopperburn" injury to occur. Mass rearing spiders, however, is still time consuming and not cost effective.

Another dominant spider predator in rice field is *Atypena formosana* (Oi), the dwarf spider and a member of the Linyphiidae family. Sigsgaard and Villareal (1999) determined its functional response based on the number of preys eaten per predator at different prey densities. They found the functional response of *A. formosana* similar to Hollings type I, II, and III functional equations with strong preference to the second instars of green leafhopper, second and third instars of the brown planthopper.

D. NATURAL ENEMIES-Like any other animals, spiders have their own foes. Among these natural enemies are 15 hymenopteran parasites comprising of six undescribed species of scelionids belonging to three genera (*Baeus*, *Ceratobaeus* and *Idris*), six ichneumonid wasps in five genera (*Astomaspis*, *Caenopimpla*, *Linella*, *Paraphylax* and *Strepsimallus*), two undetermined braconid genera, one

Pompilinae,and one each of a mantispid (Neuroptera: Mantispidae) and a sarcophagid fly (Diptera: Sarcophagidae). The small scelionid wasps are the most common egg parasitoids of the leaf folding spider, *Clubiona japonicola* Boesenberg & Strand and the orb-weavers, *Araneus inustus* (L. Koch) and *Neoscona theisi* (Walckenaer). The ichneumonid *Caenopimpla arealis* (Cushman) was specific to the lynx spider, *Oxyopes javanus* Thorell whereas the other five ichneumonids were reared from *Argiope catenulata*, *Atypena formosana* and *Tetragnatha* spp. So far the braconids were only reared from *Tetragnatha*. The undetermined mantispid was reared for the first time from the egg cocoons of *P. pseudoannulata*. A sarcophagid fly, *Pierretia litsingeri* Shinonaga and Barrion was host specific to *A. catenulata*.

Pathogens and nematodes also parasitize spiders. The fungus *Gibellula leiopus* (Vuill.) Mains, *Torrubiella* sp. and one undetermined species attacked spiders. All these fungi were observed on *A. formosana*, *Clubiona*, and salticid spiders. On the other hand, the nematode was isolated from the lycosid, *Pardosa* spp.; salticid, *Cosmophasis* sp.; and the thomisid, *Thomisus okinawensis* Strand. The extent of parasitism on spiders showed a wide range. Based on field observations and rearings of spiderlings and adults, 0.60-56% level of parasitism had been recorded.

The predators of spiders are bull frogs, toads, birds, ants and two sphecid wasps, *Chalybion bengalense* (Dahlbom) and *Sceliphron madraspatanum conspicillatum* Costa.

Similarly, the marsh fly, *Sepedon* spp. preyed on the eggs of *Tetragnatha* spp. Because some spiders are araneophagic hunters, spiders themselves are also their predators.

Natural enemies are strong limiting factors in the effective and efficient utilization of spiders in natural biological control of rice insect pests.

E. CONSERVATION PRACTICES-A number of strategies are recommended to farmers to conserve spiders and optimize their innate potential in the natural control of rice insect pests. These provisions are (1) maintain refuge areas with diverse plants and landscapes, (2) maintain rice straw stock files around rice fields, (3) avoid burning habitats surrounding rice fields, (4) avoid overgrazing rice bunds and surrounding grassy areas, (5) avoid using herbicides on grasses around rice fields, and (6) use selective insecticides judiciously against rice insect pests. All these practices are crucial in maintaining the spider population in and around rice fields.

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