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Research Article

Evaluation of feeding potential of different spider species under laboratory and greenhouse conditions

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ABSTRACT

This study evaluates the feeding efficiency of three predatory spider species: *Thyne imperialis* (jumping spider), Thomisus sp. (crab spider), and Rukkidus sp. (jumping spider), under laboratory and greenhouse conditions. The spiders were tested for their potential to control guava mealybugs (Ferrisia virgate), a major pest in guava orchards. Experiments conducted in petri dishes and potted guava plants simulated natural habitats. Results revealed that Thomisus sp. exhibited the highest predatory potential, consuming an average of 6.0 ± 0.42 mealybugs within 24 hours, followed by *Thyne imperialis* (5.0 ± 0.40) and Rukkidus sp. (3.2 ± 0.31). The overall feeding efficiency of Thomisus sp. was 20–30% higher than the other two species across all exposure durations. Greenhouse trials confirmed similar predatory trends, demonstrating the adaptability and persistence of these spiders in semi-natural conditions. These findings emphasize the potential of Thomisus sp. and *T. imperialis* as effective biological control agents for managing guava mealybugs in both laboratory and greenhouse settings.

Keywords: IPM; biological control; feeding efficiency; predatory spiders; natural enemies.

INTRODUCTION

Pakistan is the 5th largest guava producing country globally with 804,000 tons of guava production (Positive Pakistan, 2025). It is widely cultivated in various parts of Pakistan. Larkana and Hyderabad are the major guava producing districts of Sindh province. Numbers of growers have fruit orchards in Larkana, especially in Naudero and Ratodero Talukas, where orchards are spread over 30,000 acres of land. Approximately 80 insect and mite species are reported to cause growth and yield losses in guava. Among all Fruit fly is very destructive and major insect pest of Guava fruit; but nowadays the guava production has been tremendously affected by mealy bugs in Sind. Mainly two species of guava mealybugs; Ferrisia virgate and Drosicha mangiferae are prevalent pest in guava orchards of Sindh causing substantial economic losses in Sindh. Mealybugs are very difficult to eradicate due to their habit of living in the protecting cracks and crevices of the tree bark, lower surface of the leaves and within the fruit bunch. Nymphs and adults of this pest have waxy coating on their body for their protection due to which most of the insecticides do not penetrate into their body and pest can easily survive (Mani et al., 2011). Environmentally safe methods of pest control are considered an essential part of balanced agro-ecosystem management and protection (Naveed et al., 2008).

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However, in Pakistan most of the farmers use toxic chemical pesticides on many crops and orchard trees (Dich et al.,1997). The chemical pesticides used for crop protection have potentially toxic residues posing risk to human and environmental health and adverse effect on non-target organisms and natural ecosystem has been also disturbed (Ahmad and Akhtar, 2016).

The use of natural enemies for pest control is an important approach of Integrated Pest Management program. (Bellows & Fisher, 1999). In sustainable agriculture trends have developed to minimize the use of synthetic pesticides and to increase the use of biological control agent like predatory spiders as an efficient natural enemies of the crop pests (Ghafoor et al., 2006). Spiders are predatory arthropods in class Arachnida and order Araneae. Predatory spiders prey on insects and some arthropods and can perform well as an effective bio control agent in integrated pest management program. The examples include control of the cassava bugs, green mites and mango mealy bugs from Asia (Karar et al., 2006). The Spiders are contributing greatly to the suppression of insect pest populations (Nyffeler & Sunderland, 2003). Among them, Thomisus species (Thomisidae) are ambush predators that capture a wide range of soft-bodied insect pests such as aphids, whiteflies, and mealybugs, thereby playing a crucial role in maintaining ecological balance in fruit and vegetable crops (Sebastian et al., 2005; Uetz et al., 2010). *Thyne imperialis* (Salticidae) is an active hunter known for its excellent vision and predatory behavior against mobile insect pests, particularly small hemipterans and dipterans (Jackson & Pollard, 1996). Predatory spiders are valuable natural enemies in agro ecosystems, contributing significantly to pest control. This study evaluates the feeding potential of three dominant spider species, *Thyne imperialis*, Thomisus sp. and Rukkidus sp. collected from guava orchards in Sindh, Pakistan. The aim was to assess their predatory efficiency under laboratory and greenhouse conditions to determine their suitability as biological control agents of guava mealybugs.

MATERIALS AND METHODS

Collection and Maintenance of Spiders

To evaluate feeding potency of predatory spiders under laboratory and greenhouse conditions, 3 different spider species namely; *Thyne imperialis* (Jumping Spiders: Family: Salticidae), *Thomisus* sp. (Crab Spiders: Family: Thomisidae) and Rukkidus sp. (Jumping Spiders: Family: Salticidae) were collected from guava orchards. Each spider was kept individually in petri dishes (5.2 cm in diameter and 1.2 cm height) and placed at room temperature in the laboratory of department of entomology, faculty of agriculture science the University of Larkano. Guava leaves were placed in each petri dish to provide natural environment to the spiders. Few drops of water were provided in petri dishes in order to maintain humidity as the spiders do not thrive under dry conditions. A thin layer of paper towel was also placed at the base of petri dishes to retain moisture and facilitate cleaning.

Experimental Setup

Fully grown spiders of above mentioned three species were placed separately in three petri dishes (5.2 cm in diameter and 1.2 cm height) and replicated five times. Guava leaves were also placed in each petri dish to provide natural environment to the spiders and mealybugs. Prior to the use in experiment, spiders were kept starved for 48 hours to minimize the differences in individual hunger levels and then 15 mealybugs were introduced into each petri dish separately as food source at same density levels. Predatory potential was noted by counting the remaining mealybugs in each petri dish. Observations were made after 24, 48 and 72 hours of experiment to record the numbers of mealybugs consumed by each spider. The experiment was replicated 5 times. On the basis of the total numbers of mealybugs consumed by a single spider within 72 hours, the feeding efficiency of all three spiders was recorded in the laboratory conditions. Average consumption was calculated by using following formula:

$$\text{Average rate} = \frac{\text{Total numbers of mealybugs consumed}}{\text{Total numbers of mealybugs offered}} \times 100$$

Greenhouse Experiment

Similarly, for further confirmation of the results obtained from laboratory assay, same species of the predatory spiders were evaluated for their feeding potency under natural enemies' field microhabitat (greenhouse) established at experimental field, department of entomology, faculty of agriculture science, the University of Larkano. For that purpose, (two years old, 4 feet high) 15 guava plants were sown in 15 pots under greenhouse conditions. 15 mealybugs were released separately on each potted plants as food source at the same density levels. Prior to the release on potted plants, above mentioned spider sp. were kept starved for 48 hours in the laboratory to minimize the differences in individual hunger levels and then released singly on a potted plant. The experiment was replicated 5 times. After releasing of spiders, the pots were covered by muslin cloths in order to avoid escape and movement of spiders from one pot to other. Predatory potential was noted by counting the remaining mealybugs in each pot. Observations were

made after 24, 48 and 72 hours of spider released in covered pots to record the numbers of mealybugs consumed by each spider. On the basis of the total numbers of mealybugs consumed by a single spider within 72 hours, the feeding efficiency of all three spiders was recorded under greenhouse conditions. Average consumption was calculated by using the same formula as mentioned above.

Statistical Analysis

Data were analyzed using two-way Anova in Statistix 8.1 software, with feeding potential and time duration as main effects. Differences in predation rates were tested for significance using the LSD post-hoc test at a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

Three most dominant predatory spiders were tested for this study based on their voracious feeding and their abundance in most of the guava orchards of Sindh. The results (Table.1) demonstrated that Thomisus sp. exhibited the highest feeding efficiency. *Thyne imperialis* showed moderate efficiency. Rukkidus sp. consumed the least mealybug consumption. All spiders showed a consistent feeding trend across the three observation periods (24, 48, and 72 hours). The 24-hour interval accounted for the highest consumption, indicating rapid initial feeding after starvation. The results of feeding potency of predatory spiders effectively supported the natural behavior of all three spider species tested for their feeding efficiency under laboratory conditions. Overall results revealed that Thomisus sp. is the most voracious predator among the three species, making it a promising biological control agent for the control of guava mealybugs.

Table 1. Mean numbers of mealybugs consumed by each spider after 24,48 and 72 hours of release under laboratory conditions.

Spider Species Tested	Observations	Mean No. Consumed ± SE	Total Consumed	Average Rate (%)
Thyne imperialis	24 hours	5.0 ± 0.40	25	33.3
	48 hours	3.8 ± 0.35	19	25.3
	72 hours	3.8 ± 0.33	19	25.3
Thomisus sp.	24 hours	6.0 ± 0.42	30	40
	48 hours	4.6 ± 0.38	23	30.6
	72 hours	3.6 ± 0.36	18	24
Rukkidus sp.	24 hours	3.2 ± 0.31	16	21.3
	48 hours	2.8 ± 0.29	14	18.6
	72 hours	2.6 ± 0.27	13	17.3

The data (Table 2) revealed feeding potency of different spider species at various time durations. The ANOVA shows that the mean numbers of mealy bugs consumed by Thomisus sp. was significantly higher than the other spider species after 24 hours with (6.0) numbers of mealybugs followed by Thyne imperialis with (5.0) and Rukkidus sp. with (3.2) numbers of mealybugs. Similarly, the mealybugs consumed by Thomisus sp. after 48 hours was significantly higher than fed by other species with (4.6) numbers followed by *T. imperialis* with (3.8) numbers while Rukkidus sp. consumed minimum numbers (2.8) mealybugs (P=0.001). However, the mean numbers of mealybugs consumed by *T. imperials* was significantly higher (3.8) numbers followed by Thomisus sp. (3.6) and Rukkidus sp. (2.6) numbers after 72 hours (P=0.001). The data further indicated that Thomisus sp. consumed more numbers of mealybugs (6.0) after 24 hours followed by (4.6) after 48 and (3.6) after 72 hours. *T. imperialis* consumed more numbers of mealybugs (5.0) after 24 hours followed by (3.8) after 48 and 72 hours. Similarly, Rukkidus sp. consumed more numbers of mealybugs (3.2) after 24 hours followed by (2.8) after 48 and (2.6) after 72 hours.

Greenhouse Assay

Similarly, for further confirmation of the results obtained from laboratory assay, same species of the predatory spiders were evaluated for their feeding potency under greenhouse conditions. The results obtained from the greenhouse assay supported the results of laboratory assay. The data (Table 3) indicated that same pattern of feeding was found in the greenhouse conditions as found in lab experiments. Again Thomisus sp. showed the highest potency of feeding among all three species tested in the experiment.

Table 2. Feeding potency of different spider species at various time durations under laboratory conditions.

Spider Species Tested	Observation Time			Spiders species	Duration	Spiders *Duration interaction	S.E	LSD
	24 Hours	48 Hours	72 Hours					
T. imperialis	5.0b	3.8c	3.8c	0.0001	0.0001	0.0286	0.387	0.788
Thomisus sp.	6a	4.6b	3.6c					
Rukkidus sp.	3.2cd	2.8d	2.6d					

Table 3. Mean numbers of mealybugs consumed by each spider after 24, 48 and 72 hours of release under greenhouse conditions.

Spider Species Tested	Observations	Mean No. Consumed ± SE	Total Consumed	Average Rate (%)
Thyne imperialis	24 hours	3.6 ± 0.35	18	24
	48 hours	2.6 ± 0.30	13	17.3
	72 hours	2.2 ± 0.28	11	14.6
Thomisus sp.	24 hours	4.2 ± 0.40	21	28
	48 hours	3.6 ± 0.35	18	24
	72 hours	3.2 ± 0.33	16	21.3
Rukkidus sp.	24 hours	2.2 ± 0.27	11	14.6
	48 hours	1.8 ± 0.25	9	12
	72 hours	2.0 ± 0.24	10	13.3

The ANOVA (Table 4) shows that the mean numbers of mealy bugs consumed by Thomisus sp. was significantly higher than the other two spider species after 24 hours with (4.2) numbers of mealybugs followed by *Thyne imperialis* with (3.6) and Rukkidus sp. with (2.2) numbers of mealybugs. Similarly, the mealybugs consumed by Thomisus sp. after 48 hours was significantly higher than other species with (3.6) numbers followed by *T. imperialis* with (2.6) numbers while Rukkidus sp. consumed minimum numbers (1.8) mealybugs (P=0.001). The mean numbers of mealybugs consumed by Thomisus sp. was also significantly higher (3.2) numbers followed by *T. imperialis* sp. (2.2) and Rukkidus sp. (2.0) numbers after 72 hours (P=0.001).

Table 4. Feeding potency of different spider species at various time durations under greenhouse conditions.

Spider Species Tested	Observation Time			Spiders species	Duration	Spiders *Duration interaction	S.E	LSD
	24 Hours	48 Hours	72 Hours					
T. imperialis	3.6ab	2.6cd	2.2de	0.0001	0.0006	0.222	0.3598	0.7329
Thomisus sp.	4.2a	3.6ab	3.2bc					
Rukkidus sp.	2.2de	1.8e	2.0de					

The results of both experiments clearly indicated that maximum numbers of mealybugs were consumed in the lab as well as in the greenhouse conditions by Thomisus sp. proving its higher predatory competence. *Thyne imperialis* also proved satisfactory predatory efficiency, while Rukkidus sp. showed the lowest ability of feeding against guava mealybugs. The overall results obtained from both experiments concluded that Thomisus sp. is the most efficient predator under both conditions and can be taken as the most efficient natural enemies of mealybugs among all three tested predatory spiders. *Thyne imperialis* also proved himself as a second efficient predator while Rukkidus sp. has lesser feeding efficiency against guava mealybugs and may not be utilize as biological control agent.

Both experiments highlighted the significance of bio control agent selection for pest control, supporting Thomisus sp**.** and *Thyne imperialis* for their active feeding rate. These results emphasize the importance of Thomisus *sp.* and *Thyne imperialis* as an efficient bio control agent under both laboratory and greenhouse conditions. The mealybug populations could significantly be reduced by the incorporation of these natural enemies into pest management programs to promote sustainable agriculture.

DISCUSSION

The findings of this study emphasize the potential role of predatory spiders as an effective bio control agent, particularly Thomisus sp. and *Thyne imperialis*, in controlling guava mealybug, a serious threat in guava orchards of Sindh nowadays. The predatory efficiency of spiders under lab as well as in greenhouse conditions demonstrated regular patterns, emphasizing the ecological role of spiders in IPM programs. Among all tested species, Thomisus sp. was the most efficient sp. which revealed the highest predatory efficiency across all observation intervals under both experimental conditions. These results support earlier studies carried out by Jackson & Pollard (1996) and Nyffeler & Sunderland (2003) who reported that crab spider (Thomisidae) is an active predator capable of feeding various soft bodied insects, including mealybugs, whiteflies, and aphids. Due to their strong forelegs and mimetic body color, their hunting ability increases which allow them to remain hidden on flowers and leaves during prey. The results of this study also agree with the studies of Ghafoor et al. (2006), who reported the importance of integration of predatory spiders within IPM systems. Several studies have been reported from Pakistan that emphasizes the diversity and potential of native predatory spider fauna in various cropping systems. Khan et al. (2021) reported the significant role of crab and jumping spiders in fruit orchards of Punjab, revealing their role in suppressing soft-bodied insect pests. Similarly, Rajput et al. (2023) highlighted that Thomisus sp. and *Thyne imperialis* significantly reduced guava mealybug populations under controlled and semi-field conditions.

Jumping spider, *Thyne imperialis* is a member of Salticidae, showed moderate feeding efficiency. Harland & Jackson (2000) reported that Salticids are well known for their powerful vision and active predatory habits. Although *Thyne imperialis* showed low predation rate than Thomisus sp., but it also consumed a significant number of mealybugs, which makes it secondary potential biological control agent of mealybugs in guava orchards. These findings are aligned with earlier studies carried out by Richman & Whitcomb (1981) and Pekar & Toft (2015) who emphasized the significant role of Salticids in prey selection and their behavior regarding adaptability to various microhabitats.

Present studies further revealed that Rukkidus sp., even though a jumping spider, but showed the lowest feeding potential. This could be due to its limited aggressiveness, particular prey selection or physiological characteristics that make it less efficient against mealybugs. Furthermore, waxy coating of mealybugs may prevent them certain predators and low predatory potential of Rukkidus sp. may occur due to such morphological features. (Serrano & Folgarait, 2013).

The studies showed that most of the predation was occurred after 24 hours of release, as spiders were kept starved for 48 hours before their release that was standardized hunger levels across individuals. This pattern suggests that starvation strongly stimulate spiders that impacts initial feeding response (Pekar, 2005). However, predation rates slowly dropped after first 24 hours of feeding, which may reveal repletion or shortage of prey availability as per confined experimental design.

Similar pattern of feeding behavior was found between lab and greenhouse experiments, confirming the ecological stability of the observed predatory response. To assess spider performance under natural circumstances, the greenhouse conditions worked as semi natural environment or actual field conditions. The uniformity between both environmental conditions highlights the reliability of these results for practical application in guava orchards.

The present findings agreed with the studies carried out by Marc et al. (1999) and Ghafoor et al. (2006) that supported the integration of potentially active predatory spiders into IPM programs. Moreover, chemical control methods often fail to reach hidden mealybug populations and can also disturb natural ecosystem (Mani et al., 2011; Ahmad & Akhtar, 2016). Using native predators like Thomisus sp. and *Thyne imperialis* offers an ecologically efficient alternate. Besides, indiscriminate use of pesticides creates ecological imbalance, developed resistance and resurgence in pests (Naveed et al., 2008) making spider-based sustainable pest control method.

The studies also highlight the significance of predator selection in integrated pest management programs. All three tested species are native and naturally occurring in guava orchards, only Thomisus sp. and *Thyne imperialis* demonstrated practical predation rates. These findings indicate that successful biological control of pests relies not only on availability of predators but also on their functional behaviors like prey catching efficiency, ability to adopt local microhabitats, and feeding behavior.

CONCLUSION

These findings determine that Thomisus sp. is the most active predator for guava mealybugs under laboratory and greenhouse conditions, followed by *T. imperialis*. These both species can include in integrated pest management programs. Integration of very effective predatory spiders into guava pest management tactics, contributing to sustainable ecofriendly agricultural practices and could significantly reduce dependence on toxic chemicals that have

long residual effects on crops, natural enemies and ecosystem. Future studies should carry out the long-term survival, reproduction, and field dispersal behavior of these spiders, as well as their interaction with other natural enemies and compatibility with other IPM components.

AUTHOR'S CONTRIBUTION

Performed the experiment: Shabana Naz Mazari & Abdul Samad Soomro, analyzed the data: Agha Mushtaque Ahmed and Tufail Ahmed Wagan, contributed in material: Shah Nawaz Khuhro and Fahad Nazir Khoso, designed the experiment & wrote the paper: Shahjahan Rajput.

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AVAILABILITY OF DATA AND MATERIAL

All data generated or analyzed in this study are presented within this article in the form of tables and figures.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the relevant forum.

CONSENT FOR PUBLICATION

All the authors are agreed on the publication.

CONFLICT OF INTERESTS

Authors have no conflict of Interest regarding this publication.

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