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# Safety of insecticidal sprays to spider and predatory coccinellids in varied rice cultivation systems

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**Abstract**
A study was conducted to understand the impact of insecticides on spiders and predatory coccinellids in different cultivation systems of rice. The experiment was laid out in the College Farm, College of Agriculture, Rajendranagar in *kharif* seasons of 2014-15 and 2015-16 in a split plot design, where rice crop was grown in the form of three main modules with three different methods of establishment *viz*., transplantation, broadcasting and drumsown rice with three sub-modules under each main module *viz*., organic protection, farmers' practices and 'no protection'. Need based application of plant protection measures was taken up in the farmers' practices and organic protection practices. Data on spiders and predatory Coccinellids counts taken before and after the imposition of treatments revealed that significantly higher predator numbers were observed in 'no protection plots" > organic protection plots > farmers' practices in both the years of study. At three days after spray, transplanted 'no protection' plots recorded significantly highest number of spiders (27.18/quadrat), while at seven and fifteen days after spray, drumsown 'no protection' practices recorded significantly higher predator numbers compared to the other treatment (29.04 and 31.36 spiders/quadrat respectively). Similarly, Coccinellids were found to be in significantly higher numbers in transplanted 'no protection' plots' at three and seven days after spray (20.82 and 22.48 spiders/quadrat), while at fifteen days after spraying, drumsown 'no protection' plots recorded significantly higher populations of the beetles (23.63 beetles/quadrat). Significantly lesser population of the beetles at three and seven days after spraying were observed in drumsown 'farmers' protection' plots (10.51 to 12.56 beetles/quadrat), while in the farmers' practices plots of transplanted and broadcasted modules, significantly least beetle number (14.46-14.48 beetles/quadrat) were recorded.

**Keywords:** Spiders, coccinellids, chemical insecticides, toxicity, neem oil

## Introduction
Rice is the staple food for 3 billion people around the world. More than 800 pests have been recorded on the crop (Litsinger, 2012) [1]. Chemical insecticides give good management of pests, however, leave long time effects on the environment, non target flora and fauna and toxic residues in plant produce, besides raising input costs. Integrated pest management tactics suggest minimizing the use of chemical insecticides due to their hostility to beneficial insects. They disturb the balance in the food chain of the ecosystem and cause profound effects on various trophic levels. They are known to alter the behaviour and predation efficacy of the potential generalist predators in rice crop *viz*., like spiders and Coccinellids. Impact on their predation ability further affects their survival and reproduction. Spiders and Coccinellids are generalist predators and contribute greatly to natural control. There is great potential for increasing the benefits derived from naturally occurring biological control agents, through the elimination or reduction in the use of pesticides toxic to natural enemies (El-Wakeil *et al*., 2013) [2] and the impact of insecticides on the biological agents needs to be understood and explored to formulate an IPM program. Hence, the present experiment was planned to study the effects of most commonly used broad-spectrum insecticides in rice *viz*., Chlorpyriphos and a botanical insecticide *viz*., neem oil on the abundance and diversity of spiders and Coccinellids in rice were studied.

## Materials and methods
The study was conducted during *kharif* seasons of 2014-15 and 2015-16 in the College Farm, College of Agricultural Rajendranagar, Hyderabad. The experiment was laid out in a plot of 1500 sq.m. at College farm, Rajendranagar with rice variety BPT 5204.

Design of the experiment consisted of three main modules transplantation, broadcasting and drumsowing, each of which hadthree types of plant protection measures *viz*., organic protection, farmers' practice and "no protection" (Fig.1.). The size of each module was 36 X 12.$m^2$. Recommended dosages of fertilizers were applied to all the modules as per PJTSAU recommendations.

In each main plot, three sub-plots were prepared by forming the treatment bunds. Size of the treatment plots was 12 m X 12.m. Treatment sprays were taken up at 36 SMW and again at 39 SMW. Sub-treatments under each module included organic protection (use of Trichocards, pheromone traps, botanical sprays) farmers' practices (spray of chlorpyriphos @ 2.50 ml/L water) and 'no protection'.

**Organic protection package was implemented and it consisted of the following components**

1) **Biological control:** Trichocards containing *Trichogramma japonicum* were pinned to the underside of the leaves @ 50,000 $ha^{-1}$ / release and six such releases were carried out starting at 35 days after transplantation. *T.chilonis*cards were also pinned to the leaves @ 50,000 $ha^{-1}$ /release and six such releases were carried out starting at 37 standard week at the time of the second spray when leaf folder adults were noticed in the field.
2) **Use of pheromone traps:** Pheromone traps were purchased from M/s.Agri Life Ltd., Bollaram, Medak dist., and were installed in the organic protection plots at 30 DAT. The lure was changed once every 22 days till 70 DAT.
3) **Botanicals:** Sprays of Neem oil 1.0% were taken up in the organic protection plots when the pest crossed economic threshold level once at 36 SMW and again at 69 SMW

**Farmers' Practices**

In this sub-treatment, carbofuran 3G granules were applied to the crop one week before pulling of nursery applied at the rate of 200 g/cent of nursery in the transplantation module plots. In the broadcasted and drumsown rice, carbofuran granules were applied at 30 days after sowing at the rate of 10 kg / acre. In addition, foliar sprays of chlorpyriphos @ 2.50 ml/L water were given when the pests crossed the Economic Threshold Level (ETL) once at 36 SMW and again at 39 SMW.

**No Protection practices**

This was the untreated sub treatment.

**Observations on the predators**

Observations on the populations of spiders and coccinellid predators were recorded in each of the treatment plots in five quadrats (1m X 1m) / each treatment plot one day before and one, three and seven days after the spray. In each plot, the metal quadrat was placed in the four corners and in the centre to get a uniform count of the insects in that plot.

**Diversity Indices**

To study the Diversity of spiders and coccinellids, indices were calculated using the following formulae.

**Species Richness**: This was calculated using the following formula: Species richness (S) = number of species/genera collected.

Species diversity (H') was computed using Shannon-Wiener index of diversity (Shannon and Wiener, 1949) [3]

$$\text{Species diversity (H')} = -\sum_{i=1}^{k} p_i \ln p_i$$

where,

$p_i$ = Proportion of ith species in the total sample

$p_i = f_i/n$

n = Total number of specimen in the sample

$f_i$ = Number of specimen of the $i^{th}$ species

k = total number of species

ln = natural logarithm ($\log_e$)

Pielou's Evenness Index or equitability (E) was calculated using the following formula given by (Pielou, 1960) [4].

$$E = \frac{H'}{\text{Ln (S)}}$$

Where, Ln (S) = natural logarithm of the number of species present

**Total predator density/sq.m** was calculated using the formula

$$\frac{\text{Total no.of predators recorded}}{\text{No.of quadrats observed}}$$

**Results**

**Safety to Spiders**

Analysis of two year data indicated that there was a significant reduction in spider population after the insecticidal sprays but the diversity was unaffected both the years. Establishment method had a profound effect on the abundance with significantly higher numbers in drumsown and transplanted rice.

At three days after spray, number of spiders was significantly affected. Significantly highest number of spiders were recorded in transplanted 'no protection' plots (27.18/quadrat) > broadcasted 'no protection' plots (26.48/quadrat) >drumsown 'no protection' plots (25.74/ quadrat) >drumsown organic plots(19.14/ quadrat) > transplanted organic plots (17.81/quadrat) = broadcasted organic plots (17.66/quadrat) >drumsown farmers' practices (14.85/quadrat) = transplanted farmers' organic plots (14.66/quadrat) > broadcasted farmers' practices (13.33/quadrat) (Table.1.). In general, the abundance in decreasing order was 'No protection' plots > Organic protection plots > farmers' practices.

At seven days after spray, the descending order of treatments with respect to numbers of spiders was as follows: transplanted 'no protection' plot (29.07/quadrat)=drumsown 'no protection' (29.04/quadrat) > broadcasted 'no protection' (28.67/quadrat) >transplanted = drumsown organic protection (22.56 and 22.70/quadrat, respectively) > broadcasted organic plot(22.29/ quadrat) > transplanted farmers' practices(18.70/quadrat) > broadcasted farmers' practices(18.44 /quadrat) = drumsown farmers' practices (18.29/quadrat). In general, the abundance in decreasing order was found to be 'No protection' plots > Organic protection plots > farmers' practices.

**Table 1:** Safety of insecticidal sprays to spiders

| Main Treatments/sub-treatment | Spider population/quadrat (mean of two years) | | | |
|---|---|---|---|---|
| | **1 DBS** | **3 DAS** | **7 DAS** | **15 DAS** |
| **Establishment Method** | | | | |
| M1 Transplanted rice | 20.86(13.70) | 19.89(13.26)[a] | 23.44(14.46)[a] | 27.87(15.81)[c] |
| M2 Broadcasted rice | 20.44(13.66) | 19.16(13.00)[b] | 23.13(14.37)[b] | 28.59(16.04)[b] |
| M3 Drumsown rice | 20.44(13.66) | 19.91(13.30)[a] | 23.34(14.43)[a] | 29.04(16.16)[a] |
| CD (0.05) | NS | 0.18 | 0.11 | 0.07 |
| **Plant Protection measure** | | | | |
| S1 Organic protection | 20.27(13.61) | 18.20(12.79)[b] | 22.52(14.23)[b] | 28.59(16.14)[b] |
| S2 Farmers' Practices | 20.32(13.66) | 14.28(11.33)[c] | 18.47(12.89)[c] | 25.79(15.23)[c] |
| S3 No Protection | 20.30(13.65) | 26.47(15.43)[a] | 28.92(16.13)[a] | 30.75(16.64)[a] |
| CD (0.05) | NS | 0.14 | 0.12 | 0.06 |
| **Interaction Effects (M X S); Main at same level or different level sub** | | | | |
| Transplanted organic protection | 20.52(4.53) | 17.81(4.22)[e] | 22.56(4.75)[c] | 29.30(5.41)[d] |
| Transplanted farmers' practices | 21.53(4.64) | 14.66(3.83)[f] | 18.70(4.32)[e] | 23.75(4.87)[i] |
| Transplanted 'no protection' | 20.53(4.53) | 27.18(5.21)[a] | 29.07(5.39)[a] | 30.56(5.53)[b] |
| Broadcasted organic protection | 20.01(4.47) | 17.66(4.20)[e] | 22.29(4.72)[d] | 28.40(5.33)[f] |
| Broadcasted farmers' practices | 20.54(4.53) | 13.33 (3.65)[g] | 18.44(4.29)[f] | 27.04(5.20)[g] |
| Broadcasted 'no protection' | 20.76(4.56) | 26.48(5.15)[b] | 28.67(5.35)[b] | 30.33(5.51)[c] |
| Drumsown organic protection | 20.30(4.50) | 19.14(4.37)[d] | 22.70(4.76)[c] | 29.16(5.40)[e] |
| Drumsown farmers' practices | 20.15(4.49) | 14.85(3.85)[f] | 18.29(4.28)[f] | 26.58(5.16)[h] |
| Drumsown 'no protection' | 20.86(4.57) | 25.74(5.07)[c] | 29.04(5.39)[a] | 31.36(5.60)[a] |
| CD (0.05) | NS | 0.25 | 0.20 | 0.10 |

Figures in parentheses are square root transformed values
Values in a column with the same alphabet are not significantly different.
DBS – Day before sowing
DAS – Days after sowing

At fifteen days after spray also, 'no protection' plots registered significantly higher number of spiders and 31.36/ quadrat spiders were recorded in drumsown 'no protection' plots which were more than transplanted 'no protection' plots (30.56/quadrat) followed by broadcasted 'no protection' plots (30.33/quadrat). Organic protection plots differed significantly among themselves and with the other plots also (transplanted, drumsown and broadcasted with 29.30, 29.16 and 28.40/ quadrat, respectively). The farmers' practices in broadcasted, drumsown and transplanted plots recorded (27.04, 26.58 and 23.75/quadrat, respectively).

## Coccinellids

Results of analysis of two years' data revealed that Coccinellids were sensitive to chemical sprays because even after fifteen days, lesser population were noticed in treated plots. However, after the sprays, there was no decrease or change in the diversity of the coccinellids and only a decrease in their abundance was noticed. At three days after spray, maximum number of coccinellids were recorded in transplanted 'no protection' plots (20.82/quadrat) followed by drumsown 'no protection' plots (20.44/quadrat) and broadcasted 'no protection' plots (20.16/ quadrat) which were significantly inferior to the former (transplanted 'no protection' plots). Next were the drumsown organic plots (14.44/quadrat) which had significantly lesser population of coccinellids. It was on par with transplanted organic plot with 14.46 beetles/quadrat followed by broadcasted organic plot with 14.10 beetles/quadrat. Farmers' practices in all the three establishment methods contained very less number of coccinellid beetles. Farmers' practices in all the methods of rice establishment registered least number of beetles (broadcasted plot (11.21/ quadrat, transplanted rice (10.65/quadrat and drumsown farmers' practices 10.51 adults/quadrat (Table.2.).

At seven days after spray, the 'no protection' plots continued to harbor significantly highest number of beetles (22.48/quadrat in transplanted rice, 21.59 and 21.56/quadrat, respectively in broadcasted rice and drumsown rice). The latter two treatments were on par with each other but differed significantly from the first treatment. Drumsown organic treatment with 17.48 beetles/ quadrat was the next better one followed by 16.47 beetles/quadrat in broadcasted organic treatment and they differed significantly from each other. Transplanted organic stood next with 16.33 beetles/quadrat. This was then followed by the farmers' practice treatments of all types of main treatments which were on par with each other with 12.88, 12.56 and 12.33 in broadcasted, drumsown and transplanted systems, respectively.

At fifteen days after spray, all the treatments differed significantly from each and were in the following descending order : drumsown 'no protection' plots (23.63/quadrat) > transplanted 'no protection' plots (23.00/quadrat)>broadcasted 'no protection' plot (22.89/quadrat) >drumsown organic protection plot (18.79/quadrat) = broadcasted organic protection plot (18.79/quadrat) > transplanted organic protection plot (18.55/quadrat) >drumsown farmers' practices(14.85/ quadrat)> broadcasted farmers' practices (14.48/quadrat) = transplanted farmers' practices (14.47/quadrat).

Tahir *et al.* (2019) [5] reported that spiders spent less time on insecticide/herbicide-treated surfaces. Insecticide/herbicide treated Neoscona theisi consumed less prey than untreated control spiders. Similarly when N.theisi were offered insecticide/herbicide treated prey, they consumed significantly less.

**Table 2:** Safety of insecticidal sprays to Coccinellid predators

| Main Treatments/sub-treatment | Coccinellid population/quadrat (mean of two years) | | | |
|---|---|---|---|---|
| | 1 DBS | 3 DAS | 7 DAS | 15 DAS |
| **Establishment Method** | | | | |
| M1 Transplanted rice | 18.03(12.74) | 15.31(11.63)ᵃ | 17.05(12.29)ᵇ | 18.67(12.91)ᶜ |
| M2 Broadcasted rice | 18.00(12.73) | 15.16(11.59)ᵇ | 17.07(12.33)ᵇ | 18.72(12.92)ᵇ |
| M3 Drumsown rice | 18.01(12.73) | 15.13(11.56)ᵇ | 17.20(12.37)ᵃ | 19.09(13.05)ᵃ |
| CD (0.05) | NS | 0.07 | 0.06 | 0.03 |
| **Plant Protection measure** | | | | |
| S1 Organic protection | 18.01(12.73) | 14.33(11.36)ᵇ | 16.85(12.31)ᵇ | 18.71(12.98)ᵇ |
| S2 Farmers' Practices | 18.01(12.73) | 10.79(9.85)c | 12.59(10.65)ᶜ | 14.60(11.46)ᶜ |
| S3 No Protection | 18.03(12.74) | 20.47(13.57)ᵃ | 21.87(14.03)ᵃ | 23.17(14.45)ᵃ |
| CD (0.05) | NS | 0.05 | 0.05 | 0.05 |
| **Interaction Effects (M X S) Main at same level or different level sub** | | | | |
| Transplanted organic protection | 18.04(4.25) | 14.46(3.80)ᵈ | 16.33(4.04)ᵉ | 18.55(4.31)ᵉ |
| Transplanted farmers' practices | 18.00(4.24) | 10.65(3.26)ᵍ | 12.33(3.51)ᶠ | 14.46(3.80)ᵍ |
| Transplanted 'no protection' | 18.06(4.25) | 20.82(4.56)ᵃ | 22.48(4.74)ᵃ | 23.00(4.80)ᵇ |
| Broadcasted organic protection | 17.98(4.24) | 14.10(3.75)ᵉ | 16.74(4.09)ᵈ | 18.79(4.34)ᵈ |
| Broadcasted farmers' practices | 18.02(4.25) | 11.21(3.35)ᶠ | 12.88(3.59)ᶠ | 14.48(3.81)ᵍ |
| Broadcasted 'no protection' | 18.01(4.24) | 20.16(4.49)ᶜ | 21.59(4.65)ᵇ | 22.89(4.79)ᶜ |
| Drumsown organic protection | 18.01(4.24) | 14.44(3.79)ᵈ | 17.48(4.18)ᶜ | 18.79(4.33)ᵈ |
| Drumsown farmers' practices | 18.00(4.24) | 10.51(3.24)ʰ | 12.56(3.54)ᶠ | 14.85(3.85)ᶠ |
| Drumsown 'no protection' | 18.02(4.25) | 20.44(4.52)ᵇ | 21.56(4.64)ᵇ | 23.63(4.86)ᵃ |
| CD (0.05) | NS | 0.09 | 0.09 | 0.09 |

Figures in parentheses are square root transformed values
Values in a column with the same alphabet are not significantly different.
DBS – Day before sowing
DAS – Days after sowing

## Discussion

The 'no protection' plots recorded maximum number of spiders compared to the organic protection plots and the farmers' practices. Chemical insecticides were found to have adverse effects on spider population, since they not only have direct toxicity on the spiders but also poison the food chain which is detrimental for the spiders. As they are obligate predators, the prey they feed upon may become toxic or extinct after a chemical spray and affect their existence. Similar results were reported Sherif *et al.* (2001) [6] who reported that the total encountered spiders throughout the experimental period were 367,248 and 570 individually for carbofuran, monocrotophos and untreated plots, respectively and the application of carbofuran eliminated 35.61% of spider population, while monocrotophos was more toxic, eliminating 56.49%of spiders. Higher mortalities of spiders were reported for monocrotophos and carbofuran; 82.70 and 47.83 %, respectively (Mesbah and Sherif, 1999) [7]. Spiders are less affected by fungicides and herbicides than by insecticides (Yardin and Edwards, 1998) [8]. Spiders such as the wolf spider, *P. pseudoannuiata* are highly tolerant to botanical insecticides such as Neem-based chemicals (Markandeya and Divakar, 1999) [9]. Joseph *et al.*, 2010 [10] reported that among the Neem products, Azadirachtin 0.004%, caused relatively high mortality and was almost similar to the chemical pesticides in its effect, whereas Neem oil and NSKE were safe to the spiders [9].

Chemical pesticides showed a negative impact on the numbers of coccinellids though not on their diversity. This could be due to the scarcity of prey which is negatively affected by the chemical sprays and the direct effects of the sprays on the predator. This could convert to reduction in predator population and impede natural control at large. Species of generalist predators that are well adapted to the transient environments created by annual crops may be adversely affected, temporarily, on a local scale by such events but will persist on a larger scale and can re-invade from adjoining patches or fields. It is clear that if the event happens to be detrimental to the prey but not to the predator (e.g., application of an aphicide), specialist predator numbers may decline too as total prey abundance declines (Symondson *et al.*, 2002) [11]. Similar results as in the present study were observed Choudhary *et al.* (2017) [12] who reported that different chemical insecticide Dinetofuran recorded 0.13 beetles/hill population and were more fatal to Coccinellids in rice, than the Neem products and all Neem based insecticides were found safer recording 2.53 beetles/hill and thus were less toxic.

## Conclusions

Chemical insecticides were found to decrease spider population, since they not only have direct toxicity on the spiders but also poison the food chain which is detrimental for the spider. This decrease in population was found to be more in the farmers' practices compared to the 'no protection' plots. Coccinellids were also found to be affected adversely by the chemical sprays as most of organic protection and 'no protection' plots registered maximum populations of beetles. Such findings call for judicious and careful usage of chemical insecticides, which have long lasting effects on the environment.

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