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# Comparative effectiveness of an integrated pest management system and other control tactics for managing the spider mite *Tetranychus ludeni* (Acari: Tetranychidae) on eggplant

G.V.P. REDDY
*Department of Ecology and Environmental Science, University of Kuopio, P.O. Box 1627, FIN-70211 Kuopio, Finland (e-mail: G.Reddy@uku.fi; phone: 358-17-163205; fax: 358-17-163191)*

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**Abstract.** The effect of an integrated pest management (IPM) package, host plant resistance, *Chrysoperla carnea* predation and neem oil were evaluated against the spider mite *Tetranychus ludeni* on eggplant *(Solanum melongena* L.) fields in 1996 and 1997, by estimating the mite population density and yield levels. Compared with the IPM package (Panruti local, *C. carnea* plus neem oil), the standard (susceptible) eggplant variety ($MDU_1$) grown by farmers and treated with an acaricide (dicofol) had significantly higher mite densities. The predator *C. carnea* was recorded in significantly lower numbers in plots with the standard variety compared to a resistant variety (panruti local) with the full IPM package. Eggplant yield level and crop value were highest in the IPM-treated plots followed by Panruti local plus *C. carnea*. The standard variety treated with an acaricide had the lowest yield and value. These results indicated the usefulness of host plant resistance complemented by biorational control agents, such as *C. carnea* and neem oil, that these are suitable components in an IPM programme for managing the spider mite in endemic areas.

## Introduction

The spider mite *Tetranychus ludeni* Zacher (Acari: Tetranychidae) is exclusively phytophagous and commonly occurs on many cultivated crops, especially on vegetable crops, causing substantial losses in India (Channabasavanna 1971). Out of these crops, both eggplant and okra are often damaged by high numbers of mites (Reddy and Baskaran 1991). This mite appears in the first week of April, population peaks in June, and mite density declines sharply in July (Kumar and Sharma 1993; Singh 1995).

*T. ludeni* from cotton has developed resistance to all organophosphate insecticides tested (Herron et al. 1998), and miticide sprays gave variable control due to the difficulties of applying the spray to the underside of leaves and to widespread resistance within pest populations (Goodwin 1990) and resurgence (Patil 1989). The consequent threat to eggplant production has led to increased interest in alternative control approaches. Integrated Pest Management (IPM) is a viable alternative, including use of chemicals, host plant resistance and biological control. Several tactics, including host plant resistance (Reddy and Baskaran 1991, 2001)), a lacewing predator, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) (Sharanabasava and Manjunatha l998a; Sharanabasava and Manjunatha 1998b) and neem oil (Sharanabasava et al. 1999), have been proven effective in controlling spider mites on other vegetable crops.

Lacewings are considered to be one of the most effective general predators, feeding on eggs and young larvae of moths, aphids, mites and immature stages of soft-bodied insects (New 1975, 1988). In the present study, *C. carnea* was selected as one of the IPM components based on the results of Sharanabasava and Manjunatha (1998a,b) and Pal et al. (1989).*C. carnea* has been used recently as one of the IPM components to control lepidopterous pests (Reddy and Guerrero 2000; Reddy and Manjunatha 2000).

Neem oil has been reported to have insecticidal, antifeedant, growth-inhibition and repellent properties, and to be safe to *C. carnea* (Reddy and Manjunatha 2000). Sharanabasava et al. (1999) reported that neem oil (5% concentration) is effective against spider mites in okra.

Neem oil has also been used recently as one of the IPM components to control lepidopterous pests (e.g Reddy and Guerrero (2000); Reddy and Manjunatha (2000)).

The present study was initiated to determine whether integrating several tactics could effectively control *T. ludeni* on eggplant.

## Materials and methods

The study was carried out at the Agricultural Research Station, Hagari, Karnataka-State (India), from June-September 1996 and January-April 1997. Five treatments were replicated four times and randomly assigned to plots in a randomised block design. The treatments consisted of combinations of two eggplant varieties, Panruti local (a variety highly resistant to *T. ludeni*) and $MDU_1$ (the most susceptible variety widely grown by farmers) (Reddy and Baskaran 1991, 2001), the green lacewing, *C. carnea*, neem oil (5 % concentration) and an acaricide (dicofol [kelthane] 18.5 EC). The following were the treatment combinations:

1. Panruti local, release of *C. carnea* at 15 days after transplanting (DAT), plus two sprays of neem oil at 30 and 45 DAT (the full IPM package);
2. Panruti local plus release of *C. carnea* at 15, 30 and 45 DAT;
3. Panruti local plus 3 sprays of neem oil at 15, 30 and 45 DAT;
4. $MDU_1$, release of *C. carnea* at 15 DAT, plus two sprays of neem oil at 30 and 45 DAT;
5. $MDU_1$ plus 3 sprays of acaricide at 15, 30 and 45 DAT.

Treatment plots were 8×8 m and separated from other plots by 1.5 m to avoid spray drift or treatment effects. Thirty-day-old seedlings of respective eggplant varieties were planted with 60×75 cm spacing. The recommended fertilisers were applied: farmyard manure 25 tons/ha and NPK 125:100:50 kg/ha; 50% before planting, 25 % each at 6 and 10 weeks after planting. The plots were irrigated once every 4–5 days. No fungicide or herbicide was necessary in either plot. To determine mite population levels six plants were selected randomly per plot. In each plant three leaves were selected randomly, one per top, middle and bottom third of the plant. On the underside of each of these leaves all mites were counted in a 2.5 $cm^2$ area (halfway the leaf, right next to the midrib). For this, a piece of plexiglass with a 2.5 $cm^2$ hole was used, and a hand lens. Counts were made on the number of *C. carnea* larvae present on twelve randomly selected plants in each treatment. These counts were made early in the morning at eight weekly intervals starting two weeks after transplanting. Counts were averaged over time.

Lacewings were obtained from Pest Control Ltd., Bangalore. Inoculations with *C. carnea* larvae at the rate of 640/130 plants were made by manually distributing them over the two centre beds in the appropriate plots. The larvae were distributed late in the afternoon of the day they were received. Relevant plots were treated with neem oil+Teepol, obtained locally, at the rate of 3 1+500 ml/ha. The acaricide dicofol 18.5 EC (Bayer Ltd.) was applied to appropriate plots at the rate of 2.5 l/ha. Spray applications were made using a lever operated knapsack sprayer (Aspee, Mumbai) with a nozzle (0.914×0.939 mm) and a hollow cone jet operated at 3-bar pressure. The fruits were harvested on maturity and weighed. Gross profit was calculated as the difference of the value of the marketable portion of the eggplant minus the cost to produce (labour, materials, biological agents, application of insecticides). Net profit was expressed as the gross profit minus the cost of insecticides and their application. Costs and gross and net profits were compared between the various treatments. Data were analysed using multiple comparisons' test (Statistica, Stat Soft Inc). The main interest was to compare the full IPM with the $MDU_1$+acaricide treatment, since the latter was the farmer's customary practice.

## Results

Mite population levels were significantly lower on the resistant Panruti local eggplant variety, than on the susceptible $MDU_1$ (Table 1). On Panruti local the mite densities were lowest when treated with lacewings+neem oil, compared to lacewings alone or neem oil alone. On $MDU_1$ lacewings+neem oil resulted in much lower mite densities than dicofol. Patterns were consistent between years.

In Panruti local plots, mean lacewing numbers were the same for the lacewings+neem oil and the lacewings-alone treatment (Table 2). Lacewing numbers were significantly higher in the Panruti local plots than in the $MDU_1$ plots. The very low numbers in the plots treated with neem oil alone suggest that the barriers between the plots with different treatments were effective. Also the patterns in lacewing numbers were consistent between the two successive years.

*Table 1.* Mean *Tetranychus ludeni* densities of two varieties of field-grown eggplants, treated in different ways in 1996 and 1997

| Treatments | Mean no. of mites / 2.5 cm$^2$ ± SEM* | |
|---|---|---|
| | 1996 | 1997 |
| Panruti local, *C. carnea* and neem oil (full IPM package) | 3.2 ± 0.18a | 2.4 ± 0.54a |
| Panruti local and *C. carnea* | 4.1 ± 1.63a | 4.3 ± 1.76b |
| Panruti local and neem oil | 6.4 ± 1.78b | 4.5 ± 1.82b |
| MDU$_1$, *C. carnea* and neem oil | 9.1 ± 1.08c | 6.1 ± 1.43c |
| MDU$_1$ and acaricide (dicofol) | 22.4 ± 2.83d | 18.3 ± 2.18d |

* Means within a column followed by the same letter are not significantly different (Multiple comparison' test, $P$=0.05)

*Table 2.* Mean *Chrysoperla carnea* densities recorded in different treatments

| Treatments | Mean number/plant ± SEM* | |
|---|---|---|
| | 1996 | 1997 |
| Panruti local, *C. carnea* and neem oil (full IPM package) | 5.0 ± 0.18a | 4.4 ± 0.08a |
| Panruti local and *C. carnea* | 5.2 ± 2.12a | 4.8 ± 1.78a |
| Panruti local and neem oil | 0.4 ± 0.05c | 0.8 ± 0.0lc |
| MDU$_1$, *C. carnea* and neem oil | 3.5 ± 2.21b | 2.5 ± 1.19b |
| MDU$_1$ and acaricide (dicofol) | 0.0 ± 0.00c | 0.1 ± 0.07c |

* Population level was estimated by counting the number of larvae present in 12 plants randomly selected in each plot. Means within a column followed by the same letter are not significantly different (Multiple comparisons' test, $P$=0.05)

Table 3 shows that total fruit yields were higher for Panruti local than for MDU$_1$. Panruti local plots that received full-IPM treatment yielded the highest fruit weight, whereas acaricide treated MDU$_1$ plots yielded the lowest fruit weight. In 1997 yields for all treatments were somewhat higher that in 1996, but the differences between treatments were almost similar (Table 3).

A simple economic analysis indicates that Panruti local was more profitable than MDU$_1$ (Table 4). Furthermore, the eggplant harvest was most valuable after full-IPM treatment. Least valuable was the produce after the acaricide treatment-compared to the other treatments, application of dicofol was most costly (Table 4) and the resulting yield was smallest (Table 3).

## Discussion

There have been few attempts so far to control spider mites on vegetables using full-integrated pest management components. One study in India by Pal et al. (1989) demonstrated the importance of integrated control against *T. cinnabarinus* on eggplant. It gave very little insight in the relative role of predators (phytoseiid

*Table 3.* Mean yield (fruit weight) of eggplant in the integrated pest management (IPM) and other treatments during 1996 and 1997

| Treatments | Kg / plot (Mean ± SEM)* | |
|---|---|---|
| | 1996 | 1997 |
| Panruti local, *C. carnea* and neem oil (full IPM package) | 454.5 ± 3.23a | 520.2 ± 6.17a |
| Panruti local and *C. carnea* | 383.4 ± 2.63b | 417.3 ± 5.01b |
| Panruti local and neem oil | 336.8 ± 4.22c | 431.6 ± 2.34b |
| $MDU_1$, *C. carnea* and neem oil | 234.2 ± 2.19d | 382.4 ± 7.19c |
| $MDU_1$ and acaricide (dicofol) | 204.6 ± 3.86e | 232.8 ± 4.52d |

* Means within a column followed by the same letter are not significantly different (Multiple comparisons' test, *P*=0.05)

*Table 4.* Economic analysis of investment vs. benefit in the IPM and other treatments. Values are in US $.

| Treatments | 1996* | | | 1997* | | |
|---|---|---|---|---|---|---|
| | Cost | Gross profit | Net profit | Cost | Gross Profit | Net profit |
| Panruti local, *C. carnea* and neem oil (full IPM package) | 24 | 101a | 77a | 25 | 116a | 91a |
| Panruti local and *C.carnea* | 27 | 85a | 58b | 28 | 93a | 65b |
| Panruti local and neem oil | 22 | 74b | 52bc | 24 | 96a | 72bc |
| $MDU_1$, *C. carnea* and neem oil | 24 | 50c | 26d | 25 | 85b | 60d |
| $MDU_1$ and acaricide (dicofol) | 32 | 45cd | 13e | 35 | 52c | 17e |

* Means within a column followed by the same letter are not significantly different (Multiple comparisons' test, *P*=0.05)

mites and lacewings) and chemical control and no comparison was made with farmers practice. The present study showed that a full-IPM treatment was superior - not only in reducing mite density, also with respect to economic profit - compared with the current practice of treating the $MDU_1$ variety with acaricide. Our previous studies (Reddy and Baskaran 1991, 2001) indicated that the eggplant variety Panruti local is resistant to *T. ludeni* while $MDU_1$ is highly susceptible. Nevertheless, many farmers continue to cultivate $MDU_1$ because they are accustomed to it.

The lacewing predator, *C. carnea* thrived better on the resistant variety than on the susceptible one. Host plant resistance often appears compatible with the biological control provided by predators, as several studies demonstrated an additive relationship between host plant resistance and predation (Trumble and Hare 1997). There are few reports indicating heavy predation in non-preferred plants by predators. For example, brown rice plant hopper, *Nilaparvatha lugens* (Homoptera: Delphacidae), suffered heavier predation by the spider, *Lycosa pseudoannulata* (Araneida: Lycosidae) on non-preferred rice cultivars (Kartohardjono and Heinrichs 1984), and both fall armyworm, *Spodoptera frugiperda*, and corn earworms, *Helicoverpa zea* (Lepidoptera: Noctuidae) were more heavily attacked by *Orius insidiosus* (Hemiptera: Anthocoridae) on non-preferred maize varieties (Isenhour et al. 1989). This may be due to antixenosis in resistant plants, causing increased movement of prey which presumably facilitated their discovery and capture by predators (Trumble and Hare 1997).

Dicofol (Kelthane) has been widely used to control spider mite populations on various crop plants. This chemical has given satisfactory control for 20–30 years back as reported by Wilcox and Howland (1961); Singh et al. (1981). Others reported that dicofol is effective against spider mites (Pal et al. 1989; Palaniswamy and Subramaniam 1977; Srinivasa and Sugeetha 1999) but Goyal (1982) concluded that on eggplant dicofol had virtually no effect on mites. In our present study we obtained no evidence for effectiveness of dicofol (i.e. not at the rate and frequency as applied here). This chemical also has been shown to induce resistance in spider mites (e.g. (Dennehy and Granett 1984; Pree 1987)) and to cause residue problem in strawberry and common beans (Ahmed and Ismail 1996).

The economic analysis in the present study clearly showed that the full IPM package resulted in a higher yield of eggplant, as well as better gross and net profits than regular insecticidal treatments or treatments with biological agents alone. Compared to the conventional acaricide treatment, an additional advantage of the IPM package is the much lower risk of insecticidal resistance development.

Overall, the results of the present study indicate that the IPM programme incorporating host plant resistance and biorational control agents (predator and neem oil) may lead to a more sustainable management system for spider mites than conventional control methods. Therefore, this IPM programme should be adapted through the extension agents or units among the farming community to safe guard the environment.

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