# Biological Control of Coconut mite: Effect of Innundative Release of the Predatory Mite, *Neoseiulus baraki* (Acari: Phytoseiidae)

N. S. Aratchige*, L. C. P. Fernando, A. D. N. T. Kumara, K. V. N. N. Jayalath, K. F. G. Perera, and N. I. Suwandarathne

*Coconut Research Institute of Sri Lanka, Bandirippuwa Estate, Lunuwila, Sri Lanka*

* - Corresponding author: nayanie2003@yahoo.com

## ABSTRACT

In a previous study, single inundative release of laboratory reared Phytoseiid predatory mite, *Neoseiulus baraki* into coconut palms infested by coconut mite, *Aceria guerreronis* was found to be effective in increasing *N. baraki* populations and reducing coconut mite populations on the nuts. However, the effectiveness of innundative releases on improving the quality of the harvest and the cost-effectiveness of its release has not been confirmed yet. Field experiments were conducted to determine the suitable frequency and the rate of release (number of palms for releases) of *N. baraki*. Three frequencies (at 2-, 4- and 6-month intervals) and three rates (16, 11 and 6 palms/ac representing 1/4$^{th}$, 1/6$^{th}$ and 1/10$^{th}$ of an ac) were tested and the outcome was evaluated in terms of quality of the harvested nuts of palms. Release of *N. baraki* at 2- or 4-month intervals resulted in a higher percentage of normal-sized nuts (86.1, 85.2, 73.2 and 70.9% at 2-, 4-, 6- month intervals and control respectively) and lower percentage of small-sized nuts (10.9, 13.6, 25.9 and 27.4% at 2-, 4-, 6- month intervals and control respectively) in the harvest. Release of predatory mites in 1/4$^{th}$ of an acre reduced the percentage of small-sized nuts in the harvest (16.9% compared to 21.0-30.1% in other rates and the control). A pilot scale trial conducted in two plantations to evaluate the effectiveness of release of *N. baraki* using selected frequency of release and number of palms resulted in a higher percentage of normal-priced nuts (85.6 and 88.4% in two plantations compared to 79.1 and 80.1% in unreleased blocks) and a lower percentage of small-sized nuts (13.3 and 10.1% in two plantations compared to 20.0 and 17.2% in unreleased blocks). The benefit-cost analysis revealed that the release of *N. baraki* in this manner is cost effective in relation to what is spent by the grower.

**Key words**: *Aceria guerreronis, coconut mite, cost-benefit analysis, Neoseiulus baraki*

## INTRODUCTION

Predatory mite, *Neoseiulus baraki* Athias-Henriot (Acari: Phytoseiidae) is an important biological control agent of the coconut mite, *Aceria guerreronis* Keifer (Acari: Eriophyidae) (Fernando *et al.*, 2003, 2010; Reis *et al.*, 2008; Negloh *et al.*, 2008). It is the most common predatory mite found in association with the coconut mite in Sri Lanka (Fernando *et al.*, 2002, Moraes *et al.*, 2004) and also the most effective predatory mite of the coconut mite, due to its strong spatial and temporal co-occurrence with the coconut mite (Fernando *et al.*, 2003, 2010; Aratchige *et al.*, 2012) and due to the flattened idiosoma that allows it to reach the cryptic habitat of the coconut mite (Moraes *et al.*, 2004). Therefore, it was speculated that augmentative/innundative release of *N. baraki* would hold a promise for the control of coconut mite. Its potential as a biological control agent of coconut mite has been reported in a previous study which revealed that a single inundative release of *N. baraki* could significantly increase its population resulting in a significant reduction in the coconut mite population in released palms during the post-release period (Fernando *et al.*, 2010).

However, due to the perennial nature of the coconut palm in which the immature nuts are present throughout the year and the fact that coconut mite infests nuts of 2-6 months, a single inundative release of *N. baraki* may not provide reduction in coconut mite densities for a longer period. Hence, augmentative/innundative release of *N. baraki* in large numbers at frequent intervals would be necessary until it is established in the plantations. Also, multiple releases of *N. baraki* may be more profitable compared to a single release of *N. baraki* in achieving better economic benefits.

In addition to decreasing coconut mite populations, multiple releases of *N. baraki* would also result in improving the quality of the harvested nuts. i.e. a reduction in nuts with damage scars and the number of small-sized nuts. The coconut mite affects the yield of coconut by causing premature nut fall, reduction in nut size and malformation in nuts. In addition, scarring of nut surface makes de-husking of mature nuts difficult and costly. Hence, recording of yield parameters at harvest would confirm the economic benefits of releases of *N. baraki*. A remunerative financial benefit should be ensured to coconut growers for them to invest on disease control measures in a perennial crop like coconuts. Therefore, collection of yield data following release of *N. baraki* is useful in determining whether such a recommendation is cost effective.

The studies reported here were aimed at determining the optimum frequency of release and the release rate (number of palms per acre) of *N. baraki*. Thereafter, a pilot scale trial was conducted to evaluate the effectiveness of releasing *N. baraki* on the yield parameters (number of normal-sized nuts/ small-sized nuts) and thereby determine the cost effectiveness of releasing *N. baraki*.

## METHODS AND MATERIALS

### Rearing of *N. baraki*

*Neoseiulus baraki* were reared in a tray-type arena (Aratchige *et al.*, 2010) for the experiments conducted to determine the frequency and rate of release of *N. baraki*. For the pilot-scale trial, sachet-type rearing units (Kumara *et al.*, unpublished) were used. Both these rearing methods are briefly described below.

The tray-type arena consisted of a black plastic sheet of 30 x 38 cm pasted on a plastic tray (44 x 35 x 3 cm). A thin layer of insect glue (Stikem Special®, Sea Bright Associates, USA) was applied along the periphery of the sheet to prevent the escape of mites and to safeguard the arena from external contaminants. A plastic foam pad (10 x 10 x 5 cm) wrapped with a wet tissue paper and placed on a glass sheet (10 x 10 cm) was used to provide mites with drinking water and to maintain high humidity in the rearing unit. A piece of fine net (4 x 4 cm) was placed underneath the glass sheet to serve as an egg laying substrate for the mites. About 20, *Tyrophagus putrescentiae* Schrank (Acari: Acaridae) mites of different stages were introduced in to the arena as food for *N. baraki*. About 1 g of rice bran and flour mixture (1:1) was sprinkled on the black polyvinyl plastic sheet once a week as food for *T. putrescentiae*. Three weeks after introducing *T. putrescentiae*, about 20 individuals of *N. baraki* of different stages were introduced in to each arena. Each individual tray with mites was covered with another inverted tray of the same size and maintained in an air-conditioned room (27 ± 2 °C) before releasing in to the field. *T. putrescentiae* was added at 3-week intervals.

The sachet-type rearing unit consisted of a polypropylene sachet of 30 x 35 cm. In a partially separated chamber in one side of the sachet, a moist folded tissue paper (4 x 2 cm) was placed to provide drinking water to the mites and create a high relative humidity. Approximately, 200 *T. putrescentiae* and 10 females and 3-4 males of *N. baraki* were introduced in to each sachet. One teaspoon of a mixture of rice bran and wheat flour (1:1) was provided as food for *T. putrescentiae*. The open side of the sachet was sealed using a polyethylene sealer and placed in an air-conditioned room (27 ± 2 °C) for 8 weeks. After 8 weeks, about 5000 *N. baraki* individuals can be obtained per sachet (Kumara *et al.*, unpublished)

### Determination of effective frequency of release of *N. baraki*

The experiment was conducted in a plantation in the Low country Intermediate zone (IL1b) of Sri Lanka. Four blocks (app. 1 ac) of coconut palms infested with coconut mites were selected. Each block was at least 10 rows apart. In each block, only one release frequency was tested where *N. baraki* were released on to ten coconut mite infested palms. The experiment was conducted as a single palm plot experiment (Kularatne *et al.*, 2006) which negated the need for replication in several blocks.

About 45 days after introducing *N. baraki* into tray-type arenas (when about 5000 *N. baraki* are present per tray), the black plastic sheet on which the mites were reared in the tray-type arena were separated from the tray without the glue layer and put into separate polypropylene sachets (gauge 150) and sealed. In the field, *N. baraki* was released on to the selected palms by hanging the cut-open sachets on 3-5 month old bunches. These bunches were marked with tags to identify them at harvest. Release frequencies tested in this experiment were at 2-month, 4-month and 6-month intervals. About 5000 *N. baraki* per palm was used at each release (Aratchige *et al.*, 2008) and the releases were continued at these frequencies for two years. 3-5 month old bunches in ten palms where *N. baraki* was not released (control) were also marked with tags.

Data from two harvests of mature nuts in the marked palms were recorded prior to release of *N. baraki* (pre-release data). Thereafter, mature nuts were harvested at 2-month intervals and the total number of nuts, number of coconut mite-damaged nuts, number of normal-sized nuts (that are sold at the normal price) and small-sized nuts (sold at half of the price of a normal-sized nuts) in the harvest was made for each palm for a period of 12 months after the first release.

**Determination of suitable rate (i.e. suitable number of palms in a plantation) of release of *N. baraki***

The experiment was conducted in two coconut plantations in the Low country Intermediate zone (IL1b) of Sri Lanka. Four, 1 ac blocks (8 rows apart) were selected in each plantation. In each block of 1 ac, either 16 or 11 or 6 palms, representing 1/4th, 1/6th and 1/10th of the plantation respectively, were selected for releases of the predatory mite. On each palm, about 5000 predatory mites (Aratchige *et al.*, 2008) were released at 4-month intervals. Prior to release of *N. baraki* and at monthly intervals after release, the total numbers of nuts, infested nuts, normal-sized nuts and small-sized nuts in the harvest were counted from each palm in each block for 12 months.

**Pilot trial: Determination of the effect of releasing *N. baraki* to manage coconut mite**

After determining the number of *N. baraki* to be released per palm (Aratchige *et al.*, 2008), optimum frequency of release and the optimum number of palms in plantation to be released (this paper), pilot scale trials were conducted to determine the effect of releasing *N. baraki* on the yield of palms. This field trial was conducted in 2 coconut plantations (Galkuliya estate and Puliyankulama estate) each over 25 ac in extent and located in the Low country Intermediate zone (IL1b) of Sri Lanka. In each plantation, two 5-acre blocks, 25 rows apart were selected. *N. baraki* produced in sachet-type rearing units (Kumara *et al.*, unpublished) were released on to 75 randomly selected palms in one block of 5 ac in each plantation, representing 1/4th of the block. In general, highest populations of coconut mites are reported in February-March and June-September in Sri Lanka and these months are relatively with low rainfalls (Aratchige *et al.*, 2012). Also, due to practical difficulties, releases could not be carried out in rainy seasons. Therefore, the releases were repeated in February, May-June and August (depending upon the periods without rains) and continued for 2 years by releasing about 5,000 *N. baraki* per palm at each release (Aratchige *et al.*, 2008). In each plantation, a control block was maintained without the release of

*N. baraki*. Harvest records were collected from all released palms in the experiment block and 75 selected palms in the control block. Total number of nuts from the harvest of each palm was counted and categorized in to different categories such as infested nuts, normal-sized nuts and small-sized nuts for 10 picks in Galkuliya estate and 6 picks in Puliyankulama estate.

**Benefit –cost analysis of innundative release of *N. baraki***

Harvest data collected in the pilot scale trial was used for benefit-cost analysis using the indicators, benefit-cost ratio (BCR) and gross margin (GM). These indicators for the released-palms were compared with those of the control palms. Market price of a nut was taken as Rs. 23.00 while the cost of production of one sachet of predatory mites and the cost of labour for release per palm were taken as Rs. 15.00 and Rs. 50.00 respectively. These indicators were calculated for the entire period of the study (10 picks for Galkuliya estate and 6 picks for Puliyankulma estate)

**Data analysis**

All statistical analyses were carried out using SPSS Version 17. Percentages of different categories of harvested nuts, i.e. percentages of coconut mite-infested nuts, normal-sized and small-sized nuts were calculated and were subjected to repeated measures covariance analysis with pre-release data as the covariate. Means were compared using Least Significant Differences at 95% confidence intervals.

## RESULTS

**Determination of effective frequency of release of *N. baraki***

Release of *N. baraki* at different frequencies significantly affected the percentage of infested nuts in the harvest (df=3, F= 3.6, P = 0.02). A lower percentage of infested nuts was observed in palms that received *N. baraki* at 2- month intervals (63.0%) than in the palms that received *N. barki* at 6-month intervals (79.6%) or palms in the control block (85.8%) (Table 1). Percentages of normal-sized nuts and small-sized nuts in the harvest were also significantly different (df=3, F= 3.5, P = 0.03 and df=3, F= 3.9, P = 0.02 for normal-sized nuts and small-sized nuts respectively). Significantly higher percentage of normal-sized nuts was collected from the palms that received *N. baraki* at 2- or 4- month intervals (86.1 and 85.2% respectively) than from the palms that were released with *N. baraki* at 6-month intervals or palms in the control block (73.2 and 70.9% respectively) (Table 1). Release of *N. baraki* at 2-month intervals resulted in a significantly lower percentage of small-sized nuts (16.9%) compared to release at 6-month intervals and control palms (26.9 and 30.1% respectively) (Table1).

**Table 1 - Estimated marginal means*±SE of percentage harvested nuts in different categories in the palms on to which *N. baraki* was released at intervals of 2, 4 and 6 months**

| Nut category | Frequency of predator release | | | Control |
|---|---|---|---|---|
| | 2-month interval | 4-month interval | 6-month interval | |
| Infested nuts | 63.0±5.2a | 65.1±5.2ab | 79.6±5.2ab | 85.8±6.3b |
| Normal-sized nuts | 86.1±4.1a | 85.2±4.9a | 73.2±4.6b | 70.9±6.1 |
| Small-sized nuts | 10.9±3.9a | 13.6±3.9ab | 25.9±3.8b | 27.4±4.6b |

Means followed by the same letter in each row are not statistically significant at P=0.05, *based on the covariate

**Table 2 - Estimated marginal means*±SE of percentage harvested nuts of different categories in palms on to which *N. baraki* was released at 5000 mites per palm at 3-month intervals at different release rates (no. of palms/ac)**

| Fruit category | Rates of predator release | | | Control |
|---|---|---|---|---|
| | 16 palms/ac (1/4th of palms) | 11 palms/ac (1/6th of palms) | 6 palms/ac (1/10th of palms) | |
| Infested nuts | 72.1±5.9ns | 76.5.1±5.9ns | 81.6±6.2ns | 85.4±6.9ns |
| Normal-sized nuts | 79.2±6.3ns | 78.2±7.9ns | 71.2±6.1ns | 68.1±7.8ns |
| Small-sized nuts | 16.9±4.9a | 21.0±4.8ab | 26.9±4.8b | 30.1±5.2b |

Means followed by the same letter in each row are not statistically significant at P=0.05, ns-not significant, *based on the covariate

**Determination of suitable rate (i.e. suitable number of palms in a plantation) of release of *N. baraki***

There was no statistically significant difference in the percentage of infested nuts in the harvest with different number of palms being treated (df=3, F= 1.2, P=0.31). However, the lowest percentage of infested nuts was recorded in the block where *N. baraki* was released at the rate of 1/4th of an acre (72.1%) (Table 2). Higher percentage of normal-sized nuts (79.2%) was also observed in the same block although this difference was not statistically significant (df=3, F= 1.4, P=0.26, Table 2). The percentage of small-sized nuts was significantly different (df=3, F= 3.1, P=0.04) and the lowest percentage of such nuts (16.9%) was recorded in the block where *N. baraki* was released on to 1/4th of palms per ac (Table 2).

**Table 3: Estimated marginal means*±SE of percentage harvested nuts of different categories in palms on to which *N. baraki* was released at 5000 mites per palm at 3-month intervals on to 75 palms/ac**

| Estate | Treatment | Infested nuts | Normal-sized nuts | Small-sized nuts |
|---|---|---|---|---|
| Puliyankulama | Released | 79.4±2.3ns | 85.6±2.0a | 13.3±1.6a |
| | Control | 78.3±3.1ns | 79.1±2.7b | 20.0±2.9b |
| Galkuliya | Released | 70.9±2.3ns | 88.4±a | 10.1±1.3a |
| | Control | 72.1±3.6ns | 80.1±b | 17.2±2.0b |

Means followed by the same letter in each column for the two estates separately are not statistically significant at P=0.05, ns-not significant, *based on the covariate

**Pilot scale trial: Determination of the effect of releasing *N. baraki* to manage coconut mite**

In both plantations, percentage of infested nuts were similar between the palms on to which *N. baraki* were released and the palms in the control blocks (df=1, F=2.3, P=0.14 and df=1, F=0.13, P=0.75 for Galkuliya estate and Puliyankulama estate respectively, Table 3). Significantly higher percentages of normal-sized nuts (df=1, F=6.5, P=0.01, 88.4% and df=1, F=4.4, P=0.04, 85.6% for Galkuliya estate and Puliyankulama estate respectively, Table 3) and lower percentage of small-sized nuts (df=1, F=11.4, P<0.01, 10.1% and df=1, F=6.5, P=0.01, 13.3% for Galkuliya estate and Puliyankulama estate respectively, Table 3) were recorded in the palms in the block in to which *N. baraki* were released compared to control blocks (Table 3).

**Benefit – cost analysis of innundative release of *N. baraki***

Release of *N. baraki* in February, May-June and August at about 5000 mites per palm on to 1/4th of palms in the plantation for 2 years resulted in BCR of 3.11 and 1.76 in Galkuliya estate and Puliyankulama estate respectively confirming that release of *N. baraki* is cost effective. Furthermore, a higher GM was reported in *N. baraki* released palms compared to control palms (Rs 2,412 and Rs 1,010 in Galkuliya estate and Puliyankulama estate respectively).

## DISCUSSION

The findings of the study infer that the release of about 5000 number of *N. baraki* at 2- or 4- month intervals on to 16 palms per ac (representing 1/4th of the plantation) is effective in increasing the normal-sized nuts and decreasing the small-sized nuts in the harvest. This is one of the important elements in the control strategy of the coconut mite, from a growers' point, because small-sized nuts can considerably account for the economic loss due to damage by coconut mite. Such nuts are either rejected by the buyers or they fetch a lower price than normal-sized nuts. In any augmentative biological control method, analysis of cost-benefit is crucial for its efficacy (King *et al.*, 1985; Parella *et al.*, 1992). Economics of release of *N. baraki* to control coconut mite is a serious concern of coconut growers. This is especially because, due to the tall stature of coconut palms, release of *N. baraki* would incur higher costs compared to many other crops. The economic analysis of releasing *N. baraki* resulted in a benefit-cost ratio of higher than 1 confirming the cost effectiveness of releasing *N. baraki* at the selected levels. Therefore, release of *N. baraki* at about 5000 mites per palm at 4 month intervals on to 16 palms per ac is made as an interim recommendation. However, due to practical difficulties release of *N. baraki* could only be carried out during dry months (with less-intense rainfall) namely February, May-June and August which are also months with higher coconut mite populations (Aratchige *et al.*, 2012).

The present study is the first to establish the effect of release of *N. baraki* on the harvest. However, release of *N. baraki* has resulted in lower number of coconut mites when released at 2- and 4-month intervals (Aratchige *et al.*, unpublished). Nevertheless long term data collection on mite census was not done due to logistical difficulties.

A lower BCR recorded from the Puliyankulama estate compared to the Galkuliya estate could not be explained from our experiments. However, our intention was not to compare the BCR between two estates and probably the differences in the general conditions of palms in the two estates may have contributed to these differences.

Results of the studies reported in this paper have given rise to the first biological control recommendation in the world using a predatory mite against the coconut mite. Although efforts have been intensified towards the direction of biological control in other countries, Sri Lanka is the first to make this recommendation using *N. baraki* as a biological control agent against the coconut mite. Further, this study is a pioneering effort to document economics of the biological control approach for coconut mite. In coconut, determination of expected yield gains after release of *N. baraki* to control the coconut mite is possible only if long term data on harvest is available. By way of collecting harvest data over long time periods, after termination of releases of *N. baraki*, expected yield gains as well as the post-release residue period of the control measure can be determined. Therefore, the collection of yield data is a useful measure to evaluate the long term effectiveness of release of *N. baraki*. These finding have opened the way to field releases, provided sufficient number of *N. baraki* are mass produced. This is being planned at the national level with the involvement of other stake holders in the coconut industry in Sri Lanka.

## ACKNOWLEDGEMENT

Authors wish to acknowledge the technical support given by Mr. S. P. Manoj and Miss C. Hettiarachchi.

## REFERENCES


Aratchige, N.S., L.C.P. Fernando, A.D.N.T. Kumara, N.I. Suwandharathne, K.F.G. Perera, D.C.L. Hapuarachchi, and P.H.P.R De Silva. (2008). Recent advances in research on biological control of the coconut mite *Aceria guerreronis* Keifer in Sri Lanka. pp. 313-321. *In* N.P.A.D. Nainanayake and J.M.D.T. Everard (eds.) Proceedings of the Second Symposium on Plantation Crop Research - Export competitiveness through quality improvements. Coconut Research Institute, Lunuwila, Sri Lanka.

Aratchige, N.S., L.C.P. Fernando, P.H.P.R. de Silva,K.F.G.Perera,C.S.Hettiarachchi,K.P. Waidyarathne, and S.M.V. Jayawaredena. (2010). A new tray-type arena to mass rear *Neoseiulus baraki*, a predatory mite of coconut mite, *Aceria guerreronis* in the laboratory. *Crop Protection* 29: 556-560.

Aratchige, N.S., L.C.P. Fernando, K.P. Waidyarathne, and K.A.S. Chandrasiri. (2012). Population dynamics of *Aceria guerreronis* (Acari: Eriophyidae) and its predatory mite, *Neoseiulus baraki* (Acari: Phytoseiidae) in two coconut growing areas in Sri Lanka. *Experimental and Applied Acarology* 56: 319-325. (DOI: 10.1007/s10493-012-9519-z)

Fernando, L.C.P., I.R. Wickramanada, and N.S. Aratchige. (2002). Status of coconut mite, *Aceria guerreronis* in Sri Lanka. pp. 1-8. *In* L.C.P. Fernando, G.J. de Moraes, and I.R. Wickramanada. (eds.) Proceedings of the International workshop on Coconut Mite *(Aceria guerreronis)*. Coconut Research Institute, Lunuwila, Sri Lanka.

Fernando, L.C.P., N.S. Aratchige, and T.S.G. Peiris. (2003). Distribution pattern of coconut mite *Aceria guerreronis* and its predator *Neoseiulus* aff. *paspalivorus* on coconut palms. *Experimental and Applied Acarology* 31: 71-78.

Fernando, L.C.P., K.P. Waidyarathne, K.F.G. Perera, P.H.P.R. de Silva. (2010). Evidence for suppressing coconut mite *Aceria guerreronis* by inundative release of the predatory mite, *Neoseiulus baraki*. *Biological Control* 53: 108-111.

King, E.G., K.R. Hopper, and J.E. Powell. (1985). Analysis of syatems for biological control of crop arthopod pests in the U.S. by augmentation of predators and parasites. pp.201-227. *In* M.A. Hoy, and D.C. Herzog (eds.) Biological Control in Agricultural IPM Systems. Academic Press, London.

Kularatne, J.D.J.S., T.S.G. Peiris, and S. Samita. (2006). Feasibility of single palm plot in coconut experimentation. *Tropical Agricultural Reserach* 18: 306-313.

Moraes, G.J. de, P.C. Lopes, and L.C.P. Fernando. (2004). Phytoseiid mites (Acari: Phytoseiidae) of coconut growing areas in Sri Lanka, with descriptions of three new species. *Journal of the Acarology Society of Japan* 13: 141-160

Negloh, K., R. Hanna, and P. Schausberger. (2008). Comparative demography and diet breadth of Brazilian and African populations of the predatory mite *Neoseiulus baraki*, a candidate for biological control of coconut mite. *Biological Control* 46: 523-531.

Parella, M.P., K.M. Heinz, and L. Nunney. (1992). Biological control through augmentative releases of natural enemies: a strategy whose time has come. American Entomologist. 38: 172-179.

Reis, A.C., M.G.C. Gondim Jr., G.J. de Moraes, R. Hanna, P. Schausberger, L.E. Lawson-Balagbo, and R. Barros (2008). Population dynamics of *Aceria guerreronis* Keifer (Acari: Eriophyidae) and associated predators on coconut fruits in Northeastern Brazil. *Neotrop Entomol* 37: 457-462.