Impact of Mass Scale Release of *Neoseiulus baraki*, Predaceous Mite of The Coconut Mite in Growers' Plantations: Two Case Studies

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Abstract

The coconut mite, *Aceria guerreronis* Keifer (Acari: Eriophyidae) is a major pest of coconut in several coconut producing countries worldwide. From the inception of its invasion into Sri Lanka, biological control has been regarded as the most sustainable method for the management of coconut mite. Research carried out to identify a suitable biological control agent to manage the coconut mite resulted in the recommendation of the release of the predaceous mite, *Neoseiulus baraki* Athias-Henriot (Acari: Phytoseiidae) at approximately 5,000 per palm in 3- or 4-month intervals on to quarter of the plantation. Analytical results of two case studies to evaluate the effectiveness of carrying out this recommendation in growers' plantations are reported in this paper. Multiple releases of *N. baraki* into a coconut mite infested field resulted in significant decreases in percentages of infested ($P = 0.021$) and small-sized fruits ($P = 0.028$) and increases in fresh fruit weight ($P < 0.001$), husked fruit weight ($P < 0.001$) and kernel thickness ($P = 0.01$) in the harvest. Percentage of rejected fruits in the harvest showed a declining trend ($Y = -0.2129(T) + 14.368$ with $P<0.0001$, where Y = Percentage of rejected fruits in the harvest, T = time; $R^2 = 0.805$) over time after release of *N. baraki*. The findings reported in the present paper provide evidence that the recommendation on releasing *N. baraki* to control the coconut mite is viable in reducing the coconut mite damage, small fruits and rejections and in increasing the fruit weights and kernel thickness in harvested fruits.

Keywords: *Aceria guerreronis, Biological control, Coconut mite, Neoseiulus baraki*

Introduction

Coconut mite, *Aceria guerreronis* Keifer (Acari: Eriophyidae) is a key pest of coconut in Sri Lanka. At present, the coconut mite has invaded all districts except Nuwara Eliya which is mainly a hilly area where coconut is not as predominantly grown as in the other districts (Aratchige, 2014). However, the incidence of coconut mite varies from district to district with higher incidences in the dry - and intermediate-zones than in the wet-zone. Feeding of coconut mite on the meristematic region under the bracts of coconut fruits produces necrotic and suberized fruit surfaces with deep, longitudinal fissures and gummy exudates. In a severe infestation, fruit is distorted, stunted and unevenly grown if coconut mite infestation is concentrated on one side of the fruit surface. Small and deformed fruits (Alam and Islam, 2014), premature fruit drop (Nair, 2002; Wickramananda *et al.*, 2007) and reductions in copra yield (Hernández-Roque, 1977; Howard *et al.*, 2001; Moore and Howard, 1996; Muralidharan *et al.*, 2001; Alam and Islam, 2014), husks (Wickramananda *et al.*, 2007), total yield (Kumar and Ramaraju, 2010) and length and tensile strength of fibre (Naseema Beevi *et al.*, 2003) contribute to the crop loss due to coconut mite damage. In Sri Lanka, an estimated 15.8% of total crop loss was observed when the losses due to button and immature fruit fall, size reduction in the harvested fruits and fruit deformation were combined (Wickramananda *et al.*, 2007).

As with all eriophyoid mites, coconut mite has perfectly evolved as a pest. Its small size, secluded habitat, high reproduction rate, ability to build into permanent infestations and tall stature of the host plant make the control of coconut mite, always a challenge. However, both chemical and non-chemical methods have been tested in Sri Lanka to manage the coconut mite. As a chemical control method, spraying of 20 % palm oil and 0.5 % sulphur in an aqueous emulsion with soap powder has been recommended to control the coconut mite (Fernando and Chandrasiri, 2010).

Neoseiulus baraki Athias-Henriot (Acari: Phytoseiidae) is the most abundant predaceous mite in association with the coconut mite in Sri Lanka (Moraes *et al.*, 2004). It has a flat and elongated idiosoma with short distal setae and short legs (Moraes and Zacarias, 2002; Moraes *et al.*, 2004) enabling it to creep under the perianth, an ability to feed and develop on coconut mites (Añon, 2003) and is closely associated with its host (Fernando *et al.*, 2003; Aratchige, 2007; Aratchige *et al.*, 2012a). Release of laboratory reared *N. baraki* at the rate of approximately 5,000 per palm on to quarter of a plantation at 3-4 month intervals has resulted in a higher percentage of normal-sized fruits in the harvest and a lower percentage of small-sized fruits (Aratchige *et al.*, 2012b). Assessing the economic impact of releasing *N. baraki* is of paramount importance because basically biological control program should be considered when the benefits are greater than the costs (Jetter, 2005). Under experimental conditions, release of *N. baraki* has been proven to be profitable as the economic benefits of investing in biological control of coconut mite by *N. baraki* surpasses cost (Aratchige *et al.*, 2012b). Therefore, the release of *N. baraki* at the rate of approximately 5,000 per palm on to quarter of a plantation at 3-4 month intervals has been recommended in Sri Lanka to control the coconut mite damage.

For the growers to carry out this recommendation, *N. baraki* is produced and supplied from 20 laboratories maintained by the Coconut Research Institute, Coconut Cultivation Board, Chilaw Plantation Ltd and Kurunegala Plantation Ltd. During 2013-2015, more than 500,000 sachets with *N. baraki* have been released to growers' plantations from these laboratories. Analysis of two case studies with an objective of assessing the impact of release of *N. baraki* from the mass production laboratories in growers' plantations are reported in this paper.

Materials and Methods

Production of *N. baraki*

Neoseiulus baraki used in the experiments explained below were mass produced using the sachet-type rearing units which consisted of a polypropylene sachet of 30 x 35 cm (Kumara *et al.*, 2014). 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 *Tyrophagus putrescentiae* and 10 females and 3 - 4 males of *N. baraki* were introduced into each sachet. Approximately 5g 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 polythene sealer and maintained in an air-conditioned room with natural light at 16 h photoperiod and at 27 ± 2^0 C for 8 weeks. After 8 weeks, about 5,000 *N. baraki* individuals can be obtained per sachet (Kumara *et al.*, 2014).

Effect of release of *N. baraki* on the fruit components in the harvest

Though a number of estates, either government or private owned, practice release of *N. baraki* to control the coconut mite, data could not be collected from many of them as they were judged to be lacking either essential information sufficient for statistical comparisons or not releasing *N. baraki* as per the recommendation. Some data could not be considered because data from suitable experimental control plots were not available or control plots have been maintained differently from the treatment plots or control plots contain either a different coconut variety or palms of a different age. Therefore, data could be used only from a released block and a control block at the Isolated Seed Garden, Ambakelle in the Low Country Intermediate zone (IL_3). Two blocks (approximately 2 ha each) of coconut palms (Ambakelle Tall variety) infested with the coconut mites were selected. These blocks were apart of approximately 15 rows of coconut palms. *N. baraki* produced in sachet-type rearing units (Kumara *et al.*, 2014) were released on to 75 randomly selected palms in one block, representing a quarter of the block and the releases were repeated at 3-month intervals (Released block). The other block was maintained without the release of *N. baraki* (Control block) and both blocks received equal management practices recommended by the Coconut Research Institute.

Harvest records were collected at approximately 45-day intervals from 75 palms each from the released block and the control block. Total number of fruits from the harvest of each palm was counted and categorized into different categories such as uninfested fruits (Figure1A), infested fruits (Figure 1B, C, D and E), infested but normal-sized fruits (that could be sold at the normal price, Figure1B), infested and small-sized fruits (fruits that fetch half of the normal price, Figure 1C) and fruits with discontinued damage scars from the perianth of the fruit (Figure 1D). Fresh fruit weight (with husk), husked fruit weight and kernel thickness were measured from 50 randomly chosen harvested fruits from each pick in experimental blocks. Percentages of infested fruits, normal-sized fruits and small-sized fruits were calculated from the data collected in each pick and were subjected to repeated measures Analysis of Covariance (ANCOVA) using pre-release data as the covariate. Total of 9 data sets which were comprised of 5 sets of data prior to the initiation of the release of *N. baraki* (pre-release data) and 4 sets of data after the initiation of the release (post release data) were used in the analysis. Means of the fresh fruit weight, husked fruit weight and kernel thickness between two groups were compared using independent samples T-test. All data were analyzed using SPSS software (Version 17).

Effect of release of *N. baraki* on the rejections of harvested fruits

Data on the total number of fruits in the pick and the rejected fruits from the buyers due to coconut mite damage (Figure 1E) from the harvest from one field of 6 ha of the Daisy Valley Estate, Mawathagama (Low Country Intermediate zone - IL_{1b}) were collected. Release of *N. baraki* has been taken place from 2012 according the recommendation made by the Coconut Research Institute. Data were collected from the records maintained by the estate. Pick data were collected for each pick (7 picks per year, as picking took place at 45 day intervals) from 2010 to 2012 (pre-release data) and from 2013 to 2015 (post release data). The analysis could not be repeated in another site as data exclusively on the rejections due to coconut mite damage in the harvest was not available for a sufficiently long time period. General linear regression analysis was separately implemented on pre and post release data to extract the underlying trends in two different scenarios.

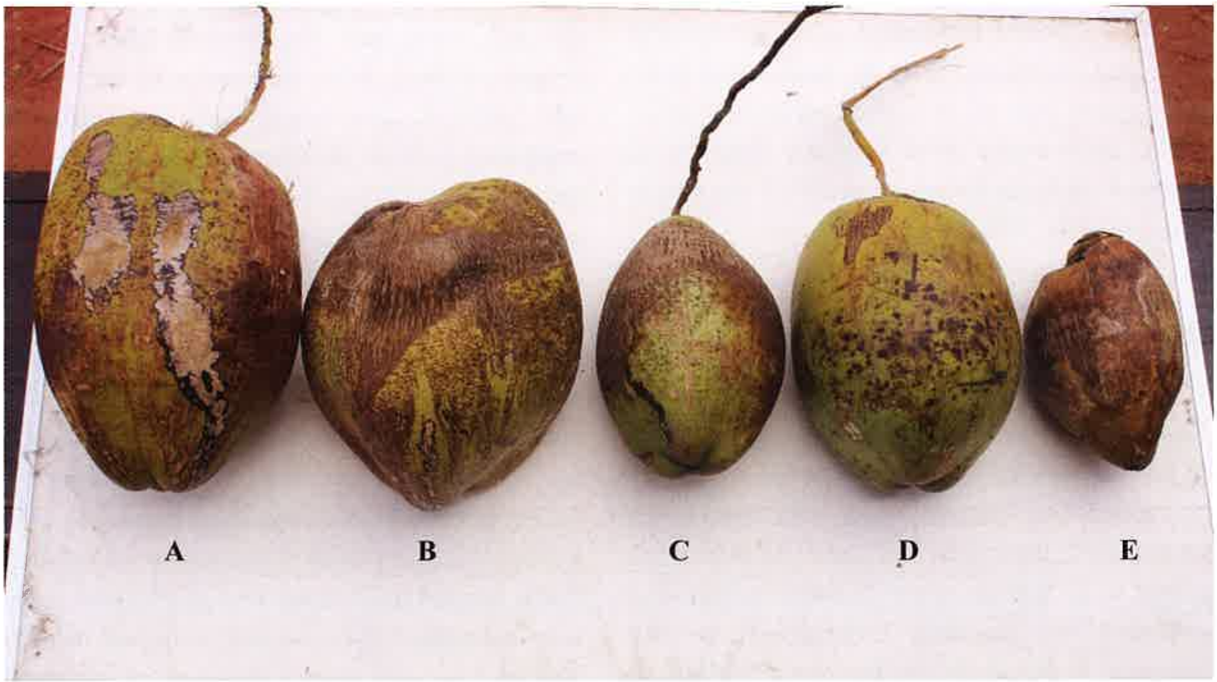

Figure 1. Different categories of fruits in the harvest (A-Uninfested fruit, B-Infested but normal-sized fruit, C-Infested and small-sized fruit, D-Infested fruit with discontinued damage scar from the perianth, E-Rejected fruits from the buyers)

Results and Discussion

Effect of release of *N. baraki* on the fruit components in the harvest

Study revealed that all the parameters were similar in treated and control blocks prior to releasing of *N. baraki*. The repeated measures ANCOVA showed a significant effect of releasing *N. baraki* on the percentage of the infested fruits in the harvest ($F_{1,81}$ = 5.583, P = 0.021). Percentage of infested fruits was lower on palms that were released with *N. baraki* than on control palms (Table 1). Regardless of the release of *N. baraki*, the percentage of normal-sized fruits in the harvest remained unaltered ($F_{1,81}$ = 2.050, P = 0.156). Nevertheless, with the release of *N. baraki* a 6% increase of normal-sized fruits was observed in the released block compared to the control block (Table 1). This indicates little or no effect of releasing *N. baraki* in increasing the percentage of normal-sized fruits in the harvest. However, significant increase in the normal-sized fruits was observed when *N. baraki* was released for a longer period of time and the data on 10 post release picks were analyzed (Aratchige *et al.*, 2012b). Significantly lower percentage of small-sized fruits in the harvest was observed in the block where *N. baraki* was released ($F_{1,81}$ = 5.033, P = 0.028). Percentage of small-sized fruits in the harvest was 6.3% in the released block whereas it was 17.2% in the control block, a 63% decrease in the released block (Table 1). Importantly, there was no interaction between treatment and time for any of the parameter considered indicating that the effect of treatment is temporally consistent.

The degree of suppression of coconut mite numbers was not measured to evaluate the effectiveness of the release of *N. baraki* in the study reported in this paper. This is because the percent suppression of pest populations alone does not provide sufficient information about the economic efficacy *per se* (Collier and VanSteenwyk 2004). Damage scar is discontinued from the perianth region (Figure 1D), when the coconut mite densities are reduced under the perianth region of the fruit and therefore, could be considered as an indirect measurement of the changes in the coconut mite populations. ANCOVA for repeated measures showed a highly significant effect of releasing *N. baraki* on the percentage of fruits with discontinued damage scars from the perianth of the fruits ($F_{1,74}$ = 36.94, P<0.001) with more than 200% increase in the released block (Table 1). This indicates that the coconut mite populations are decreased following the release of *N. baraki*.

Table 1. Effect of release of *N. baraki* on the percentages of infested fruits, normal-sized fruits, small-sized fruits and fruits with discontinued damage scars

Parameter	Estimated mean (±SE, N)	
	Released palms	**Control**
% infested fruits	83.0 (±2.8, 44)	93.1 (±3.1, 37)
% normal-sized fruits	92.1 (±2.4, 48)	86.8 (±2.7, 40)
% small-sized fruits	6.3 (±3.2, 48)	17.2 (±3.5, 40)
% fruits with discontinued damage scars	19.1 (±1.5, 48)	5.3 (±1.7, 48)

Fresh weight of the harvested fruits remained same in the pre-release picks ($P > 0.3$) except in the 4th pre-release pick ($P = 0.04$). In post release picks, except for the 1st pick, significantly higher fresh fruit weight was observed in the palms in the released block than that in the control block ($P < 0.001$, Figure 2). Husked fruit weights remained same during the pre-release picks and in the 1st post release pick ($P > 0.26$) and differed significantly thereafter ($P < 0.001$, Figure 3). Higher husked fruit weights were recorded from the palms in the released block compared to the control block. Kernel thickness was similar between the palms in the released block and the control block in the 3rd ($P = 0.56$) and 4th ($P > 0.99$) pre-release picks and the 1st ($P = 0.5$) post release pick. Significantly higher kernel thicknesses were observed in the 1st ($P < 0.001$), 2nd ($P = 0.003$) and 5th ($P = 0.03$) pre-release picks and 2nd ($P < 0.001$), 3rd ($P = 0.01$) and 4th ($P < 0.001$) post release picks (Figure 4). This clearly indicates that the release of *N. baraki* increases the coconut fruit weight and the thickness of the kernel.

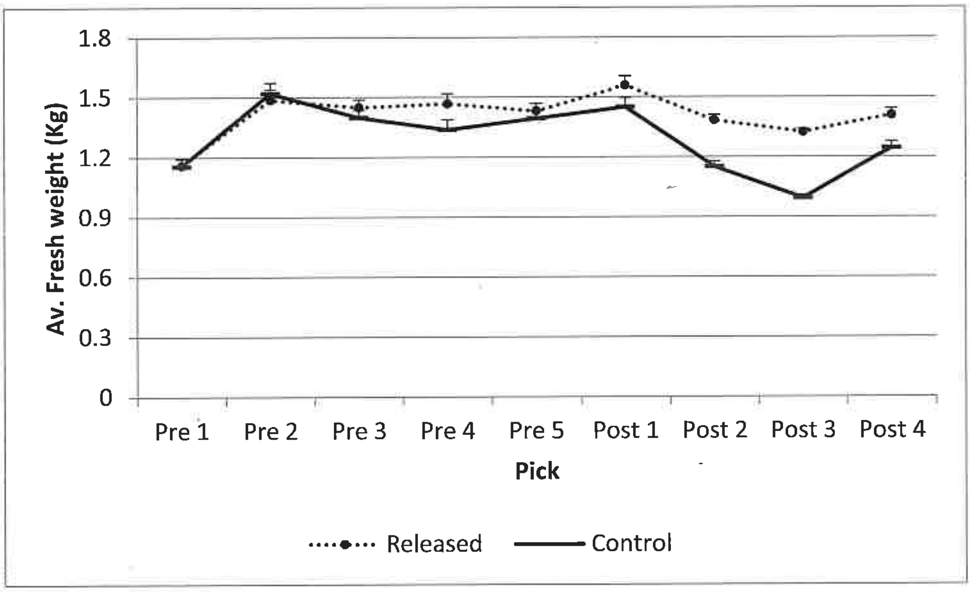

Figure 2. Effect of release of *N. baraki* on the fresh weight of fruits in the harvest (vertical bars represent standard error)

Effect of release of *N. baraki* on the rejections of harvested fruits

Data on percentage rejections of fruits from the harvest in the Daisy Valley estate showed statistically significant downward linear trend after releasing of *N. baraki* ($Y = -0.2129(T) + 14.368$ with $P<0.0001$, where Y = Percentage of rejected fruits in the harvest, T = time) in which 80.5% of the observed variability is accounted by the model (Figure 5). There was no such linear trend in the data prior to releasing *N. baraki* ($Y = -0.0187(T) + 11.114$, $P = 0.46$ and $R^2=3\%$) (Figure 5). This is an indication that the release of *N. baraki* is effective in reducing the crop loss due to rejections of harvested fruits from the buyers.

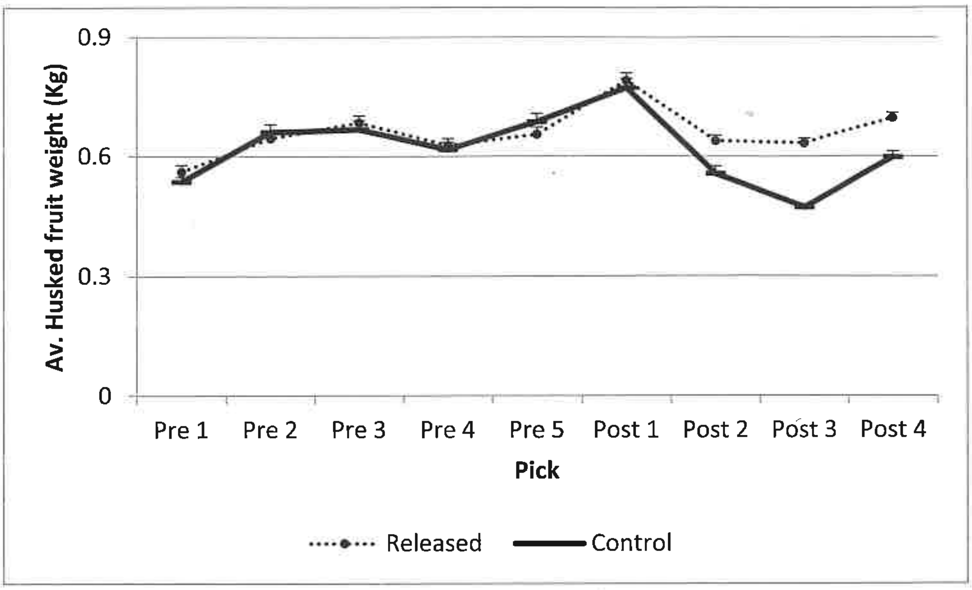

Figure 3. Effect of release of *N. baraki* on the husked weight of fruits in the harvest (vertical bars represent standard error)

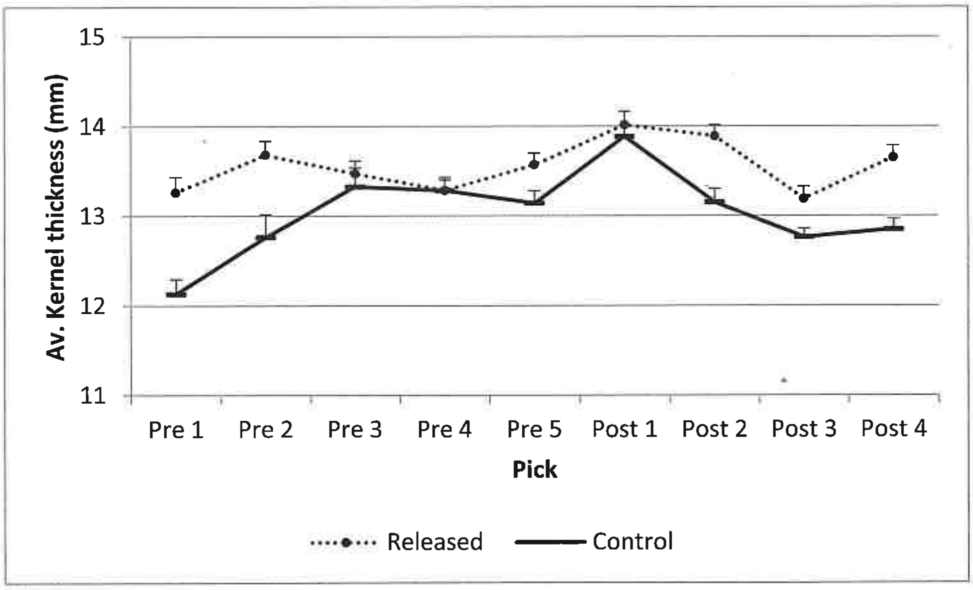

Figure 4. Effect of release of *N. baraki* on the kernel thickness of fruits in the harvest (vertical bars represent standard error)

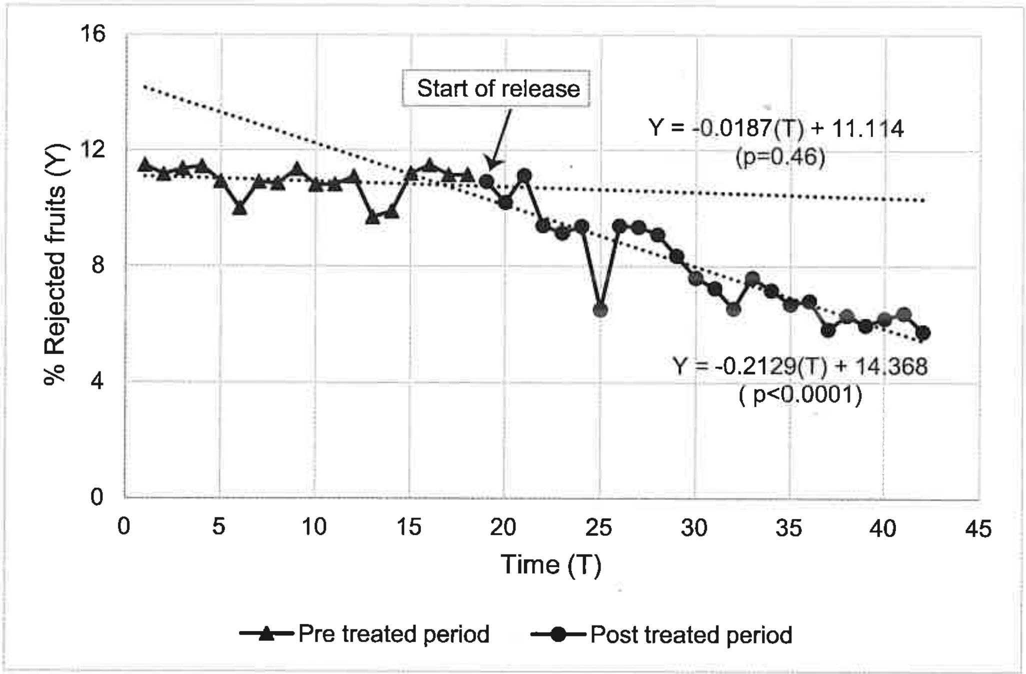

Figure 5. Percentage of rejected fruits in the harvest prior to and after the release of *N. baraki* into a field in the Daisy Valley estate, Mawathagama

Cost benefit analysis of releasing *N. baraki* was not done because the 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 (Aratchige *et al.*, 2012b). However, it has previously been proven that the release of *N. baraki* to control the coconut mite is economically viable (Aratchige *et al.*, 2012b). In Benin, using an ex-ante economic analysis, it has been demonstrated that the biological control of coconut mite is a viable technology (Oleke *et al.*, 2013). They have further recommended that, contemporaneous with the release of natural predators of the coconut mite, research and extension services should be strengthened to get the optimum benefit of using biological control against the coconut mite.

The findings of the analyses reported in the present paper provide consistent evidence that the recommendation on releasing *N. baraki* to control the coconut mite is viable in reducing the coconut mite damage, size decline of fruits and rejections in the harvest due to coconut mite damage in growers' plantations. It is also evident that the release of *N. baraki* in this manner is effective in increasing the fruit weights and kernel thickness.

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References

Alam, N.S. and Islam, M.N. (2014). Mite management of coconut in Bangladesh. (*In*) Proceedings of the mite management workshop of coconut in SAARC member countries. N. Akter, A.K. Azad and M.N. Alam (Eds) SAARC Agriculture Centre (SAC), Dhaka, Bangladesh. pp 25-38.

Anon (2003). Annual Report of the Crop Protection Division, Coconut Research Institute of Sri Lanka

Aratchige, N.S. (2007). Predators and the accessibility of herbivore refuges in plants. PhD Thesis, University of Amsterdam.

Aratchige, N.S. (2014). Mite management of coconut in Sri Lanka (*In*) Proceedings of the mite management workshop of coconut in SAARC member countries. N. Akter, A.K. Azad and M.N. Alam (Eds). SAARC Agriculture Centre (SAC), Dhaka, Bangladesh. pp 87-104.

Aratchige, N.S., Fernando, L.C.P., Waidyarathne, K.P. and Chandrasiri, K.A.S. (2012a). Population dynamics of *Aceria guerreronis* (Acari: Eriophyidae) and its predatory mite, *Neoseiulus baraki* (Acari: Phytoseiidae) in two coconut growing areas in Sri Lanka Exp Appl Acarol 56:319-325. ISSN 0168-8162. DOI: 10.1007/s10493-012-9519-z.

Aratchige, N.S., Fernando, L.C.P., Kumara, A.D.N.T., Jayalath, K.V.N.N., Perera, K.F.G. and Suwandarathne, N.I. (2012b). Biological control of coconut mite: Effect of inundative release of the predatory mite, *Neoseiulus baraki* (Acari: Phytoseiidae) (*In*) Proceedings of the 4th Symposium on Plantation Crop Research – Technological Innovations for Sustainable Plantation Economy. L.S.K. Hettiarachchi and I.S.B. Abeysinghe (Eds.) Tea Research Institute of Sri Lanka, St. Coombs, Talawakelle, 22100, Sri Lanka pp 125-133.

Collier, T. and VanSteenwyk, R. A. (2004). Critical evaluation of augmentative biological control. Biol Cont 31(2): 245-256.

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

Fernando, L.C.P. and Chandrasiri, K.A.S. (2010). Effectiveness of spraying vegetable oil-sulphur emulsion to manage coconut mite, *Aceria guerreronis*. (*In*) Proceedings of the Third Symposium on Plantation Crop Research – Stakeholder empowerment through technological advances. R.S. Dharmakeerthi and A.M.W.K. Senevirathna (Eds). Rubber Research Institute of Sri Lanka, Dartonfield, Agalawatte, Sri Lanka. pp. 241-250.

Hernández-Roque, F. (1977). Combate químico del eriófido del cocotero *Aceria* (*Eriophyes*) *guerreronis* (K.) en la Costa de Guerrero. Agric Tec México 4:23–38.

Howard, F.W., Moore, D., Giblin-Davis, R.M. and Abad, R.G. (2001). Insects on palms. CABI Publishing, Wallingford.

Jetter, K. (2005). Economic framework for decision making in biological control. Biol Cont. 35, 348-357.

Kumar, P.P. and Ramaraju, K. (2010). Impact of nut-infesting eriophyid mite, *Aceria guerreronis* Keifer, on the out-turn and quality of coconut fiber. (*In*) Proceedings of XIII International Congress of Acarology. Abstracts. G.J. de Moraes, R.C. Castillo and C.H. Flechtmann (Eds) Recife, Brazil. p 214.

Kumara, A.D.N.T., Fernando, L.C.P., Suwandharathne, N.I. and Aratchige, N.S. (2014). Use of polypropylene bags for mass rearing *Neoseiulus baraki* (Acari: Phytoseiidae), a predatory mite of *Aceria guerreronis* Keifer (Acari: Eriophyidae) Bioconl Sc Tech DOI:10.10 80/0958307.2014.918245.

Moore, D. and Howard, F.W. (1996). Coconuts. (I) Eriophyoid mites: their biology, natural enemies and control. E.E. Lindquist, M.W. Sabelis and J. Bruin (Eds) Elsevier, Amsterdam, pp 561–570.

Moraes, G.J. de and Zacarias, M.S. (2002). Use of predatory mites for the control of eriophyid mites. (*In*) Proceedings of International Workshop on Coconut Mite *(Aceria guerreronis)*. L.C.P. Fernando, G.J. de Moraes and I.R. Wickramanada (Eds) Coconut Research Institute, Lunuwila, Sri Lanka. pp 78–88.

Moraes, G.J. de, Lopes, P.C. and Fernando, L.C.P. (2004). Phytoseiid mites (Acari: Phytoseiidae) of coconut growing areas in Sri Lanka, with descriptions of three new species. J Acarol Soc Jpn 13:141–160.

Muralidharan, K., Mathew, C.J., Thampan, C., Amamath, C.H., Anithakumari, P., Mohan, C., Vijayakumar, K., Sairam, C.V., Nair, C.P.R. and Arulraj, S. (2001). Pilot sample survey on the incidence and yield loss due to eriophyid mite on coconut in Alappuzha District. Indian Coconut J. 21:28–32.

Nair, C.P.R. (2002). Status of coconut eriophyid mite *Aceria guerreronis* Keifer in India. *(*In) Proceedings of the International Workshop on Coconut Mite *(Aceria guerreronis)*. L.C.P. Fernando, G.J. Moraes de, I.R. Wickramanada (Eds) Coconut Research Institute, Lunuwila, Sri Lanka, pp 9–12.

Naseema Beevi, S., Mathew, T.B., Bai, H. and Saradamma, K. (2003). Status of eriophyid mite in Kerala-Resume of work done. (*In*) Proceedings of the International Workshop on Coconut Mite Coconut eriophyid mite - Issues and strategies. H.P. Singh, P. Rethinam (Eds). Bangalore, pp 64–75.

Oleke, J.M., Manyong, V., Mignouna, D., Isinika, A., Mutabazi, K., Hanna, R. and Sabelis, M.W. (2013). Ex-ante economic analysis of biological control of coconut mite in Benin. AgBioForum, 16(2), 161-169.

Wickramananda, I.R., Peiris, T.S.G., Fernando, M.T.N., Fernando, L.C.P. and Edgington, S. (2007). Impact of the coconut mite (*Aceria guerreronis* Keifer) on the coconut industry in Sri Lanka. CORD 23:1–16.