Chapter 4
Seasonal Variation of Coconut Mite Populations and Resulting Damage to Nuts in Jamaica

Introduction

The coconut mite, *Eriophyes guerreronis* (Keifer) (Acari: Eriophyidae) breeds under the perianth of coconuts (*Cocos nucifera* Beccari) where it feeds on the meristematic tissue of the nut surface. Infestation by coconut mite is first evident from chlorosis of the damaged cells that eventually turn brown. As the fruit grows, deep fissures develop in the damaged area (Anonymous 1985, Hall 1981, Schliesske 1988). In extreme cases, fruits may have up to 80% surface area damaged, accompanied by distortion, reduced size, and a consequent decline in yield (Julia and Mariau 1979, Hall 1981, Anonymous 1985).

Coconut mite populations and the extent of damage caused by the coconut mite have responded differently to wet and dry seasons in different regions of its geographical range. The first outbreak of the coconut mite in Jamaica was in 1972 after a period of drought (Hall 1981). In Benin and the Ivory Coast, Julia and Mariau (1979) found levels of attack four to five times higher in the wet seasons than in the dry; the reverse was reported from Guerrero, Mexico (Mariau 1969). Otterbein (1988) reported that in Costa Rica the greatest nut damage was associated with frequent heavy rainfall and high humidity. Howard *et al.* (1990) found that coconut mite populations increased immediately after periods of high rainfall in Puerto Rico and Florida. They, however, did not find any statistical relationship between fluctuations of coconut mite populations and wet and dry seasons or with mean daily temperatures.

The shape and color of the coconuts are two important characteristics that determine susceptibility of coconut varieties to infestation by the coconut mite (Julia and Mariau 1979, Mariau 1986, Moore and Alexander 1990). Roundness of the nut causes greater adpression of the perianth onto the nut surface. This adpression delays colonization by the coconut mite and reduces injury to nuts (Mariau 1977, Moore and Alexander 1990, Howard and Rodriguez 1991). The degree of adpression decreases with increasing nut size (Julia and Mariau 1979, Mariau 1986, Otterbein, 1988). Dark green nuts tend to have greater resistance to coconut mite (Moore and Alexander 1990) while Yellow Malayan Dwarf cultivars are more susceptible to mite infestation than its other color morphs, tall and hybrid cultivars (Mariau 1977, 1986, Julia and Mariau 1979, Otterbein 1988, Moore and Alexander 1990).

Coconut mites colonize nuts from one to six months after fertilization (Moore *et al.* 1989). The flowers are fertilized within two months after inflorescence. Peak coconut mite populations occur on 3- to 6-month old nuts, then the numbers decline sharply so that nuts over 9 months old have relatively low coconut mite populations (Moore and Alexander 1987). Damage to plant organs by eriophyid mites is more severe when these organs are attacked in the early stages of their development (Albrigo and McCoy 1974).

Griffith (1984) reported that strong wind currents are the most important means by which coconut mites disperse. Most coconut plantations in Jamaica are located on the coastal plains in the eastern portion of the island. They are either exposed to the North East Trade Winds and to the South East Trade Winds in the northeastern and southeastern regions of the island, respectively.

The objectives of this study are as follows:

1) To compare seasonal variations in coconut mite populations and coconut damage within two ecological zones in eastern Jamaica.
2) To distinguish differences between coconut mite populations and levels of damage on Maypan and Red Malayan Dwarf coconut varieties.
3) To describe differences in levels of coconut mite populations and damage among nuts of different ages.
4) To determine if the location of trees within a stand affects coconut mite populations and nut damage.
5) To determine if nut orientation to prevailing winds influences the extent of coconut mite damage.

Materials and methods

The two ecological zones were distinguished by the amount of rainfall they receive per year. Zone 1 gets 4,000 to 5,000 mm rainfall per year, and Zone 2, 1,500 to 2,000 mm rainfall per year. Three farms were used in this study, one (Farm 1) in the High Rainfall Zone, and two (Farms 2a and 2b) in the Low Rainfall Zone (Figure 1). These last two farms are about 10 km apart. Farm 2a had a 0.6 ha plot with Red Malayan Dwarf coconuts and Farms 2b, a 2 ha plot with Maypan coconuts. Farm 1 had a 0.4 ha plot with Red Malayan Dwarf 2 ha plot with Maypan coconuts. The Red Malayan Dwarf plots in Zones 1 and 2 were 0.3 and 3.8 km from the coast, respectively. The Maypans were 0.05 and 0.02 km from the coast in Zones 1 and 2, respectively. During the study period the Red Malayan Dwarfs were 5-7 m tall while the Maypans were 9 to 11 m tall.

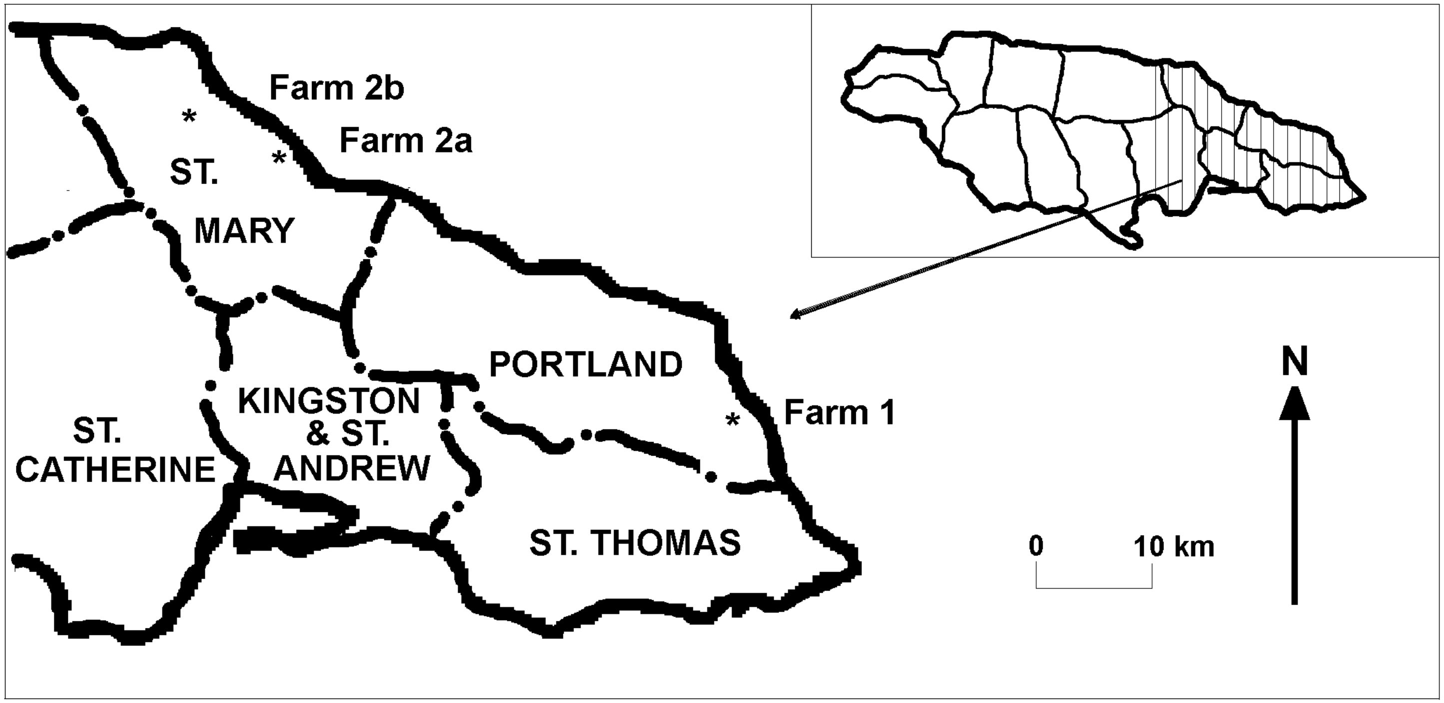


Figure 1. Farms in eastern Jamaica on which seasonal variations in coconut mite populations and resulting damage to nuts were studied during January 1993 to May 1994.

Plots were divided into inner and outer regions by a 15 m boundary from the edge of each plot. In each plot fourteen randomly selected trees were marked, seven of these from the edge of the plot (outer trees) and the other seven from the inner regions of the plot. (inner trees). On each tree coconut bunches were numbered, starting with the youngest. Bunch numbers indicate the approximate age (in months) of each bunch. Nuts from 2-, 4- and 10-month old bunches were examined *in situ* for visible symptoms of coconut mite damage each month, from January 1993 to May 1994. Damage was graded based on modification of the categories used by Moore *et al.* (1989). These categories are (See Figure 2):

Grade 0 - nuts with no mite damage,

Grade 1 - nuts with 1-29% surface area damage,

Grade 2 - nuts with 30-59% surface area damage and less than 20% reduction in size,

Grade 3 - nuts with 60-80% surface area damage, 20-29% reduction in size and with some deformation,

Grade 4 - nuts with over 80% surface area damage, over 30% reduction and often greatly deformed.

A compass was used to find the direction each bunch faced. Cardinal points were grouped into four categories as follows:

Group	Cardinal points
South east (SE)	SSE, SE, ESE, S
North west (NW)	WNW, NW, NNW, N
South west (SW)	SSW, SW, WSW, W
North east (NE)	NNE, NE, ENE, E

No destructive sampling was done on these trees. Each month a pair of nuts (damaged and undamaged where possible) was removed from the 2-, 4- and 10-month old bunches of three neighboring unmarked inner and outer trees within the study area. These nuts were labeled and taken to the laboratory for microscopic examination where each was graded for coconut mite damage as described above. The perianth were removed and each tepal (episepal/sepal/petal) was examined under a stereomicroscope. In addition, the entire external surface of 2-month old nuts was examined under magnification. For 4- and 10-month old nuts, the top of the nut, (ca. one inch below the peduncle) was removed and the meristematic region examined; other damaged surfaces were peeled off for microscopic study. The number of mites present (live and dead) on these nuts was counted. Where the number of mites on a nut was too large to be counted directly, they were washed from these surfaces into 10 ml of 2% soap solution with the aid of a small paint

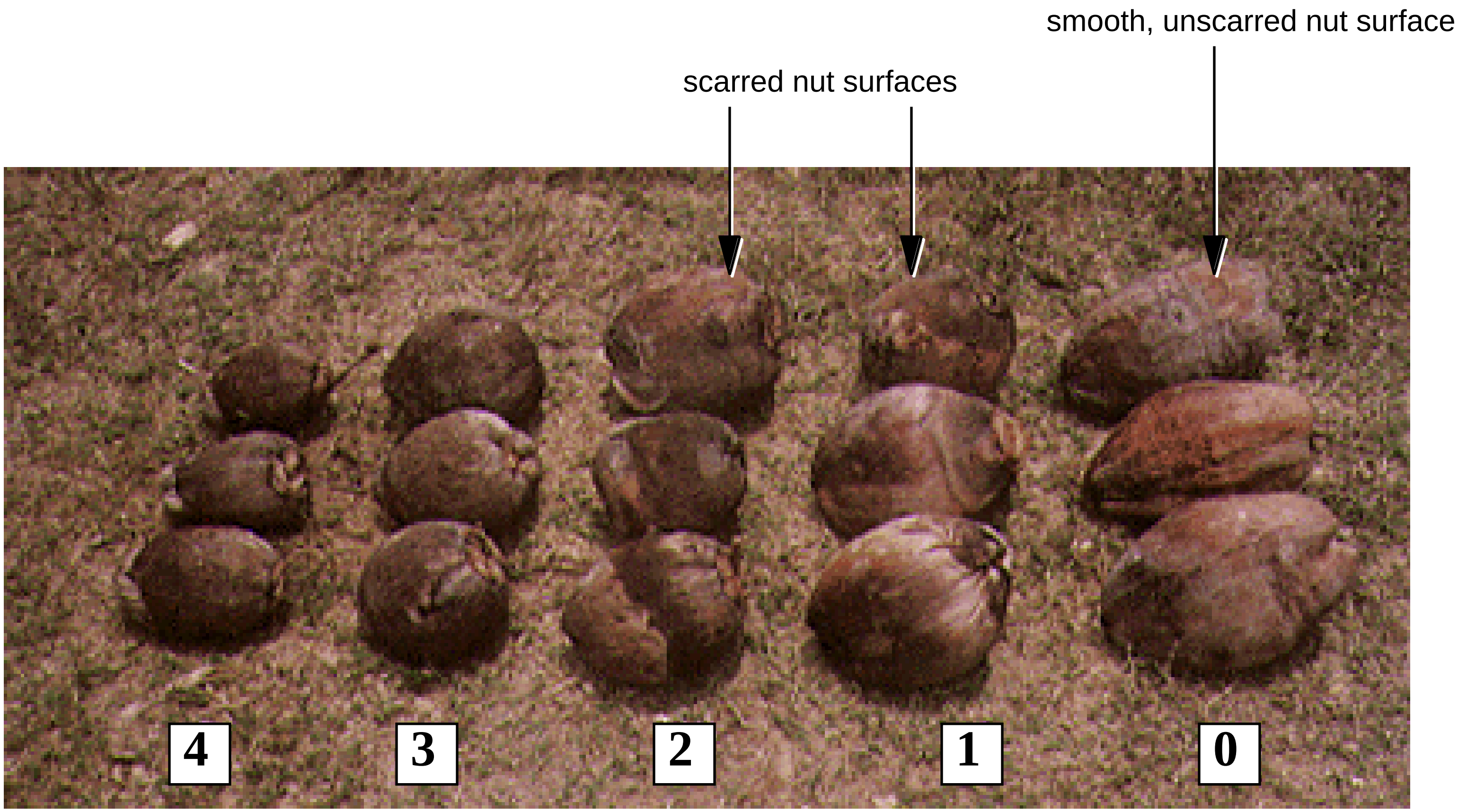


Figure 2. Nuts graded according to the extent of damage caused by the coconut mite *Eriophyes guerreronis* (Keifer). Grade 0 are nuts without coconut mite damage, grade 1 - nuts with 1-29% surface area damage, grade 2 - nuts with 30-59% surface area damage,grade 3 - nuts with 60-79% surface area damage, and grade 4 - nuts with > 80% surface area damage.

brush. Three 0.02 ml aliquot samples (s) of the soap solution with mites were placed into Perspex counting dishes (Easterbrook and Fuller 1986) and the number of mites (m) in each counted. The number of mites in 10 ml of soap solution (i.e. number of mites per nut, M) was estimated as:

$$M = \frac{\left[\sum_{s=1}^{3} m\right] 10}{3 \quad 0.02}$$

Mite counts were grouped into five categories, 0, 1-100, 101-1000, 1001-5000 and >5000. Samples were taken from January 1993 to May 1994 and the mean monthly rainfall for this period was obtained from the Meteorological Office in Kingston, Jamaica. Rainfall data for Farms 1, 2a and 2b were obtained from stations within 9.5, 5 and 1.5 km of these farms, respectively

Effects of variety, age of nut, tree position, and time, on mite population and coconut damage were analyzed using Categorical Data Modeling, CATMOD, (SAS Institute Inc. 1985) and a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985). Seasonal variations in coconut mite population and damage were compared using least-square means, (SAS Institute Inc. 1985). The five damage categories were collapsed into three groups to satisfy the requirements of the data analyses because few nuts were found in grades 3 and 4. Collapsing of these categories were based on least-square means and multiple comparisons of surface areas of nuts damage by the coconut mite and were as follows:

Grade 0 - nuts with 0% surface area damage,

Grade 1 - nuts with up to 29% surface area damage,

Grade 2 - nuts with > 30% surface area damage,

Results

1) Seasonal variations in coconut mite populations and damage to nuts within two ecological zones in eastern Jamaica

There were no significant differences between the mean numbers of live coconut mites per nut ($p > 0.05$) in the two rainfall zones (Table 1). Neither were there any significant differences between the mean numbers of dead coconut mites per nuts ($p > 0.05$) in the two rainfall zones (Table 1). The percentage and severity of damage caused by the coconut mite differed significantly between the localities. Coconut trees in the Low Rainfall Zone had 0.7% more damaged nuts than those in the High Rainfall Zone ($p < 0.002$, Table 2). A relatively smaller percentage of nuts in the Low Rainfall Zone had severe damage (i.e. surface area damage $\geq$ 30%) than those in the High Rainfall Zone (p <

Table 1. Populations of live and dead coconut mite on nuts in High and Low Rainfall Zones in eastern Jamaica during January 1993 to May 1994. The High Rainfall Zone gets 4,000 to 5,000 mm rainfall per year, and the Low Rainfall Zone, 1,500 to 20,00 mm rainfall per year. Zones followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Mite population	Rainfall zone	No. of nuts	No. of coconut mites				
			0	1-100	101-1000	1001-5000	>5000
Live	High **a**	1,090	55.41± 1.51	23.03 ± 1.28	9.0 8 ± 0.87	4.59 ± 0.63	7.89 ± 0.82
	Low **a**	1,054	54.74 ± 1.53	24.48 ± 1.32	8.16 ± 0.84	3.89 ± 0.60	8.73 ± 0.87
Dead	High **a**	1,090	70.09 ± 1.39	12.57 ± 1.00	8.26 ± 0.83	3.76 ± 0.58	5.32 ± 0.68
	Low **a**	1,054	71.82 ± 1.39	11.76 ± 0.99	6.64 ± 0.77	3.51 ± 0.57	6.26 ± 0.75

Table 2. Damage to nuts by the coconut mite in High and Low Rainfall Zones in eastern Jamaica during January 1993 to May 1994. The High Rainfall Zone gets 4,000 to 5,000 mm rainfall per year, and the Low Rainfall Zone, 1,500 to 2,000 mm rainfall per year. Zones followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Rainfall zone	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
High **a**	11,561	79.37 ± 0.38	16 .74 ± 0.35	3.89 ± 0.18
Low **b**	10,31	78.70 ± 0.40	17.78 ± 0.38	3.51 ± 0.08

0.004). Except for the amount, the pattern of rainfall was similar at all three sites (Figure 3). On each farm, mean monthly rainfall exceeded 200 mm during April to June 1993. Farm 1consistently received a greater volume of rainfall than Farms 2a and 2b, respectively (Figure 3).

No significant relationships were found between monthly rainfall and the pattern of mite fluctuation ($p > 0.05$). During April to September 1993, coconut mite populations were significantly lower ($p < 0.0001$) than any other period between January 1993 and May 1994 (Table 3 and Figures 4a-5d). There were no interactions between farm and time on the percentage of nuts that were damaged by the coconut mite ($p > 0.05$). Seasonal differences in the number of nuts with coconut mite damage and the extent of damage were significant ($p < 0.0001$). Significantly fewer nuts had coconut mite damage during July to December 1993 than any other period between January 1993 and May 1994 (Table 4, Figure 6). In addition, less surface area damage to nuts occurred during this time (Table 4).

2) Differences between coconut mite populations and levels of coconut mite damage on Maypan and Red Malayan Dwarf coconut varieties

There were no significant locality by variety interactions on the number of live coconut mites per nut ($p > 0.05$). Maypan nuts had higher infestations of live coconut mites than Red Malayan Dwarf nuts ($p < 0.0001$). Both varieties had similar percentages of nuts with the two highest counts of live mites (Table 5). Significant locality by variety interactions occurred with the number of dead coconut mites ($p = 0.45$). Nuts of the Red Malayan Dwarf plot in the Low Rainfall Zone had fewer dead coconut mites than nuts of the same variety in the High Rainfall Zone and nuts of the two Maypan plots (Table 5). The percentage of nuts with over 100 dead coconut mites were not significantly different on the other farms. A greater percentage of the Maypan nuts had dead coconut mites than the Red Malayan Dwarf nuts ($p < 0.001$). There were no significant interactions between the main effects of farm and variety on the percentage of nuts that were damaged by the coconut mite ($p > 0.05$). Red Malayan Dwarf nuts were 8 - 10% more likely to be damaged than Maypan nuts (Table 6). Significant farm by variety interactions occurred with the severity of coconut mite damage to nuts ($p = 0.024$). Maypan nuts in the High Rainfall Zone (Maypan 1) had fewer damaged nuts but were more severely damaged nuts ($\geq$ 30% surface area damage) than nuts of the same variety (Maypan 2) in the Low Rainfall Zone ($p = 0.001$). There was no significant difference among the damage categories of Red Malayan Dwarf nuts in the two rainfall zones ($p > 0.05$, Table 6). Red Malayan Dwarf trees were two times more likely to have ≥ 30% of the surface area of nuts damaged.

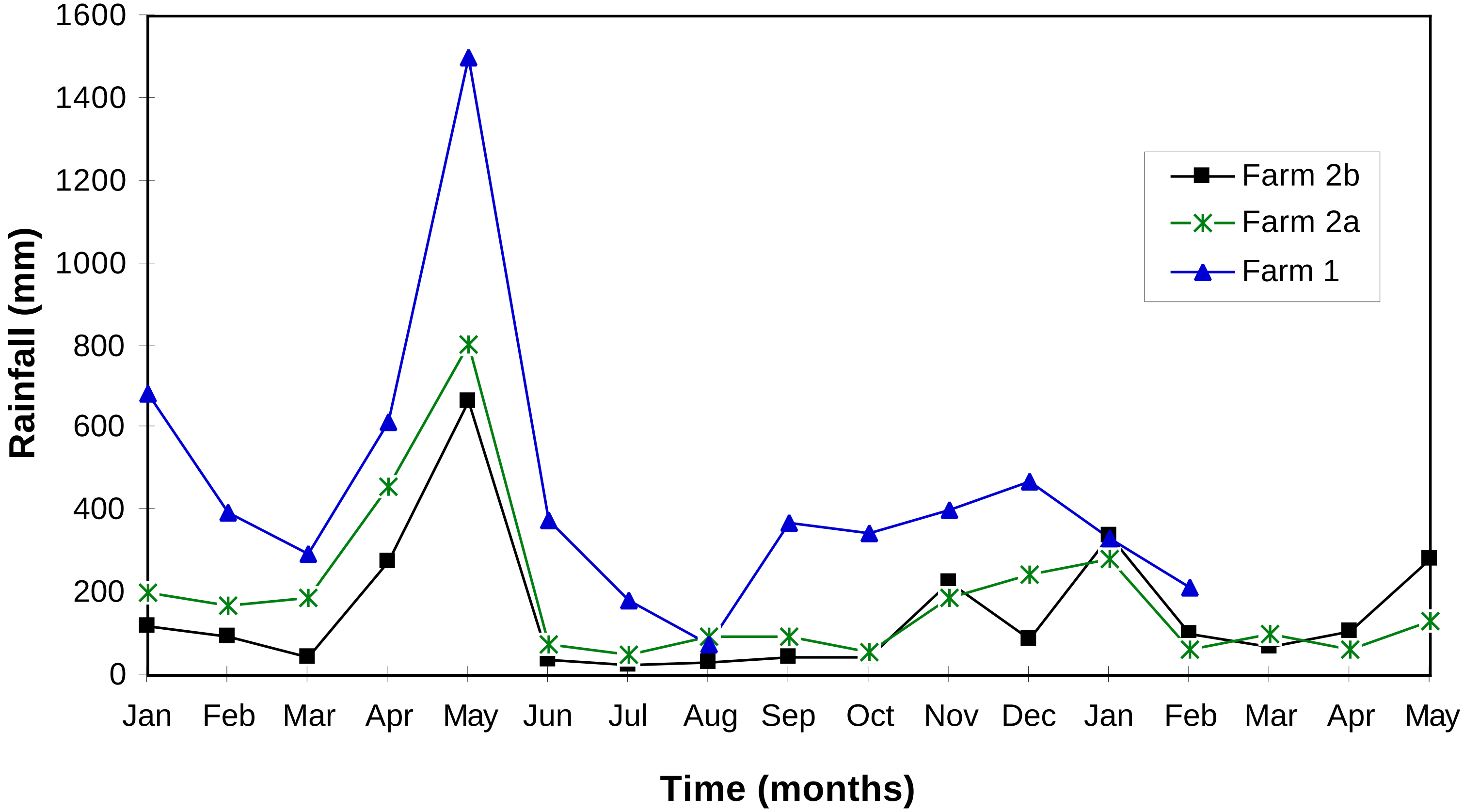


Figure 3. Monthly rainfall for sites where the seasonal variations in populations of the coconut mite, ***Eriophyes guerronis*** (Keifer), and resulting damage to nuts were observed in Jamaica, January 1993 to May 1994

Table 3. Seasonal variations in coconut mite, *E. guerreronis* , populations in eastern Jamaica during January 1993 to May 1994. Dates followed by the same letters are not significantly different (p > 0.05) based on comparisons of least-square means(SAS Institute Inc. 1985).

	Period (months)	No. of nuts	No. of coconut mites				
			0	1-100	101-1000	1001-5000	>5000
Live mites	Jan-Mar 1993 **a**	269	55.76 ± 3.03	18.59 ± 2.37	9.67 ± 1.80	4.83 ± 1.31	11.15 ± 1.92
	Apr-Jun 1993 **b**	291	82.13 ± 2.25	9.62 ± 1.73	3.78 ± 1.12	2.41 ± 0.90	2.06 ± 0.83
	Jul-Sep 1993 **b**	360	75.28 ± 2.27	15.28 ± 1.90	6.67 ± 1.31	1.94 ± 0.73	8.33 ± 0.48
	Oct-Dec 1993 **a**	504	38.29 ± 2.17	38.89 ± 2.17	7.94 ± 1.20	3.97 ± 0.87	10.91 ± 1.39
	Jan-Mar 1994 **a**	432	44.68 ± 2.39	26.39 ± 2.12	11.81 ± 1.55	6.71 ± 1.20	10.42 ± 1.47
	Apr-May 1994 **a**	288	46.88 ± 2.94	22.92 ± 2.48	11.46 ± 1.88	5.21 ± 1.31	13.54 ± 2.02
Dead Mites	Jan-Mar 1993 **acd**	269	66.91 ± 2.87	11.11 ± 1.91	10.78 ± 1.89	5.20 ± 1.35	5.95 ± 1.44
	Apr-Jun 1993 **b**	291	87.29 ± 1.95	7.56 ± 1.55	3.44 ± 1.07	6.87 ± 0.48	1.03 ± 0.59
	Jul-Sep 1993 **b**	360	85.56 ± 1.85	7.22 ± 1.36	6.39 ± 1.29	2.78 ± 0.27	0.56 ± 0.39
	Oct-Dec 1993 **ac**	504	66.87 ± 2.10	14.88 ± 1.59	5.56 ± 1.02	5.16 ± 0.99	7.54 ± 1.18
	Jan-Mar 1994 **acd**	432	59.72 ± 2.36	17.59 ± 1.83	10.42 ± 1.47	4.86 ± 1.03	7.41 ± 1.26
	Apr-May 1994 **ad**	288	63.89 ± 2.83	11.11 ± 1.85	8.68 ± 1.66	4.86 ± 1.27	11.46 ± 1.88

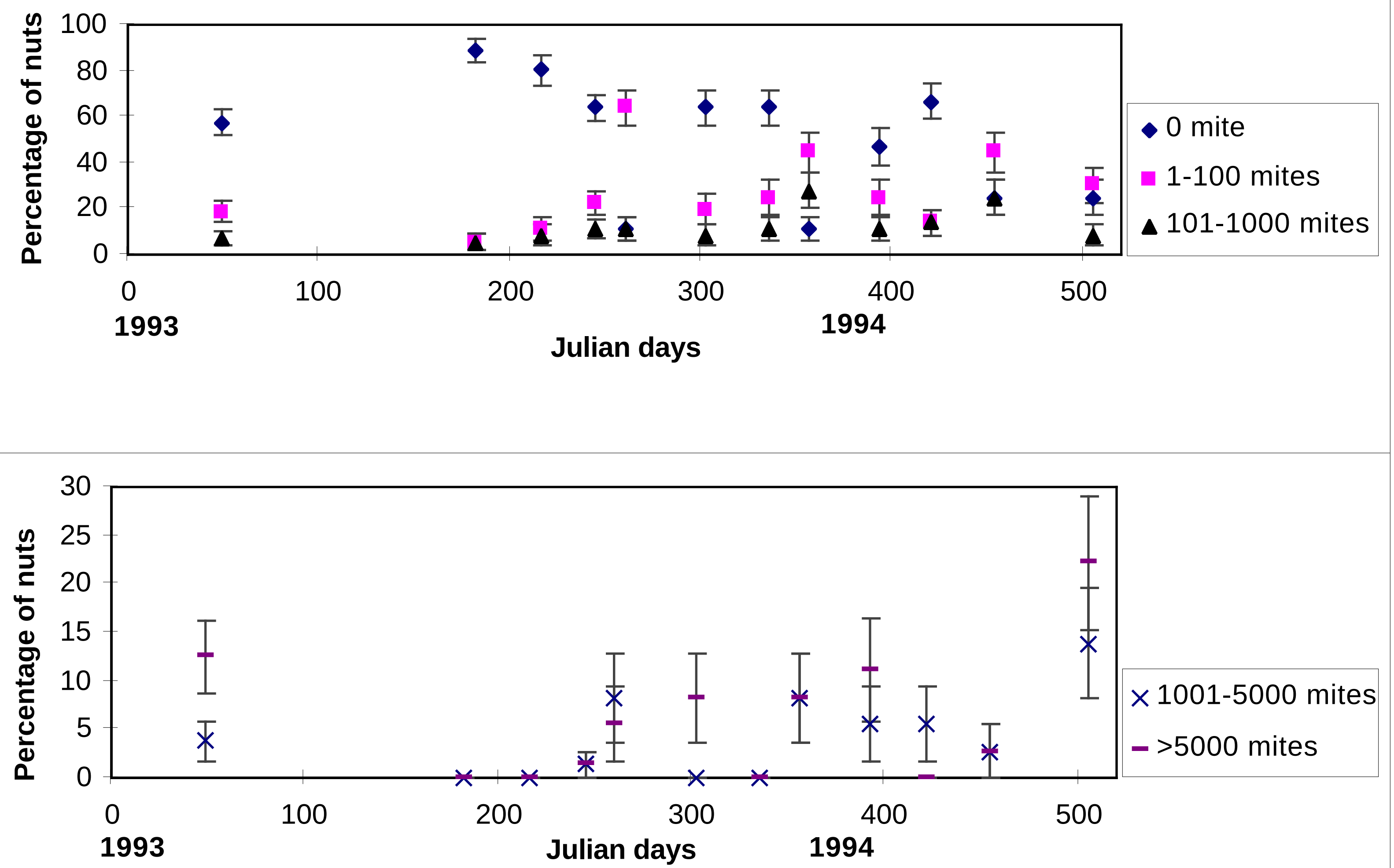
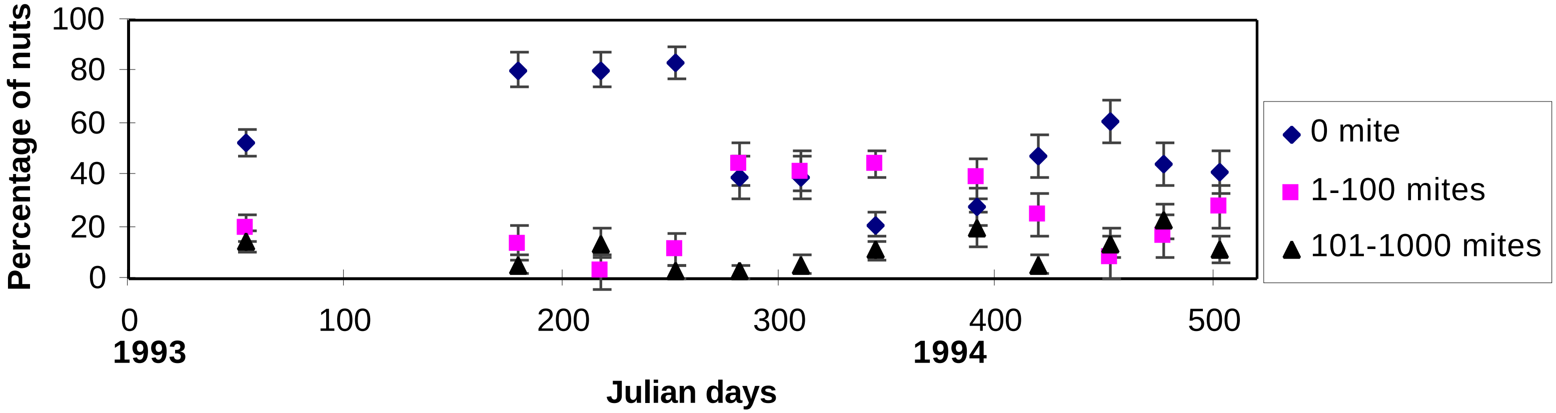


Figure 4a. Populations of live coconut mite, ***E. guerreronis*** (Keifer), on Maypan coconuts in a High Rainfall Zone (4000-5000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994



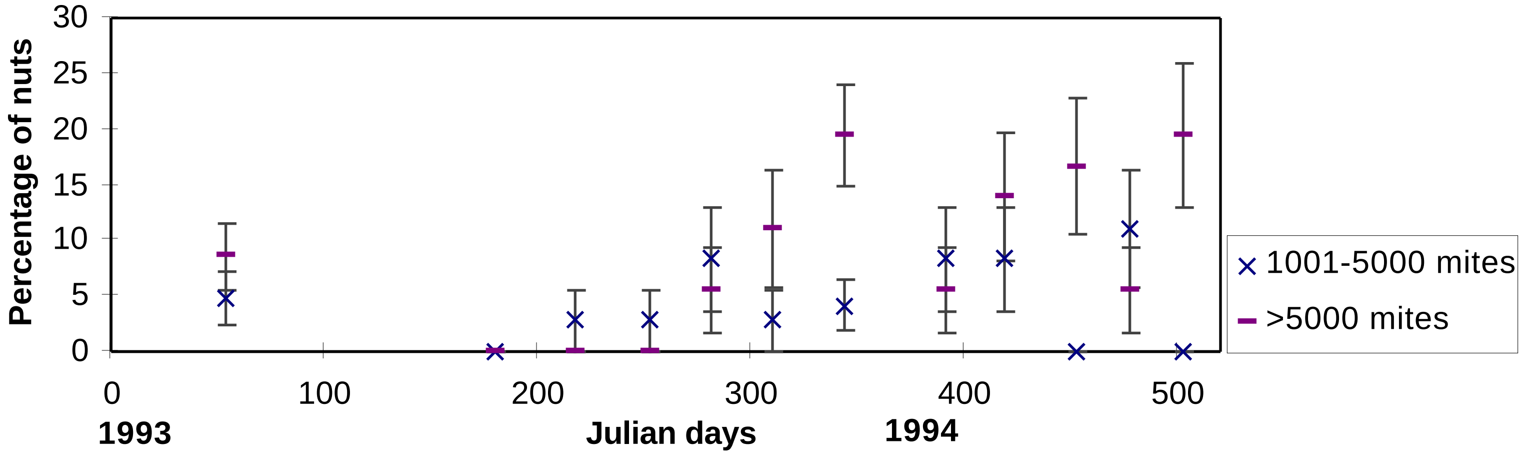


Figure 4b. Populations of live coconut mite, ***E. guerreronis*** (Keifer), on Maypan coconuts in a Low Rainfall Zone (1500-2000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994

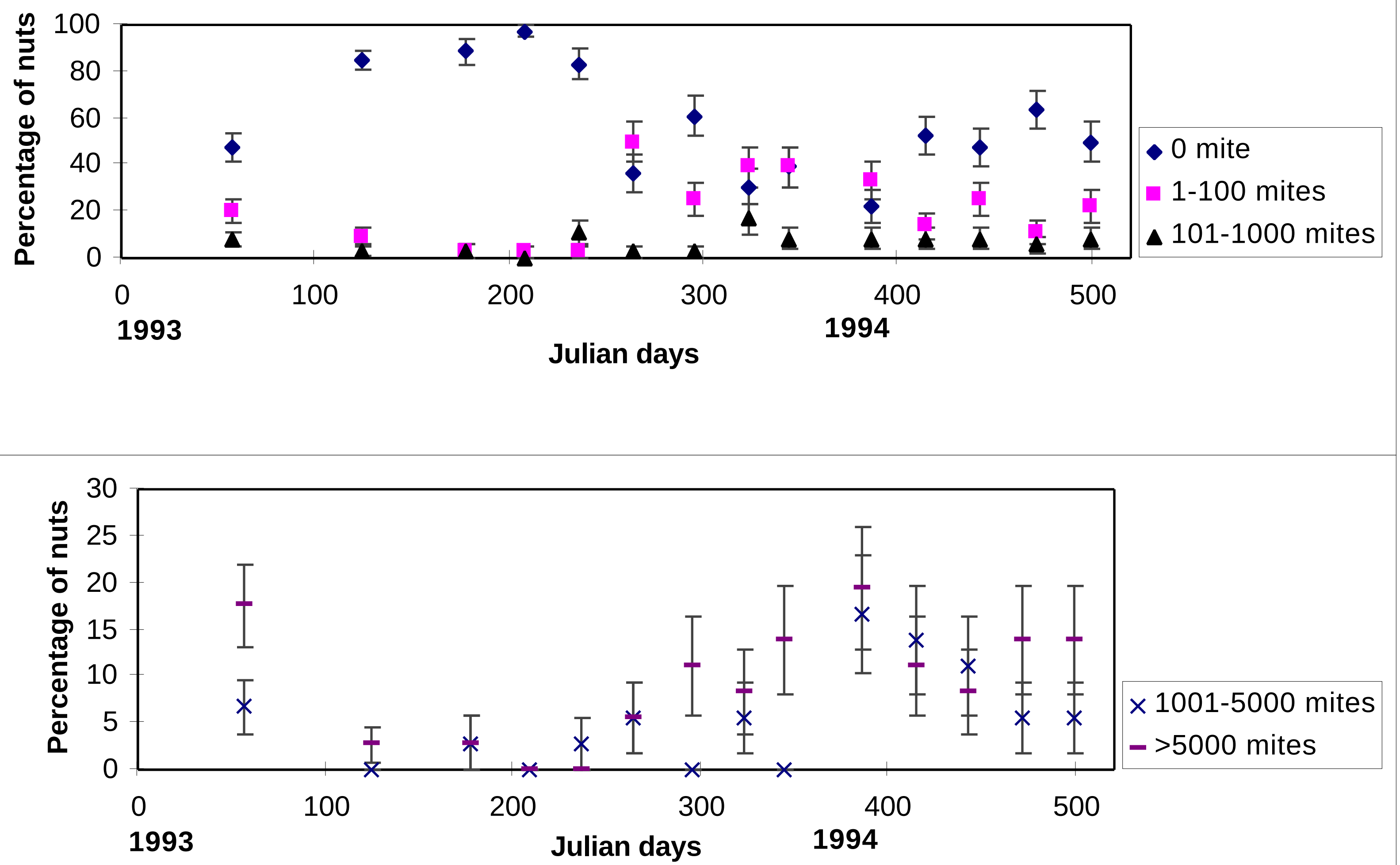


Figure 4c. Populations of live coconut mite, ***E. guerreronis*** (Keifer), on Red Malayan Dwarf coconuts in a High Rainfall Zone (4000-5000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994

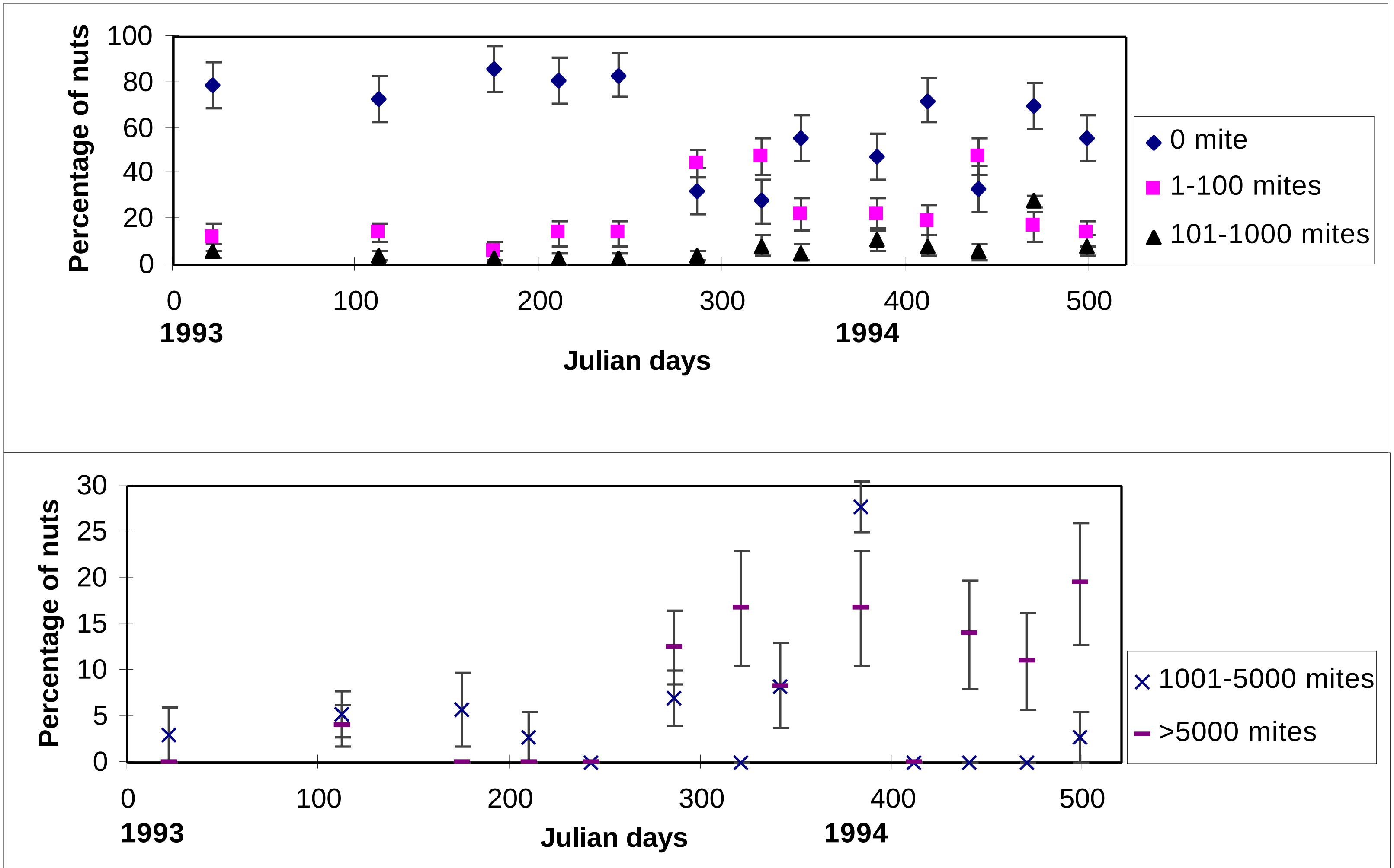


Figure 4d. Populations of live coconut mite, ***E. guerreronis*** (Keifer), on Red Malayan Dwarf coconuts in a Low Rainfall Zone (1500-2000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994

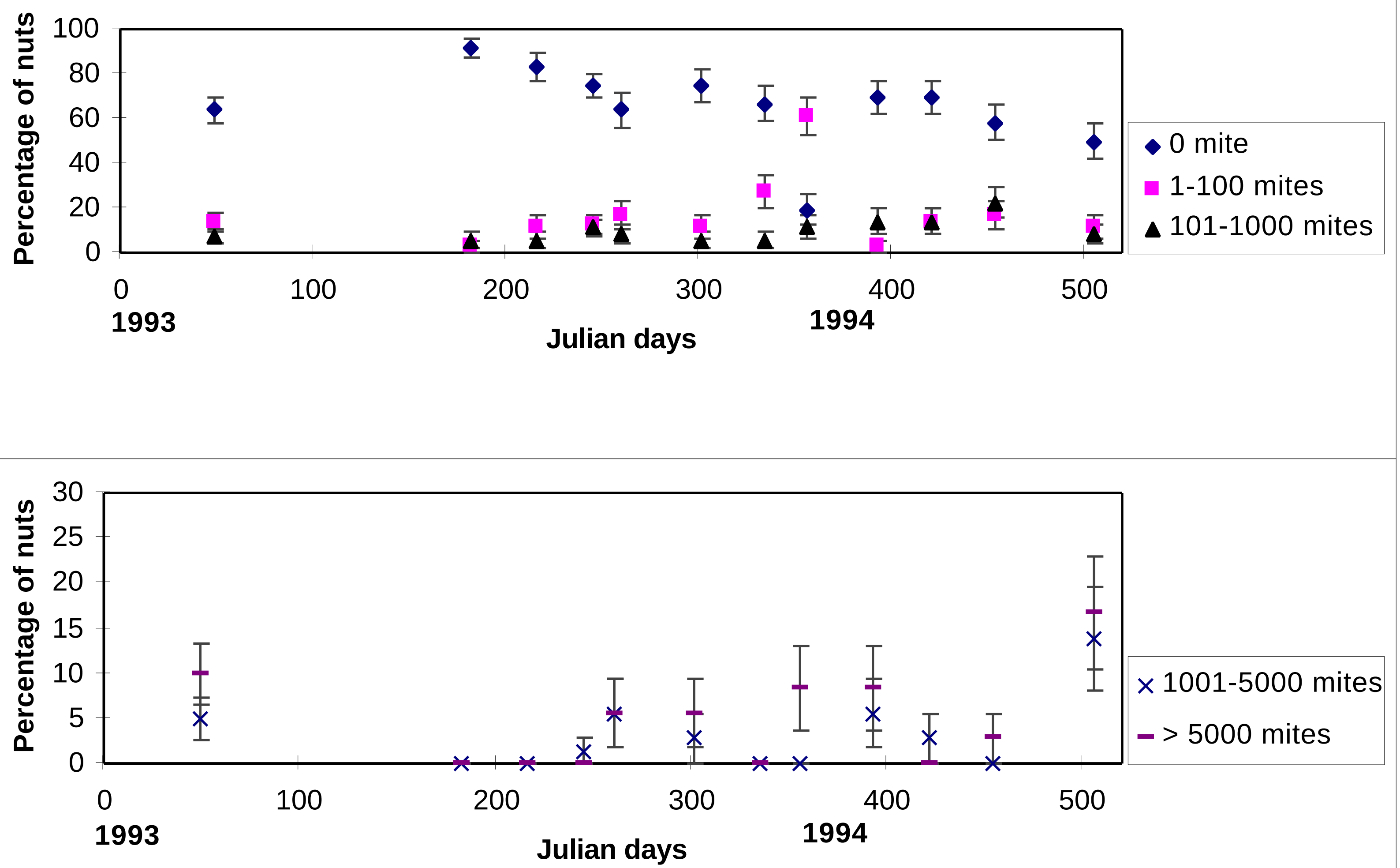


Figure 5a. Populations of dead coconut mite, ***E. guerreronis*** (Keifer), on Maypan coconuts in a High Rainfall Zone (4000-5000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994

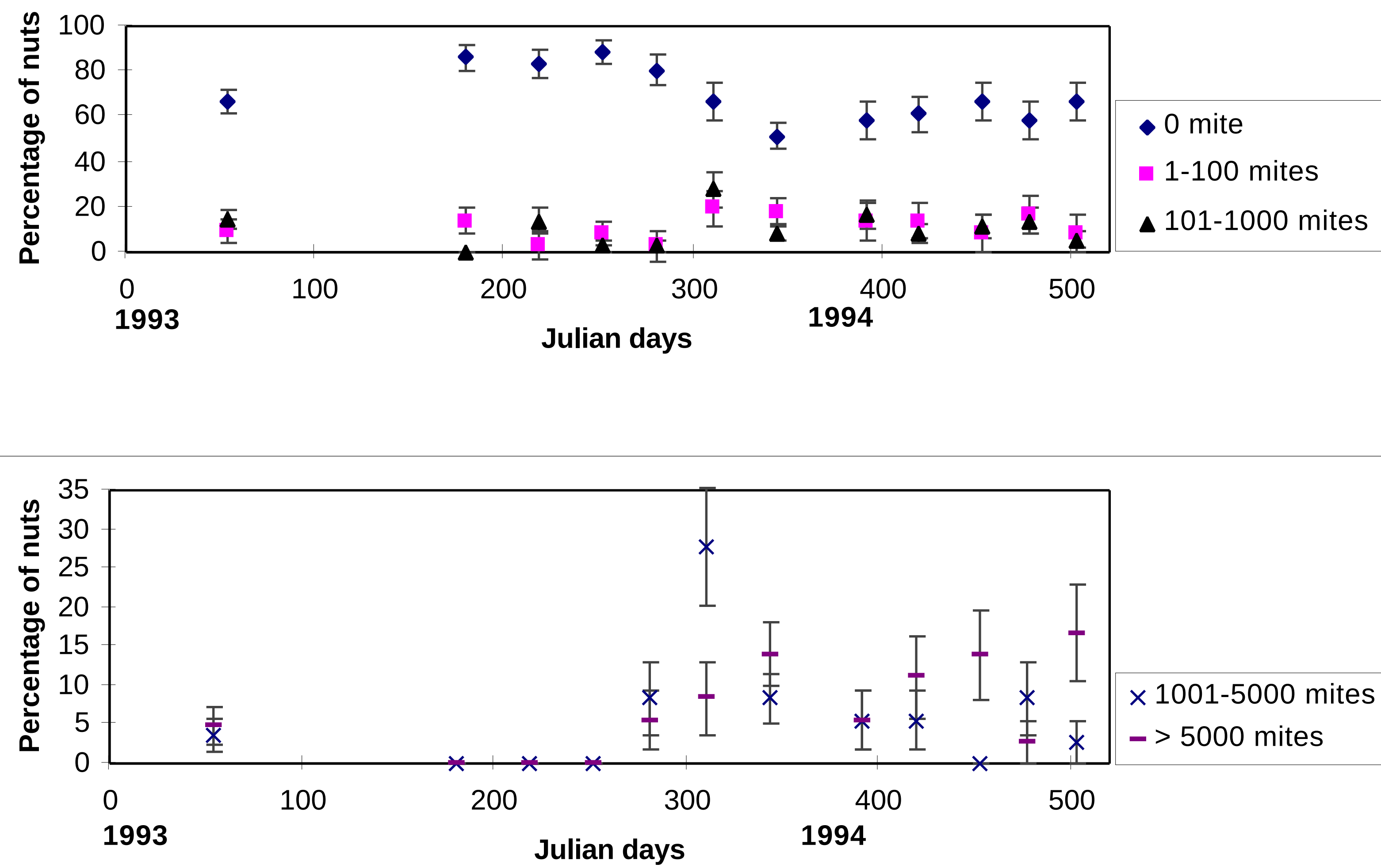


Figure 5b. Populations of dead coconut mite, ***E. guerreronis*** (Keifer), on Maypan coconuts in a Low Rainfall Zone (1500-2000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994

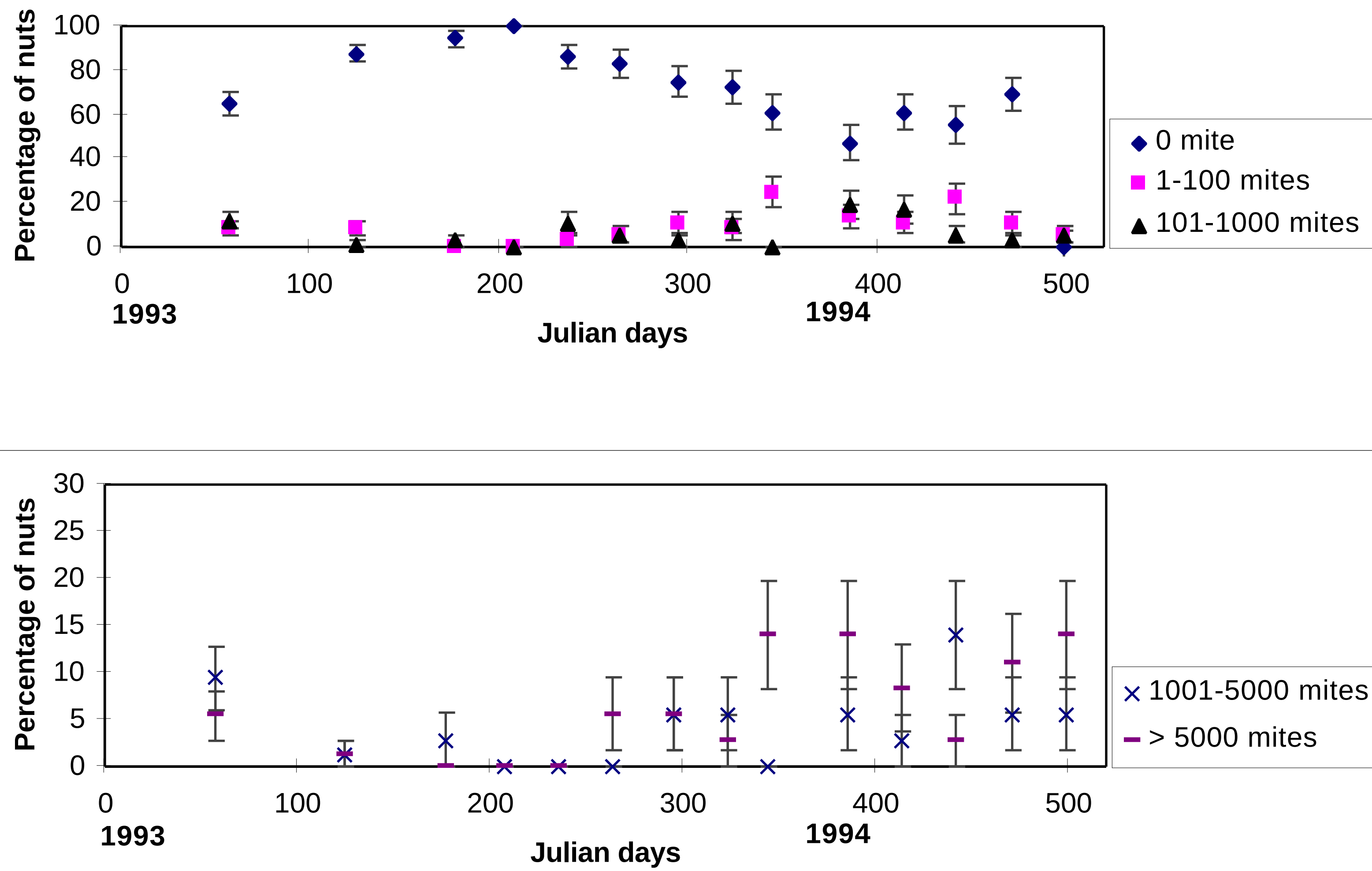
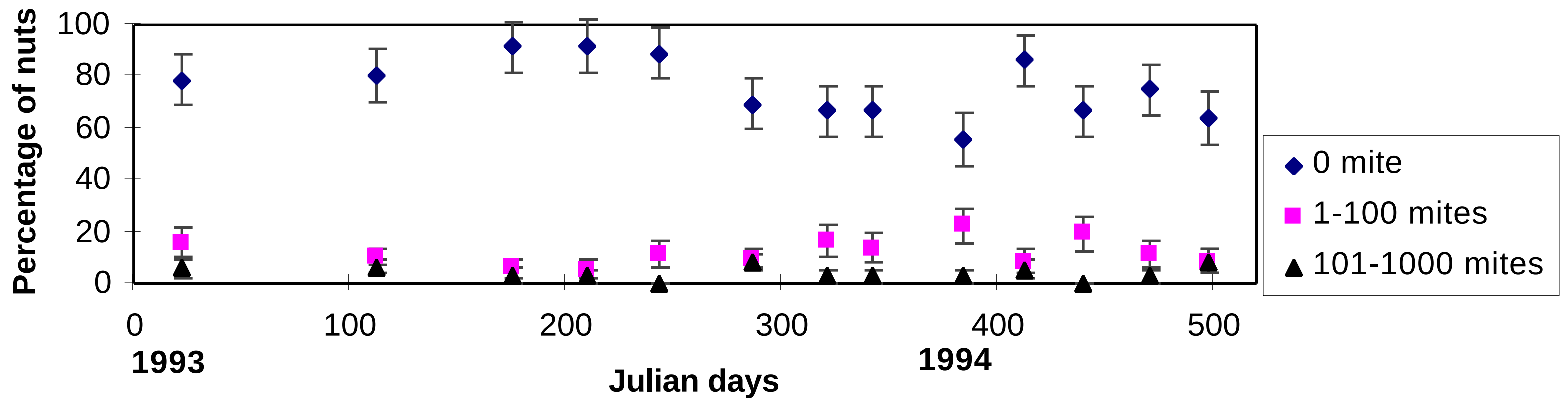


Figure 5c. Populations of dead coconut mite, ***E. guerreronis*** (Keifer), on Red Malayan Dwarf coconuts in a High Rainfall Zone (4000-5000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994



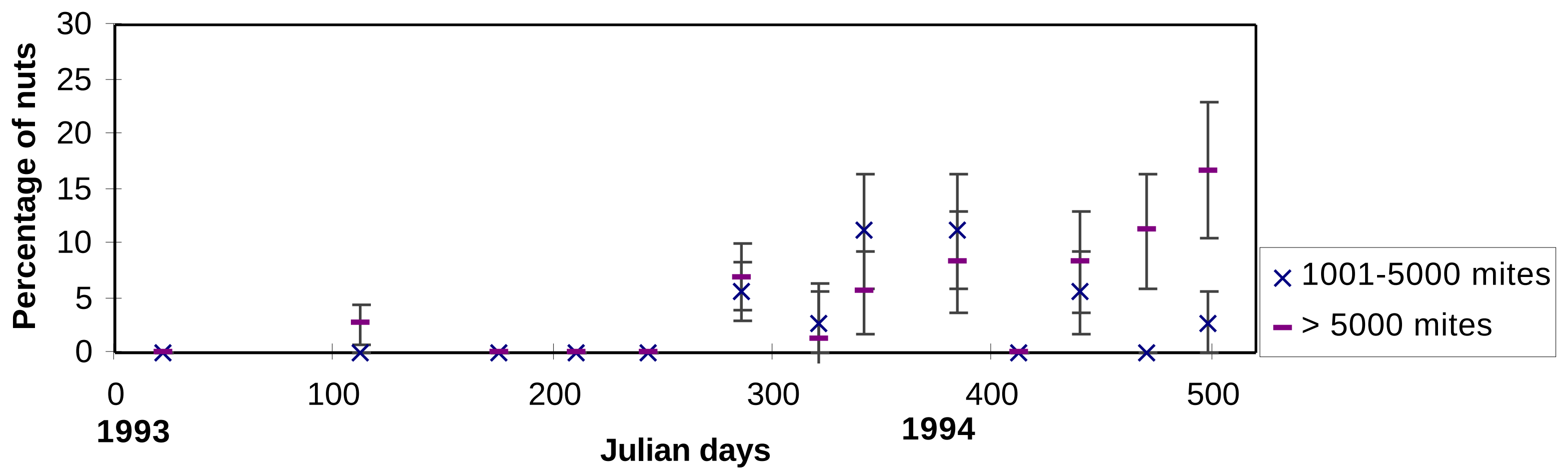


Figure 5d. Populations of dead coconut mite, ***E. guerreronis*** (Keifer), on Red Malayan Dwarf coconuts in a Low Rainfall Zone (1500-2000 mm rainfall per year) in eastern Jamaica, January 1993 to May 1994

Table 4. Seasonal variations in the number of nuts damaged by the mite *E. guerreronis* in eastern Jamaica during January 1993 to May 1994. Dates followed by the same letters are not significantly different ($p > 0.05$) based on comparisons of least-square means (SAS Institute Inc. 1985).

Time (months)	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
Jan-Mar 1993 **a**	1189	61.82 ± 1.41	30.19 ± 1.33	7.99 ± 0.79
Apr-Jun 1993 **ab**	2056	73.01 ± 0.98	21.25 ± 0.90	5.74 ± 0.51
Jul-Sep 1993 **c**	4852	88.07 ± 0.47	10.78 ± 0.45	1.53 ± 0.15
Oct-Dec 1993 **c**	6462	86.46 ± 0.43	12.58 ± 0.41	0.96 ± 0.12
Jan-Mar 1994 **ab**	4493	69.89 ± 0.68	26.04 ± 0.65	4.07 ± 0.29
Apr-May 1994 **b**	2852	73.04 ± 0.83	16.48 ± 0.69	10.48 ± 0.57

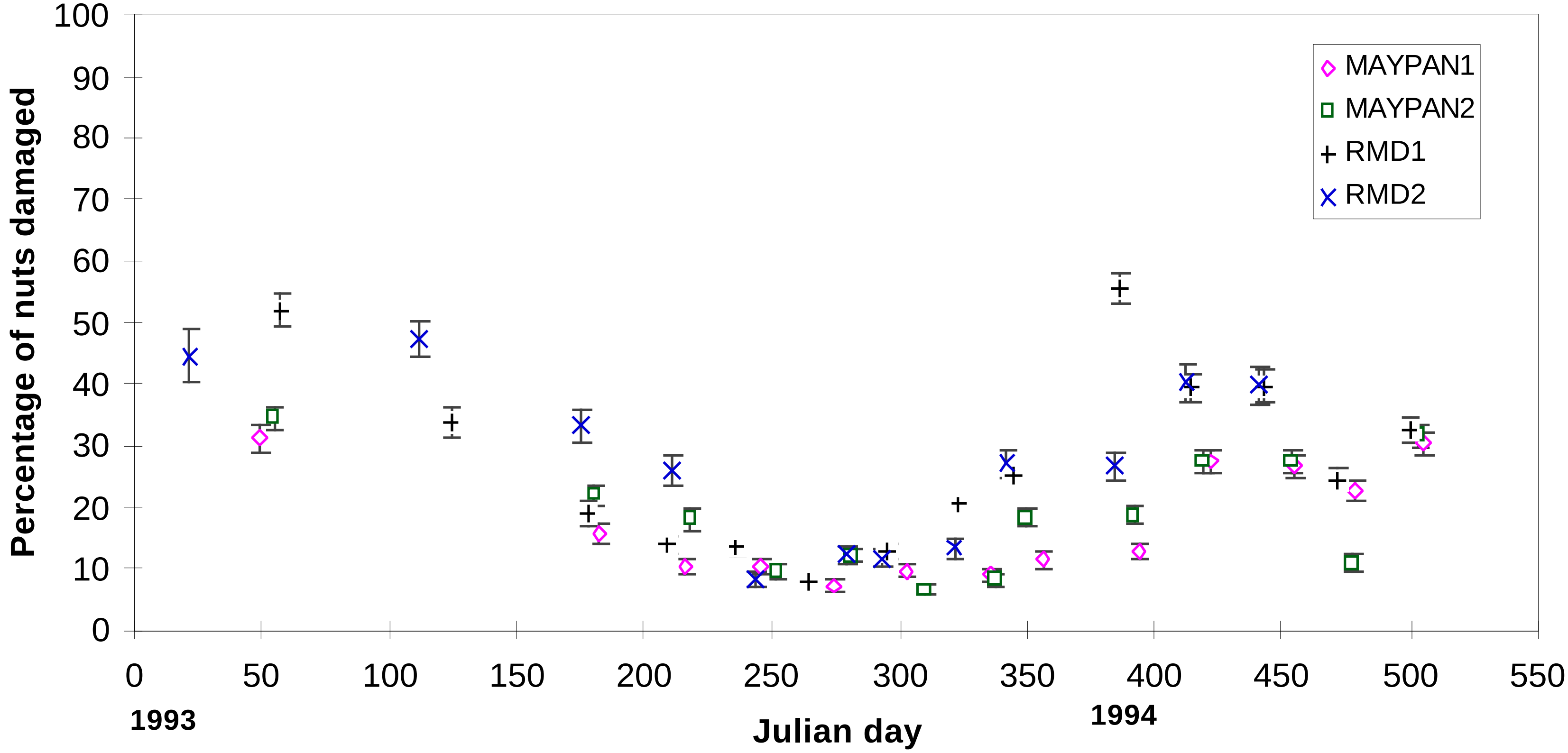


Figure 6. Percentage of Maypan and Red Malayan Dwarf (RMD) coconuts with damage caused by the coconut mite, ***Eriophyes guerreronis*** (Keifer), at selected farms in Jamaica, 1993 to 1994. The numbers 1 and 2, in the legend refers to High and Low Rainfall Zones, respectively. The High Rainfall Zone receives 4000-5000 mm of rainfall per year, while the Low Rainfall Zone receives 1500-2000 mm.

Table 5. Populations of live and dead coconut mite on Maypan and Red Malayan Dwarf coconuts in eastern Jamaica during January 1993 to May 1994. Varieties labeled 1 are within the High Rainfall Zone which gets 4,000 to 5,000 mm rainfall per year. Varieties labeled 2 are within the Low Rainfall Zone which gets 1,500 to 2,000 mm rainfall per year. Varieties followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985)**.**

	Variety	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
live mite	Maypan 1 **a**	512	51.20 ± 2.21	26.00 ± 1.9	11.91 ± 1.43	3.91 ± 0.85	6.25 ± 1.07
	Maypan 2 **a**	514	49.42 ± 2.21	25.49 ± 1.92	11.09 ± 1.39	4.47 ± 0.91	9.53 ± 1.30
	RMD 1 **b**	578	58.48 ± 2.05	20.42 ± 1.68	6.57 ± 1.03	5.19 ± 0.92	9.34 ± 1.21
	RMD 2 **b**	540	59.81 ± 2.11	23.52 ± 1.83	5.37 ± 0.97	3.33 ± 0.77	7.96 ± 1.16
dead mite	Maypan 1 **a**	512	66.02 ± 2.09	16.21 ± 1.63	9.77 ± 1.31	3.13 ± 0.77	4.88 ± 0.95
	Maypan 2 **a**	514	68.09 ± 2.06	11.67 ± 1.42	8.95 ± 1.26	4.09 ± 0.87	7.20 ± 1.14
	RMD 1 **b**	578	73.70 ± 1.83	9.34 ± 1.21	6.92 ± 1.06	4.33 ± 0.85	5.71 ± 0.97
	RMD 2 **c**	540	75.37 ± 1.85	11.85 ± 1.39	4.44 ± 0.89	2.96 ± 0.73	5.37 ± 0.97

Table 6. Damage to nuts by the coconut mite on Maypan and Red Malayan Dwarf coconuts in eastern Jamaica during January 1993 to May 1994. Varieties labeled 1 are within the High Rainfall Zone which gets 4,000 to 5,000 mm rainfall per year. Varieties labeled 2 are within the Low Rainfall Zone which gets 1,500 to 2,000 mm rainfall per year. Varieties followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Variety	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
Maypan 1 **a**	5995	83.29 ± 0.48	13.91 ± 0.45	2.80 ±0.21
Maypan 2 **b**	6676	81.79 ± 0.47	15.97 ± 0.45	2.25 ± 0.18
RMD 1 **c**	5566	75.15 ± 0.58	19.78 ± 0.53	5.07 ± 0.29
RMD 2 **c**	3667	73.17 ± 0.73	21.03 ± 0.67	5.81 ± 0.39

In February 1993 coconut mite populations on nuts of both varieties were high with about 15% and 24% of Maypan and Red Malayan Dwarf nuts having over 1,000 live coconut mites, respectively (Figures 4a-4d). In April 1993 there were only 9% of Red Malayan Dwarf nuts with that many coconut mites and by July and August 1993, 1%. In June 1993 there were no Maypan nuts with more than 1,000 coconut mites and only 1% of nuts in August 1993. Coconut mite populations started to increase by September 1993 and remained high thereafter. Similar trends were seen in the number of dead coconut mites on nuts of both varieties (Figures 5a-5d).

Throughout most of the study period the percentage of nuts with coconut mite damage was significantly higher ($p < 0.001$) in the two Red Malayan Dwarf plots than in thetwo Maypan plots (Figure 6). In April 1993 the Red Malayan Dwarf coconuts at Farm 2a had over 5% more coconut mite damage than those at Farm 1. The level of coconut mite damage at Farm 2a fell steadily from over 40% to less than 20% in July when Red Malayan Dwarf coconuts at Farm 1 had about 30% coconut mite damage. The percentage of coconut mite damage at Farm 2a remained below 20% until December 1993 when it increased to about 32%. By March 1994 about 44% of the nuts had coconut mite damage. On the Red Malayan Dwarf coconuts at Farm 1 fell from about 30% in late July to just under 20% in early September 1993 but began rising the next month. By January 1994 about 50% of the nuts were damaged. Coconut mite damage on these coconuts declined steadily to about 37% in March 1994 (Figure 6).

Coconut mite damage on the Maypan coconuts ranged between 32 and 18% at Farm 1 and between 38 and 23% at Farm 2b (Figure 6). The lowest levels of damage at Farm 1 occurred during August to November when the percentage of nuts with coconut mite damage ranged between 10 and 20%. At Farm 2b coconut mite damage was low from May to January where the percentage was < 20% and at its lowest in September with 9% (Figure 6).

There was no significant interaction between damage grades and variety on coconut mite populations ($p > 0.05$ for both live and dead mites). Coconut mite populations varied significantly ($p < 0.0001$) as the area of damage on nuts surfaces increased on Maypan and Red Malayan Dwarf nuts (Table 7). The largest populations of live coconut mites were most often found on nuts with < 30% surface area damage than on nuts with $\geq$ 30% surface area damage. The reverse was true for populations of dead mites. There were occasionally large populations of coconut mites on nuts without external symptoms of damage (Table 7).

Table 7. Populations of live coconut mite on nuts with different surface areas (SA) of damage in eastern Jamaica during January 1993 to May 1994. Numbers followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	% SA damaged	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
live mites	0 **a**	1167	68.72 ± 1.36	27.59 ± 1.31	2.57 ± 0.46	0.86 ± 0.27	0.26 ± 0.15
	1-29 **b**	822	37.59 ± 1.67	20.81 ± 1.42	14.23 ± 1.22	9.12 ± 1.00	18.25 ± 1.35
	≥ 30 **c**	142	44.37 ± 4.17	8.45 ±2.33	26.76 + 3.72	3.52 ± 1.55	16.90 ± 3.14
Dead mites	0 **a**	1167	90.57 ± 0.86	8.23 ± 0.80	0.80 ± 0.27	0.26 ± 0.15	0.09 ± 0.09
	1-29 **b**	822	46.96 ± 1.74	18.25 ± 1.35	14.36 ± 1.22	8.27 ± 0.96	12.17 ± 1.14
	≥ 30 **c**	142	47.89 ± 4.19	9.86 ± 2.97	22.54 ± 3.51	4.23 ± 1.69	15. 49 ± 3.04

3) Differences in levels of coconut mite populations and damage among nuts of different ages

No significant age by locality interactions were observed with coconut mite populations ($p > 0.05$). Significant age by variety interactions were observed for live mites ($p < 0.0001$). Twice as many 2-month old Red Malayan Dwarf nuts had live coconut mite populations exceeding 1,000 compared to Maypan nuts of the same age (Table 8). The percentage of 4-month old Red Malayan Dwarf nuts with populations of over 1,000 live coconut mites were three times more than Maypan nuts of the same age. Three times as many 10-month old Maypan nuts, however, had live coconut mite populations exceeding 1,000 in comparison to 10-month old Red Malayan Dwarf nuts (Table 8). No significant age by variety interactions were observed for the distribution of dead mites in the damage categories ($p > 0.05$). Within each variety, the greatest percentage of nuts with > 1,000 coconut mites was found on 4-month old Red Malayan Dwarf nuts and on 4- and 10-month old Maypan nuts (Table 8). Significant variety by age interactions occurred with the percentage of nuts damaged and the severity of damage to those nuts ($p < 0.0001$). Both the percentage of nuts with damage and the severity of damage caused by the coconut mite increased significantly with increasing nut age ($p < 0.0001$, Table 9). Two-month old nuts are not likely to have $\geq$ 30% of their surface area scarred by the coconut mite. Less than 2% of 2-month old nuts are likely to have visible symptoms of coconut mite damage. Conversely, more than 50% of the 10-month old nuts of either variety are likely to have damage. Two-, 4- and 10-month old Red Malayan Dwarf nuts had significantly more coconut mite damage than Maypan nuts of the same ages ($p < 0.001$). Twice as many 4- and 10-month old Red Malayan Dwarf nuts had 30% or more of their surface area scarred by the coconut mite as Maypan nuts of equivalent ages. The percentage of nuts with 1-29% surface area damage on 4- and 10-month old Red Malayan Dwarf nuts were 2.8x and 1.2x more than 4- and 10-month old Maypan nuts with the same surface area damage, respectively (Table 9).

There were significant interactions between age of nuts and severity of coconut mite damage on live and dead coconut mite populations ($p < 0.0001$). On 2-month old nuts the largest live and dead coconut mite populations were most often found on nuts with < 30% surface area damage (Table 10). It was rare to find 2-month old nuts with $\geq$ 30% surface area damage but all these nuts had live and dead coconut mite populations exceeding 5,000 and 1,000, respectively. Coconut mite populations exceeding 1,000 live mites per nut were equally abundant on 4-month old nuts with < and $\geq$ 30% surface area damage (Table 11). On 10-month old nuts, the largest coconut mite populations were mostly on nuts with < 30% surface area damage (Table 12).

Table 8. Comparing populations of coconut mite on different ages of Maypan and Red Malayan Dwarf (RMD) coconuts during January 1993 to May 1994. Varieties followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	Age (months)	Variety	No. of nuts	% of nuts with each count of live mite				
				0	1-100	101-1000	1001-5000	>5000
Live mites	2	Maypan **a**	344	67.44 ± 2.53	26.16 ± 2.37	4.65 ± 1.14	0.87 ± 0.50	0.87 + 0.50
		RMD **b**	378	65.08 ± 2.45	28.31 ± 2.17	2. 91 ± 0.86	1.06 ± 0.53	2.65 + 0.83
	4	Maypan **c**	342	47.95 ± 2.70	26.61 ± 2.39	3.51 ± 0.99	4.39 ± 1.11	17.54 + 2.06
		RMD **d**	359	41.50 ± 2.60	19.78 ± 2.10	7.24 ± 1.37	8.64 ± 1.48	22.84 + 2.22
	10	Maypan **e**	340	36.47 ± 2.61	24.41 ± 2.33	26.47 ± 2.39	7.35 ± 1.42	5.29 + 1.21
		RMD **f**	381	69.82 ± 2.35	17.59 ± 1.95	7.87 ± 1.38	3.41 ± 0.93	1.31 + 0.58
Dead mites	2	Maypan **a**	344	88.66 ± 1.71	9.88 ± 1.61	0.58 ± 0.41	0.87 ± 0.50	0.00 ± 0.00
		RMD **b**	378	87.83 ± 1.68	8.20 ± 1.41	1.06 ± 0.53	1.59 ± 0.64	1.32 ± 0.59
	4	Maypan **c**	342	68.42 ± 2.51	8.48 ± 1.51	4.97 ± 1.18	3.22 ± 0.95	14.91 ± 1.93
		RMD **d**	359	59.05 ± 2.60	7.80 ± 1.42	10.03 ± 1.59	7.52 ±1.39	15.60 ± 1.92
	10	Maypan **e**	340	43.82 ± 2.69	23.53 ± 2.30	22.65 ± 2.27	6.76 ± 1.36	3.24 ± 0.96
		RMD **f**	381	75.85 ± 2.19	15.49 ± 1.85	6.30 ± 1.24	2.10 ± 0.73	0.26 ± 0.26

Table 9. Percentage of damage observed on Maypan and Red Malayan Dwarf (RMD) nuts of different ages during January 1993 to May 1994. Varieties followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Age (months)	Variety	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
			0% SA	1-29% SA	> 30% SA
2	Maypan **a**	5387	99.78 ± 0.06	0.22 ± 0.06	0.00 ± 0.00
	RMD **b**	4124	98.69 ± 0.18	1.31 ± 0.18	0.00 ± 0.00
4	Maypan **c**	3936	92.51 ± 0.43	7.01 ± 0.41	0.72 ± 0.14
	RMD **d**	2794	78.17 ± 0.78	19.79 ± 0.75	2.04 ± 0.27
10	Maypan **e**	3348	43.22 ± 0.86	48.15 ± 0.86	8.63 ± 0.49
	RMD **f**	2315	26.44 ± 0.92	56.64 ± 1.03	18.92 ± 0.81

4) Effects of location of trees within a stand on coconut mite populations and nut damage

There were no significant interactions between the position of trees in a plot and ecological zones on the number of live and dead mites found on nuts ($p > 0.05$). Significant interactions between the main effects of tree position and variety affected the number of live and dead mites found on nuts (live mites: $p < 0.01$, dead mites: $p < 0.0001$). Maypan nuts had significantly more live and dead coconut mites on the inner trees than on the outer trees ($p = 0.015$ and $p < 0.001$, respectively, Table 13). There were no significant differences between the number of dead or of live mites on nuts of inner and outer Red Malayan Dwarf trees ($p > 0.05$, Table 14).

There was no significant interaction between the main effects of tree location and variety on the percentage of nuts with coconut mite damage ($p > 0.05$). Significant interactions between variety and tree position affected damage grades ($p = 0.0002$). Inner Maypan trees had significantly more nuts with $\geq$ 30% surface area damage than Maypan trees on the periphery of farms ($p < 0.001$, Table 15). There was no significant difference between the severity of damage to nuts in central and peripheral Red Malayan Dwarf trees ($p > 0.05$, Table 15).

5) Effects of nut orientation on coconut mite populations and the degree of coconut mite damage

Interactions between farm and bunch orientation were significant in affecting the percentage of nuts damaged and the severity of damage caused by the coconut mite ($p < 0.0001$). On Maypan trees within Zone 1 the percentage of damaged nuts facing NE was greater than those facing SW > NW > SE ($p < 0.001$, Table 16a). The percentage of nuts with surface area damage of $\geq$ 30% were less on bunches facing NW ($p < 0.001$) than on bunches facing NE = SE = SW (Table 16a). Within Zone 2 bunches that faced SW had significantly more damaged nuts ($p < 0.001$) than those which faced NE > SE > NW (Table 16b). A greater percentage of Maypan nuts from Zone 2 had surface area damage $\geq$ 30% when found on bunches facing NE than on bunches facing SE > NW > SW ($p < 0.001$, Table 16b). Red Malayan Dwarf nuts within Zone 1 had a higher percentage of damaged nuts on bunches oriented SW = SE ($p < 0.001$) than bunches oriented NE > NW (Table 17a). The most severely damaged Red Malayan Dwarf nuts in Zone 1 were seen on bunches that faced SE > NW >SW = NE ($p < 0.001$, Table 17a). On Red Malayan Dwarf nuts within Zone 2, a higher percentage of damaged nuts were on bunches oriented SW than on bunches oriented NW > NE = SE ($p < 0.001$, Table 17b). The largest percentage of severely damaged Red Malayan Dwarf nuts from Zone 1 were seen on bunches that faced SW > SE >NW > NE ($p < 0.001$, Table 17b).

Table 10. Populations of live and dead coconut mite on 2-month old nuts with different surface areas (SA) of damage in eastern Jamaica during January 1993 to May 1994. Numbers followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	% SA damaged	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
Live mites	0 **a**	690	69.28 ± 1.76	26.66 ± 1.68	3.19 ± 0.66	0.58 ± 0.29	0.29 ± 0.20
	1-29 **b**	25	0.00 ± 0.00	36.00 ± 9.60	20.00 ± 8.00	12.00 ± 6.50	32.00 ± 9.33
	≥ 30 **c**	3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	100.00 ± 0.00
Dead mites	0 **a**	690	91.30 ± 1.07	7.83 ± 1.02	5.80 ± 0.29	0.14 ± 0.14	0.14 ± 0.14
	1-29 **b**	25	16.00 ± 7.33	40.00 ± 9.78	8.00 ± 5.43	28.00 ± 8.98	8.00 ± 5.43
	≥ 30 **c**	3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	33.33 ± 27.22	66.67 ± 27.22

Table 11. Populations of live and dead coconut mite on 4-month old nuts with different surface areas (SA) of damage in eastern Jamaica during January 1993 to May 1994. Numbers followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	% SA damaged	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
Live mites	0 **a**	423	68.32 ± 2.26	29.55 ± 2.22	1.18 ± 0.53	0.716 ± 0.41	0.24 ± 0.24
	1-29 **b**	239	79.50 ± 1.75	15.48 ± 2.34	9.62 ± 1.91	17.15 ± 2.44	49.79 ± 3.23
	≥ 30 **c**	34	29.42 ± 2.90	0.00 ± 0.00	29.41 ± 7.81	5.88 ± 4.04	61.76 ± 8.33
Dead mites	0 **a**	423	91.02 ± 1.39	8.27 ± 1.34	0.71 ± 0.41	0.00 ± 0.00	0.00 ± 0.00
	1-29 **b**	239	23.03 ± 2.72	8.79 ± 1.83	17.15 ± 2.44	15.06 ± 2.31	35.98 ± 3.10
	≥ 30 **c**	34	5.88 ± 3.01	2.94 ± 2.90	26.47 ± 7.57	5.88 ± 4.04	58.82 ± 8.44

Table 12. Populations of live coconut mite on 10-month old nuts with different surface areas (SA) of damage in eastern Jamaica during January 1993 to May 1994. Numbers followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	% SA damaged	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
Live mites	0 **a**	54	64.81 ± 6.50	24.07 ± 5.82	5.56 ± 3.12	5.56 ± 3.12	0.00 ± 0.00
	1-29 **b**	558	51.97 ± 2.12	22.40 ± 1.77	15.95 ± 1.55	5.56 ± 0.96	4.12 ± 0.84
	≥ 30 **c**	105	59.05 + 4.80	11.43 ± 3.10	26.67 ± 4.32	2.86 ± 1.63	0.00 ± 0.00
Dead mites	0 **a**	54	77.78 ± 5.66	12.96 ± 4.57	5.56 ± 3.12	3.70 ± 2.57	0.00 ± 0.00
	1-29 **b**	558	58.60 ± 2.09	21.33 ± 1.73	13.44 ± 1.44	4.48 ± 0.88	2.15 ± 0.61
	≥ 30 **c**	105	62.86 ± 4.72	12.38 ± 3.21	21.90 ± 4.04	2.86 ± 1.63	0.00 ± 0.00

Table 13. The effect of tree position on coconut mite populations on Maypan trees in eastern Jamaica during January 1993 to May 1994. Inner trees are found within a 15 m boundary of each plot, while outer trees are found outside of this boundary. Positions followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	Position of trees	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
Live mites	Inner **a**	530	46.79 ± 2.17	26.23 ± 1.91	14.15 ± 1.51	3.77 ± 0.83	9.06 ± 1.23
	Outer **b**	496	54.84 ± 2.23	25.20 ± 1.95	8.67 ± 1.26	4.64 ± 0.94	6.65 ± 1.12
Dead mites	Inner **a**	530	61.51 ± 2.11	16.23 ± 1.60	12.08 ± 0.42	2.64 ± 0.70	0.75 ± 1.15
	Outer **b**	496	72.98 ± 1.99	11.49 ± 1.43	6.45 ± 1.10	4.64 ± 0.94	4.64 ± 0.94

Table 14. The effect of tree position on coconut mite populations on Red Malayan Dwarf trees in eastern Jamaica during January 1993 to May 1994. Inner trees are found within a 15 m boundary of each plot, while outer trees are found outside of this boundary. Positions followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

	Position of trees	No. of nuts	% of nuts with each count of live mite				
			0	1-100	101-1000	1001-5000	>5000
Live mites	Inner **a**	562	60.85 ± 2.06	22.95 ± 1.77	5.34 ± 0.95	3.74 ± 0.80	7.12 ± 1.08
	Outer **a**	556	57.37 ± 2.10	20.86 ± 1.72	6.65 ±1.06	4.86 ± 0.91	10.25 ± 1.29
Dead mites	Inner **a**	562	77.58 ± 1.76	10.14 ± 1.27	4.98 ± 0.92	2.67 ± 0.68	4.63 ± 0.89
	Outer **a**	556	71.41 ± 1.92	10.97 ± 1.33	0.65 ± 1.04	4.68 ± 0.90	6.47 ± 1.04

Table 15. Coconut mite damage on Maypan and Red Malayan Dwarf nuts located in the center and on the periphery of farms during January 1993 to May 1994. Inner trees are found within a 15 m boundary of each plot, while outer trees are found outside of this boundary. Positions followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Variety	Position of trees	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
			0% SA	1-29% SA	> 30% SA
Maypan	Inner **a**	6306	82.05 ± 0.48	14.49 ± 0.44	3.46 ± 0.23
	Outer **b**	6365	82.94 ± 0.47	15.49 ± 0.45	1.57 ± 0.16
Red Malayan Dwarf	Inner **a**	4492	74.38 ± 0.65	19.80 ± 0.60	5.83 ± 0.35
	Outer **a**	4741	74.29 ± 0.63	20.78 ± 0.59	4.94 ± 0.31

Table 16a. Effects of orientation on damage to nuts by the coconut mite on Maypan coconuts in the High Rainfall Zone of eastern Jamaica during January 1993 to May 1994. The High Rainfall Zone gets 4,000 to 5,000 mm rainfall per year. Orientations followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Orientation	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
SE **a**	1452	87.29 ± 0.88	9.78 ± 0.78	2.96 ± 0.44
NW **b**	1157	86.26 ± 1.01	11.50 ± 0.94	2.25 ± 0.44
SW **c**	1479	82.56 ± 0.99	14.40 ± 0.91	3.04 ± 0.45
NE **d**	1506	81.61 ± 1.00	15.54 ± 0.93	2.86 ± 0.43

Table 16b. Effects of orientation on damage to nuts by the coconut mite on Maypan coconuts in the Low Rainfall Zone of eastern Jamaica during January 1993 to May 1994. The Low Rainfall Zone gets 1,500 to 2,000 mm rainfall per year. Orientations followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Orientation	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
SE **a**	1669	86.40 ± 0.84	12.04 ± 0.80	1.56 ± 0.30
NW **b**	1099	88.26 ± 0.97	10.83 ± 0.94	9.10 ± 0.29
SW **c**	1092	77.47 ± 1.26	21.89 ± 1.25	0.64 ± 0.24
NE **d**	1842	82.03 ± 0.89	14.71 ± 0.83	3.26 ± 0.41

Table 17a. Effects of orientation on damage to nuts by the coconut mite on Red Malayan Dwarf coconuts in the High Rainfall Zone of eastern Jamaica during January 1993 to May 1994. The High Rainfall Zone gets 4,000 to 5,000 mm rainfall per year. Orientations followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Orientation	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
SE **a**	1478	73.34 ± 1.15	21.45 ± 1.07	5.21 ± 0.59
NW **b**	1189	83.10 ± 1.09	12.36 ± 0.95	4.54 ± 0.60
SW **a**	1082	73.94 ± 1.33	21.81 ± 1.23	4.25 ± 0.61
NE **c**	1494	76.24 ± 1.10	19.54 ± 1.03	4.22 ± 0.52

Table 17b. Effects of orientation on damage to nuts by the coconut mite on Red Malayan Dwarf coconuts in the Low Rainfall Zone of eastern Jamaica during January 1993 to May 1994. The Low Rainfall Zone gets 1,500 to 2,000 mm rainfall per year. Orientations followed by the same letters are not significantly different ($p > 0.05$) according to a stratified analysis of n-way cross tabulations, SAS Proc Freq, (SAS Institute Inc. 1985).

Orientation	No. of nuts	% of nuts in each damage category (SA = surface area damaged)		
		0% SA	1-29% SA	> 30% SA
SE **a**	1150	80.61 ± 1.17	13.91 ± 1.02	5.48 ± 0.67
NW **b**	592	72.47 ± 1.84	23.18 ± 1.75	3.72 ± 0.78
SW **c**	592	64.02 ± 1.97	28.50 ± 1.85	7.78 ± 1.10
NE **a**	910	79.56 ± 1.34	18.02 ± 1.27	2.42 ± 0.51

Discussion

1) Seasonal variations in coconut mite populations and damage to nuts within two ecological zones in eastern Jamaica

There have been varying reports on the relative activity of the mite during the wet and dry seasons: Howard *et al*. (1990) found that coconut mite populations increased immediately after periods of high rainfall in Puerto Rico and Florida but noted that coconut mite populations fluctuations were not associated with dry and wet seasons nor with mean daily temperatures. Julia and Mariau (1979) and Otterbein (1988) found the greatest infestations of the coconut mite to be associated with the wet seasons in Benin and the Ivory Coast, and in Costa Rica, respectively. However, Mariau (1969) reported that in Mexico, the coconut mite produced the greatest nut damage during the dry season. The coconut industry in Jamaica (Hall 1981) associated the initial outbreak of the coconut mite in Jamaica to a period of prolonged drought. The results of this study agree with the latter findings. Coconut mite infestation was high during low rainfall periods and fell sharply just after the heaviest rainfall period. Although the relative quantities were different, the seasonal pattern of rainfall was similar for both zones. Also, the pattern of coconut mite infestation was the same in both zones even when variety was considered. The decline in nut damage had a three-month lag, indicating the time taken for symptoms to appear from coconut mite actives during the period of low populations. Statistical analyses suggested that coconut mite populations and damage caused by the mite had no correlation with rainfall but the correlation might be clouded by the fact that there was only one brief phase of extremely high rainfall throughout the study period.

2) Differences between coconut mite populations and levels of coconut mite damage on Maypan and Red Malayan Dwarf coconut varieties

Red Malayan Dwarf nuts showed greater damage than Maypan nuts although a greater percentage of Maypan nuts were infested with mites than Red Malayan Dwarf nuts. The Maypan variety therefore, appears to have greater tolerance to the mite than Red Malayan Dwarf. This confirms Moore and Alexander's (1990) association between nut color and mite resistance. The earlier works of Mariau (1977 and 1986) and Julia and Mariau (1979) also alluded to this. Maypan nuts are deep green in color and Red Malayan Dwarf nuts are golden yellow. Another advantage of the Maypan variety might be that they have larger nuts which tend to have a longer developmental period than Red Malayan Dwarf nuts. This rapid growth of Maypan nuts infers rapid multiplication of new cells that would serve to reduce much of the stress in the damage area (Albrigo and McCoy 1974). At the same time, the slower growth rate of the Red Malayan Dwarf might have allowed for greater damage (Mariau 1986).

The pattern of infestation varied with time and was similar for each variety. This suggests that some factor, common to both zones, was operating simultaneously on both varieties. This could be the pattern of rainfall. The most distinct change in the levels of coconut mite occurred just after the peak rainfall period in each zone. There was a distinct decrease in infestation and severity of damage during July to December compared with the level of infestation during January to July. If one considers that the period between mite colonization and the expression of damage may take about two months (based on the information on bunches), then this corresponds very well with the period of low infestation that occurred during April to September 1993. In April and May 1993 the average monthly rainfall had well exceeded 200 mm. It would appear as though these heavy rains drastically reduced the chances of the coconut mite to colonize new nuts. It must be noted that this study only covered about 1.5 years. A longer period of research is needed to confirm the response of the coconut mite to rainfall.

3) Differences in levels of coconut mite populations and damage among nuts of different ages

Two- and 4-month old Red Malayan Dwarf nuts were more often infested and had larger populations of coconut mite than Maypan nuts of the same age. This suggests that Red Malayan Dwarf nuts might be infested earlier than Maypan nuts. The severity of damage depends on the age at which the nut is attacked (Julia and Mariau 1979, Mariau 1986, Otterbein 1988). Nuts exposed to the mite at an earlier age will develop more severe scars than those attacked at a later stage of development. Red Malayan Dwarf nuts were more susceptible to mite damage at an earlier age than Maypan nuts. Hence, all ages of Red Malayan Dwarf nuts had greater percentages of damage than Maypan nuts of similar ages. It must also be noted that 2-month old Red Malayan Dwarf nuts had more mites than equally aged Maypan nuts. Therefore, it appears that the perianth of Red Malayan Dwarf nuts is more accessible to mites than that of Maypan nuts. This could be explained by the different shapes of nuts of the two varieties (Mariau 1977 and 1986, Julia and Mariau 1979, Moore and Alexander 1990). Maypan nuts are more rounded than the Red Malayan Dwarf nuts. Roundness causes greater adpression of the perianth to the nut surface and may prevent the entry of mites beneath the perianth (Moore and Alexander 1990). Coconut mites could gain entry as nuts grow because the degree of adpression decreases with increased nut size. Then, because the Red Malayan Dwarf nuts are attacked at an earlier stage of development, the severity of mite damage is greater.

A greater percentage of 10-month old Maypan nuts were infested and had much higher populations of coconut mites than 10-month old Red Malayan Dwarf nuts. This could be due to two reasons. The first is that more Maypan nuts are infested later than Red Malayan Dwarf nuts. The second reason is that the tissues of 10-month old Maypan nuts are were often less mature and the nuts more tender than nuts of Red Malayan Dwarf (personal observation). Ten-month old Red Malayan Dwarf nuts were frequently damaged and had greater surface area damage than 10-month old Maypan nuts. It is known that coconut mites leave nuts two to three months before the nuts are fully developed or when damage to the percarp exceeds 15% because there is no renewal of meristematic tissues (Anonymous 1985). In addition, damaged nut surfaces tend to secrete resin which traps and kills the mites (Moore and Alexander 1987). Lack of suitable feeding site and high resin secretion, therefore, appeared to be the reasons for the low coconut mite populations on older Red Malayan Dwarf nuts.

4) Effects of location of trees within a stand on coconut mite populations and nut damage

Pratt (1957 IN Allen and McCoy 1979) found that high humidity encourages the development of rust mite immature stages. Otterbein (1988) found the coconut mite damage to be more severe with high humidity. The canopy of Maypan trees are less open than that of Red Malayan Dwarf trees and provides more shade and humidity in the center of plots. The openness of the Red Malayan Dwarf canopy allows for even humidity throughout each plot. This study did not identify any significant difference between the coconut mite populations and the percentage of damaged nuts of inner and outer Red Malayan Dwarf trees. Nuts of inner Maypan trees had more mites and more damage than nuts of outer Maypan trees. More detailed study is required to determine the response of the coconut mite to humidity.

5) Effects of nut orientation on coconut mite populations and the degree of coconut mite damage

Generally, nuts facing southwest had significantly more coconut mite damage than those facing northeast > southeast > northwest.. More severely damaged nuts were found on southeast > southwest > northeast > northwest than the facing bunches. This appears to be the result of dispersal of coconut mites by the North East Trade winds. The south facing bunches would have more mites settling on them because they are on the leeward side. These results concur with earlier reports that migration of coconut mite is greatly influenced by wind current (Otterbein 1988, Griffith 1984).

Long distance dispersal of the coconut mite via wind currents might be hindered by the placement of barrier crops in the path of prevailing winds. More studies need to be conducted in this area. Another area for further research is the openness of coconut tree canopy and the resulting differences in humidity on coconut mite infestation. Varietal susceptibility plays a major role in the amount of damage caused by the coconut mite. The use of resistant varieties with cultural practices are the most immediate means of managing the coconut mite, Moore *et al.* (1989).

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