Influence of Relative Humidity on Life-History Parameters of *Mononychellus progresivus* and *Oligonychus gossypii* (Acari: Tetranychidae)

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ABSTRACT Life-history parameters of *Mononychellus progresivus* Doreste and *Oligonychus gossypii* (Zacher), 2 major mite pests of cassava in Africa, were determined in the laboratory at 3 constant relative humidities (30, 60, and 90% RH) obtained with saturated salt solutions. Experiments were carried out in airtight boxes placed in an air-conditioned room at 26 ± 1°C and a photoperiod of 12:12 (L:D) h (illuminance 3,500 lux). Low (30% RH) and high (90% RH) air humidity had a negative effect on the life-history traits of both species compared with medium air humidity (60% RH). For both species, the strongest effect was obtained at 90% RH; e.g., no *M. progresivus* eggs hatched, and 96% of the immature stages of *O. gossypii* died. Relative humidity is, thus, an important abiotic factor influencing the population dynamics of both species and may explain part of the decrease in populations observed in the middle to the end of the dry season and the virtual absence of mites during the wet season.

KEY WORDS *Mononychellus progresivus, Oligonychus gossypii,* cassava

THE CASSAVA GREEN mite, *Mononychellus progresivus* Doreste, =*tanajoa* (Bondar), and the cotton red mite *Oligonychus gossypii* (Zacher), are the most common phytophagous mites found on cassava in Africa (Matthysse 1978, Yaninek and Onzo 1988, Gutierrez and Bonato 1994). *M. progresivus* is a neotropical species introduced into the African continent in the early 1970s. Pest outbreaks usually occur from the end of the dry season to the beginning of the rainy season, or from the end of the wet season to the beginning of the dry season, or both (Yaninek et al. 1989b, Skovgard et al. 1993, Bonato 1993). Reported yield loss estimates vary from 13 to 80% (Yaninek and Herren 1988, Yaninek et al. 1990). *O. gossypii* is a polyphagous mite of African origin. Severe outbreaks occur in cassava fields during the dry season and its effect on cassava growth has probably been underestimated (Bonato et al. 1994). Field studies conducted in the Congo showed that during outbreaks the infestation levels of *O. gossypii* were similar to those of *M. progresivus* (Bonato 1993). During the wet season, both species are virtually absent on cassava.

A prerequisite for understanding the population dynamics of a pest species is the identification and quantification of key factors responsible for population fluctuations. This work is part of a study conducted in central Africa on biotic and abiotic factors affecting the population dynamics of *M. progresivus* and *O. gossypii*. Our first set of experiments emphasized the influence of temperature on the biological and demographic parameters of *M. progresivus* and *O. gossypii* (Bonato et al. 1995). In the study reported here we examine the effects of relative humidity on life-history traits.

Materials and Methods

Mite and Leaf Disk Production. All mites originated from a laboratory culture initiated with several *M. progresivus* and *O. gossypii* females collected in an experimental cassava field located in Brazzaville (Congo) 3 mo before starting the experiments. Mites were reared on cassava leaf disks (variety 1M20) in an air-conditioned room (26 ± 1°C, 60 ± 5% RH, photoperiod of 12:12 [L:D] h at 3,500 lux). Leaf disks were obtained from the 1st fully developed leaves (Yaninek 1985) of 4-mo-old plants grown in plastic pots in the green house at 25–30°C.

Experimental Set-Up. Airtight plastic boxes (Mino-Gaillard, 288 by 278 by 90 mm) were used to ensure a constant relative humidity. An airtight seal on the boxes was obtained by sticking a silicon joint inside the cover. The 30, 60, and 90 ± 10% RH treatments were obtained using saturated solutions of $MgCl_2(6H_2O)$, $NaBr(2H_2O)$, and KNO_3, respectively (Virolleaud and Vigne 1983). Microventilators with speed control were placed in each box to homogenize ambient conditions and prevent gradients. Each cover had a hole with a diameter adjusted to exactly fit the size of the ther-

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Table 1. Duration in days of the egg, larva, protonymph, deutonymph, and quiescent stages and total mortalities of *M. progresivus* and *O. gossypii* at 3 constant relative humidities and 26 ± 1°C

Species	Stage	30% RH		60% RH		90% RH	
		♀	♂	♀	♂	♀	♂
M. progresivus	Egg	4.7	4.8	4.6	4.8	0	0
	Larva	1.3	1.4	1.1	1.1	0	0
	Quiescent stage 1	0.7	0.8	0.7	0.8	0	0
	Protonymph	1.3	1.3	0.9	0.8	0	0
	Quiescent stage 2	0.7	0.6	0.6	0.6	0	0
	Deutonymph	1.4	1.1	1.1	1.0	0	0
	Quiescent stage 3	0.9	0.9	0.9	0.9	0	0
	Total ± SEM	11.0 ± 0.2	10.9 ± 0.4	9.9 ± 0.1	10.0 ± 0.2	0	0
	Mortality (%)	17		10		100	
	No. adults	31	9	53	20	0	0
O. gossypii	Egg	5.1	5.0	4.9	5.0	0	5.0
	Larva	1.5	1.5	1.3	1.1	0	1.4
	Quiescent stage 1	0.4	0.3	0.6	0.6	0	0.8
	Protonymph	1.8	0.8	0.9	0.8	0	1.3
	Quiescent stage 2	0.3	0.5	0.6	0.5	0	0.4
	Deutonymph	1.8	1.5	1.2	1.1	0	1.4
	Quiescent stage 3	0.5	0.3	0.7	0.7	0	1.1
	Total ± SEM	11.4 ± 0.2	9.9 ± 0.0	10.2 ± 0.2	9.8 ± 0.2	0	11.4 ± 0.6
	Mortality (%)	85		9		96	
	No. adults	6	1	27	24	0	2

mohygrometer probe. Both temperature and hygrometry were checked and recorded during the experiments. The boxes, 2 per each of the 3 treatments, were placed in the same air-conditioned room at 26 ± 1°C, 60 ± 5% RH, and photoperiod of 12:12 (L:D) h at 3,500 lux. Modified Munger cells (Munger 1955) were used to minimize water supply in the boxes. Munger cells were made of 2 Plexiglas plates of the same size (112 by 75 by 3 mm), the upper 1 with 12 holes of 17-mm diameter, the lower 1 without holes. A water-saturated cotton strip was placed on the lower plate. The 2 plates were held together with adhesive rubber all around the edges of the 2 plates and with 4 clips (one per side). The leaf disks were placed in holes on the water-saturated cotton. A small tangle trap layer was put around each hole to prevent mite dispersion. Continuous moisture of the cotton was assured using a syringe.

Data Collection. *Developmental Time.* Four to five fertilized females were placed on each leaf disk and left to oviposit for 1 h under laboratory conditions. After removing the females and reducing the number of eggs to 1 per disk, the Munger cells were put in the airtight boxes described above. To determine developmental times, ≈50 disks per species and per treatment (Table 1) were examined 3 times a day (at 0700, 1300, and 1900 hours) and the transition of mites from one stage to another was noted.

Survival Rate, Longevity, and Fecundity of Females. Daily fecundity and mortality were recorded from emergence until death of adults. For this study, female teliochrysalides (the last preimago stage) were obtained from the mass rearing. One female teliochrysalis with 2 males were used per leaf disk. The males were killed 2 d after emergence of the adult female. The number of eggs laid per female was counted daily after female emergence. Cohorts of 30 females were used for each treatment and each species.

Statistical Analyses. Comparisons between each treatment for each species and between species in the same treatment were performed using one-way analysis of variance (ANOVA) after a $\log(x + 1)$ transformation of data. If ANOVA revealed significant differences between groups tested, means were compared using the Scheffé method (LEAS 1989). The significant level was set at $P \leq 0.05$.

Calculation of Demographic Parameters. Net reproduction rate (R_o), mean generation time (G), intrinsic rate of natural increase (r_m), and finite rate of increase (λ) (Birch 1948) were calculated using a computer program proposed by Hulting et al. (1990). This program calculates standard error for R_o and r_m, and these parameters were compared statistically using multiple pair-wise Dunn t-test with $P \leq 0.05$.

Results

Developmental Time. At 90% RH, no *M. progresivus* eggs hatched. At 60% RH, the lowest mortality of immature stages (10%) and the shortest developmental time (10 d) were recorded for both males and females (Table 1). Developmental time was significantly different between 30 and 60% RH for both sexes ($F = 12.08$; df = 6, 164; $P = 0.0001$ and the Scheffé F value was 6.65 for females and 2.15 for males). No significant difference in developmental time was found between males and females in either treatment (Scheffé F value was 0.02 for 30% RH and 0.02 for 60% RH).

Percentage mortality for *O. gossypii* was 85 and 96% at 30 and 90% RH, respectively, both of

Table 2. Longevity, mean ± SD daily fecundity, and total fecundity of *M. progresivus* and *O. gossypii* at 3 constant relative humidities and 26 ± 1°C

Species		30% RH	60% RH	90% RH
M. progresivus	Longevity	10.0 ± 0.3a	12.5 ± 0.2b	8.1 ± 0.4c
	Eggs/female/day	3.0 ± 0.2a	4.0 ± 0.2b	2.2 ± 0.2c
	Total eggs/female	21.7 ± 2.1a	42.5 ± 2.5b	8.6 ± 1.3c
	No. females	30	30	30
O. gossypii	Longevity	10.8 ± 0.3a	12.7 ± 0.2b	7.6 ± 0.7c
	Eggs/female/day	3.3 ± 0.2a	3.9 ± 0.1b	2.4 ± 0.2c
	Total eggs/female	28.8 ± 0.3a	39.8 ± 2.6b	7.2 ± 1.3c
	No. females	30	30	30

Values in the same line followed by the same letter are not significantly different (ANOVA and multicomparison Scheffé F tests, $\alpha = 0.05$).

which were higher than the 9% found at 60% RH (Table 1). At 30% RH, the mean developmental time (males and females) of 11.3 d was significantly longer than the 10.0 d found at 60% RH ($F = 12.08$; df = 6, 164; $P = 0.0001$ and Scheffé F value was 3.66); the differences between males and females were only significant at 60% RH (Scheffé F value was 2.15). At 90% RH, only 2 male larvae reached the adult stage. For both sexes and within treatment, the developmental time was similar for the 2 mite species, and both showed a higher susceptibility to high (90%) than to low air humidity (30%).

Survival Rate, Longevity, and Fecundity of Females. The 50% survival rate of adult *M. progresivus* females was reached at days 8, 11, and 13 (90, 30, and 60% RH, respectively) (Table 2; Fig. 1). Longevity was greatest at 60% RH (12.5 d) and shortest at 90% RH (8.1 d) with significant differences between all treatments ($F = 20.5$; df = 5, 178; $P < 0.0001$; Scheffé value was: $F_{30-60} = 2.2$; $F_{30-90} = 2.3$; $F_{60-90} = 2.3$) (Table 2). Likewise, the highest total fecundity of 42.5 eggs per female (4 eggs per day) was obtained at 60% RH, and the lowest total of 8.1 eggs per female (2.2 eggs per day) occurred at 90% RH (Table 2). The differences between treatments were significant ($F = 33.6$; df = 5, 178; $P < 0.0001$; Scheffé value was: $F_{30-60} = 11.86$; $F_{30-90} = 11.96$; $F_{60-90} = 11.96$).

The 50% survival rate for *O. gossypii* was reached at days 6, 12, and 14 for the 90, 30, and 60% RH treatments, respectively (Table 2; Fig. 1). Longevity showed a similar trend as for *M. progresivus* with the highest value of 12.7 days at 60% RH, and significant differences between all treatments ($F = 20.5$; df = 5, 178; $P < 0.0001$; Scheffé value was: $F_{30-60} = 2.5$; $F_{30-90} = 2.3$; $F_{60-90} = 2.2$) (Table 2). Likewise, the highest total fecundity of 39.8 eggs per female (3.9 eggs per day) was recorded at 60% RH. Differences in total number of eggs between each treatment were significant (Table 2) ($F = 33.6$; df = 5, 178; $P < 0.0001$; Scheffé value was : $F_{30-60} = 11.96$; $F_{30-90} = 11.96$; $F_{60-90} = 12.06$). Longevity and numbers of eggs laid per day were similar for both species at each humidity level. Total fecundity was only significantly higher at 30% RH for *O. gossypii* (Scheffé value was $F = 11.96$).

Demographic Parameters. No statistics were calculated for the 90% RH treatment because of zero development for *M. progresivus* and only 2 males for *O. gossypii*. At 30% RH, R_o values were

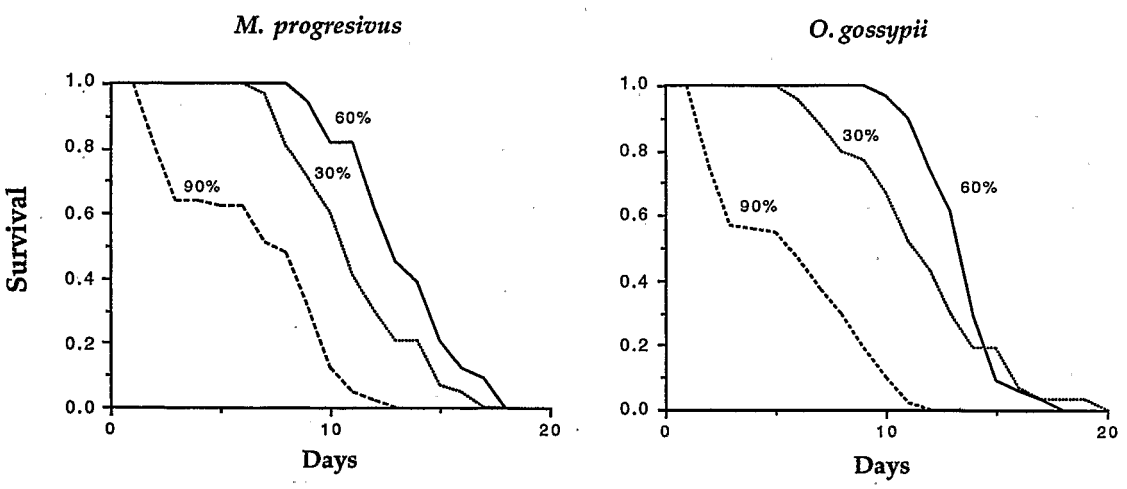

Fig. 1. Survival of *M. progresivus* and *O. gossypii* females at 30 (. . .), 60 (_), and 90% (—) RH and 26 ± 1°C.

Table 3. Life-table parameters of *M. progresivus* and *O. gossypii* at 3 constant relative humidities and 26 ± 1°C. Standard error in parentheses

Species		30% RH	60% RH
M. progresivus	R_o	12.8 ± 2.4a	26.0 ± 3.1b
	G	14.9	14.4
	r_m	0.171 ± 0.010e	0.226 ± 0.006f
	λ	1.19	1.25
O. gossypii	R_o	3.0 ± 0.6c	25.1 ± 3.2b
	G	16.8	15.1
	r_m	0.066 ± 0.010g	0.214 ± 0.008f
	λ	1.07	1.24

Values followed by the same letter are not significantly different (Dunn t-test, $\alpha = 0.05$).

half than those obtained at 60% RH in the case of *M. progresivus* and one-eighth in the case of *O. gossypii.* (Table 3) (t_{Dunn}= 6.27; df = 6, 122; $P <$ 0.05 for *M. progresivus*; and t_{Dunn}= 10.17; df = 6, 122; $P < 0.05$ for *O. gossypii*). A similar trend was observed for r_m values; these were significantly higher at 60% RH than at 30% RH (t_{Dunn} = 8.48; df = 6, 122; $P < 0.05$ for *M. progresivus*; and t_{Dunn} = 22.09; df = 6, 122; $P < 0.05$ for *O. gossypii*). Differences in R_o between *M. progresivus* and *O. gossypii* were only significant at 30% RH (t_{Dunn} = 2.93; df = 6, 122; $P < 0.05$). In the same way, *M. progresivus* r_m values were only significantly higher than *O. gossypii* values at 30% RH (t_{Dunn}= 15.79; df = 6, 122; $P < 0.05$).

Discussion

Humidity is a main factor in the ecology of spider mites. Loss or gain of water from the atmosphere is important for these small organisms because of their large surface/volume ratio (Van de Vrie et al. 1972). High humidity generally has a stronger negative effect than low humidity on mite development, survival, and fecundity (Van de Vrie et al. 1972). Under low humidity, water loss by evaporation can be compensated by increased feeding, whereas under high humidity mites have difficulty eliminating all their excess water (Boudreaux 1958) although excess water could probably be excreted as a fluid rather than as vapor (McEnroe 1963). The results obtained in this experiment showed that relative humidity influences development, fecundity, and survival of both species. Low relative humidity (30%) reduces the biotic potential of both *M. progresivus* and *O. gossypii.* The effect was stronger on survival of immature stages of *O. gossypii* and caused a substantial decrease in r_m. Thus, air humidity should be taken into account when explaining population decreases of *O. gossypii* in the middle to end of the dry season (Bonato 1993) as relative humidity can reach minimum of 25–30% RH throughout practically the whole of the African cassava belt during this period (Griffiths 1984). *M. progresivus* and *O. gossypii* cannot complete their life cycle under a constant relative humidity of 90%, which is unexpected for tropical species. However, even under the climatic conditions prevailing in the equatorial region, a constant relative humidity of 90% for several days is rare although the maximum relative humidity recorded is 95–100% RH (Griffiths 1984). Previous workers on *M. progresivus* in Africa have attributed the disappearance of this pest during the wet season to the mechanical effect of rainfall (Yaninek et al. 1989b). The results presented here suggest that high air humidity during the rainy season has the same effect on *O. gossypii* populations (nearly absent) as on *M. progresivus* populations (exceedingly low densities) (Nyiira 1972, Leuschner 1980, Akinlosotu and Leuschner 1981, Bonato 1993). Of the 3 relative humidities tested, 60% RH appeared to be the most favorable for population growth of both mite species. The r_m values of 0.226 for *M. progresivus* and 0.214 for *O. gossypii* at 60% RH are comparable to those found by Yaninek et al. (1989a) for *M. progresivus* and by Sabelis (1985) for other species under similar ambient conditions. The effect of the relative humidity on the biology of both cassava mite species shows the importance of this abiotic factor in mite life-table parameters and emphasizes the need to take it into account in further studies of population dynamics.

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