EFFECTS OF HUMIDITY AND PHOSPHORUS ON POPULATIONS OF THE EUROPEAN RED MITE *PANONYCHUS ULMI* (ACARI: TETRANYCHIDAE)[1]

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ABSTRACT

A laboratory study investigating the combined effects of phosphorus and relative humidity upon reproduction by the European red mite *Panonychus ulmi* (Koch) was conducted. Phosphorus effects were tested at two levels (Hoagland solution with or without phosphorus) and relative humidity at five levels (6%, 30%, 60%, 75% and 90%). Experiments were run at two temperatures, 21°C and 25°C, and at a day-length regime of 16L:8D. The mites' response to phosphorus was characterized by a significant increase in progeny numbers when the host plant contained "high" levels of this element. Reaction to humidity was characterized by an increase in progeny at relative humidities between 60% and 75%. Under the same RH conditions, higher numbers of progeny were generally obtained from plants containing higher levels of phosphorus; the most favorable treatment was Hoagland solution with phosphorus and 75% RH.

Key Words: Tetranychidae, spider mites, *Panonychus ulmi*, phosphorus, humidity, nutrition.

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INTRODUCTION

The European red mite (ERM), *Panonychus ulmi* (Koch), is an important pest of apple orchards in the eastern and midwestern areas of the United States (Croft and McGroarty, 1977). In Georgia, it represents an economic problem for the growers in the mountainous areas, where apple cultivation is an important agricultural endeavor (Hubbard and Purcell, 1985).

Although, the ERM has been in Georgia for more than 40 years (Taylor, 1955), basic information on this mite in Georgia is limited. Except for Jamal (1986), there is no published information about the ERM's biology and phenology. Also the effects of environmental factors, such as plant nutrition and humidity, upon population development of this mite, are unknown for this state.

Plant nutrition and humidity are important factors in controlling the population sizes of mites in the field (Gutierrez and Helle, 1985; Wrensch, 1985; Huffaker et al. 1970). The chemical constitution of the host plant may influence fecundity, egg viability, mortality and development rate of phytophagous mites (Breukel and Post, 1959). Phosphorus has been indentified as the most important element in egg production in *Tetranychus urticae* Koch (Rodriguez, 1954), and according to

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Watson (1964), a phosphorus deficiency reduced the fecundity of *T. urticae* more than nitrogen or potassium. Conversely, humidity exerts a strong influence on acarine development (Vrie et al., 1972) as loss or gain of water from the atmosphere is important for these small organisms because of their large surface/volume ratios (Crooker, 1985). In phytophagous mites, dehydration may cause the mites to increase their food consumption and metabolism to replace water loss (Rodriguez and Rodriguez, 1987).

To better utilize pest management strategies, information on mite responses to plant nutrition and such environmental effects as humidity are needed. The present study was undertaken to investigate the effect of different relative humidities and host-leaf phosphorus levels on ERM populations under controlled conditions of light and temperature.

MATERIALS AND METHODS

The mite stock population for this experiment was collected from a commercial apple orchard at the University of Georgia Horticultural Farm (Watkinsville, Oconee County, Georgia) during the summer of 1987.

Rose (*Rosa* spp.), a natural host of *Panonychus ulmi* (Pritchard and Baker, 1952; Jeppson et al., 1975) was used as the host plant in this study. The use of a miniature rose (var Baby Diana) permitted holding the entire plant in a humidity controlled chamber, without plant deterioration, for the duration of the tests.

An illustration of the environmental chamber designed for this experiment is given in Fig. 1. Chambers were made of glass and consisted of two parts: the bottom, which held the plant's root and a nutrient solution; and the top, which consisted of a dish that held a salt solution used to regulate relative humidity, and a cover which fit over the dish, giving a generally airtight chamber. A hole, which was closed with a glass stopper, was cut in the top of the cover. This opening allowed entry to the interior of the chamber with minimal disturbance of the system. Relative humidity and temperature within the chambers were measured daily through this opening, using a digital hygro-thermometer with an accuracy of 2% RH and ± 0.4°C (Cole-Parmer Instrument Company).

Two types of treatments were tested in this study: phosphorus and relative humidity. Phosphorus represented two levels: absent and present (recommended concentration for normal growth; Hoagland and Arnon, 1950). Five relative humidity levels (6, 30, 60, 75 and 90%) were used. Plants held in a no phosphorus solution (Hoagland solution lacking phosphorus) and in a normal phosphorus present solution (Hoagland solution) were used at each of the five RH levels. These were obtained by using saturated salt solutions in the environmental chambers. The salts used for each relative humidity level were; NaOH (6%), $CaCl_2.6H_2O$ (30%), glucose (60%), NaCl (75%), and KNO_3 (90%) as suggested by Winston and Bates (1950).

Rose plants used in this study had received weekly applications of nitrogen, phosphorus and potassium (20-20-20 fertilizer formula) at a nursery. When brought into the laboratory, all plant leaves were removed and for fourteen days the plants were held, without root aeration, in one of three types of nutrient solutions: Hoagland solution, Hoagland solution lacking phosphorus, or distilled water. All plants were held in these solutions until new leaves were produced, then used for experiments. No mites were reared on plants held in distilled water as these plants were used for comparisons of nutrient contents with plants held in the two types

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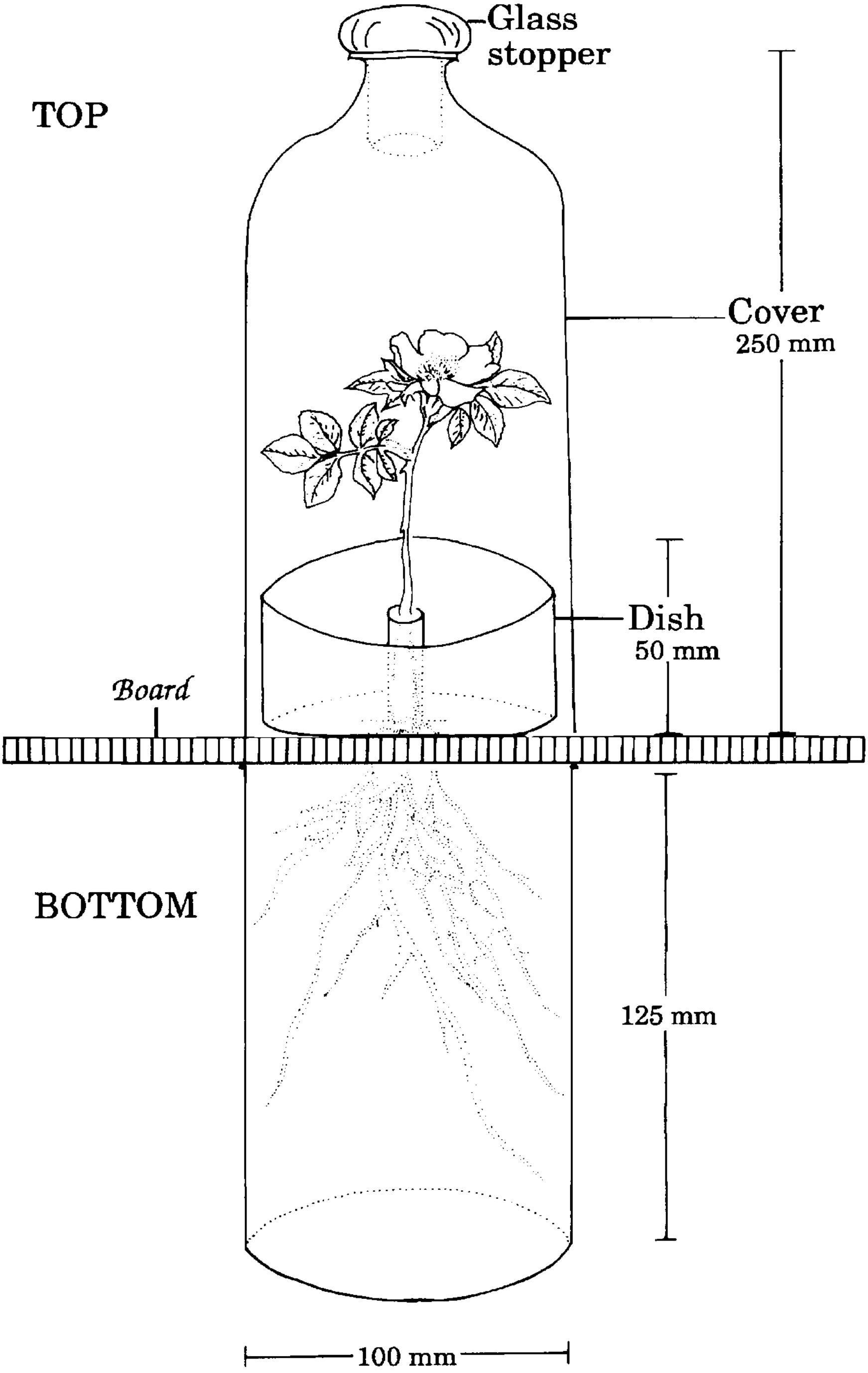

Fig. 1. Environmental chamber.

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of Hoagland solution. During the experiments, plants were maintained in the same type of nutrient solution in which they were originally held. After tests were concluded, leaves were removed and sent to the Test and Plant Analysis Laboratory (Cooperative Extension Service), University of Georgia, for chemical analyses. This provided information on the levels of phosphorus in the leaves during each test.

Experiments were set up as follows: using a camel's hair brush five teneral females were placed randomly on the plant leaves and the plants were enclosed inside the chambers. Two chambers were allocated for each treatment. After eight days the chambers were opened, and the number of progeny (eggs and immature mites) were recorded. All experiments were run under controlled conditions of light (16L:8D), and temperature (either 21°C or 25°C).

Data were transformed to $y = (x + 0.375)^{1/2}$ before analysis of variance. Means were separated by Tukey's honestly significant difference test (Zar, 1984).

RESULTS AND DISCUSSION

Preliminary investigations showed that *Panonychus ulmi* females have a two-day preoviposition period followed by a ten-day period of active oviposition. During the oviposition period, an average number of 20 eggs are laid (Dormond, unpub. data). Because teneral females were used in this experiment, and they remained inside the chambers for eight days, a maximum number of 12 eggs/female could be expected.

The importance of phosphorus in mite population development was first established by Rodriguez (1951, 1954). In 1951, working with the two-spotted spider mite *Tetranychus bimaculatus* Harvey, he showed a positive correlation between phosphorus content of tomato foliage and the number of mite progeny that developed thereon, when phophorus ranged from a trace to approximately 0.3% dry weight of the tomato foliage. Working with P^{32} and *T. urticae*, Rodriguez (1954) demonstrated that phosphorus compounds going into egg production are characterized by rapid turnover, and also that egg production consumes large quantities of phosphorus, since the rate of uptake and the rate of phosphorus utilization were virtually the same.

Results obtained in the current study using *P. ulmi* are in agreement with those of Rodriguez. When phosphorus was present in the nutrient solution (Table 1), the leaf phosphorus content was considered to be a "high" level [classification based on ranges used by Florida Cooperative Extension Service, Yeagar and Ingram (1985), see Table 2] and a significant increase in the progeny numbers was observed at 21°C and 25°C (Table 3). On the other hand, when phosphorus was absent in the nutrient solution (Table 1), the leaf element content remained at a "sufficient" level (Table 2) and the population numbers were significantly smaller (Table 3). Therefore, "high" levels of phosphorus were associated with increased population numbers of *P. ulmi.*

The spectographic analyses (Table 1) also showed the status of two other major nutrient elements, nitrogen and potassium. Plants have very small mobile reserves of N compounds, consequently, when N becomes deficient (as with plants held in distilled water) the effects appear rapidly in the actively growing areas, in this case, the leaves (Martin-Prevel et al., 1987). This explains why the nitrogen level remained "sufficient" for plants held in Hoagland solutions, and became "low" in

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Table 1. Nutrient content (nitrogen, phosphorus and potassium) of leaves from rose plants exposed to different types of nutrient solutions.

	Major elements (% of dry matter)		
Solutions	N	P	K
Hoagland	3.99	0.70	5.82
Hoagland lacking P	3.15	0.59	3.33
Distilled Water	1.28	0.59	3.36

Table 2. Foliar mineral major element (N, P, K) ranges for woody ornamentals as used by the Florida Cooperative Extension Service (Yeager and Ingram, 1985).

	Ranges (% of dry matter)					
Element	Low		Sufficient		High	
N	1.50	2.00	2.01	4.50	4.51	7.00
P	0.10	0.20	0.21	0.60	0.61	1.00
K	1.00	1.50	1.51	3.50	3.51	6.00

Table 3. European red mite populations after eight days on rose plants in nutrient solution with or without phosphorus and held at different temperatures.

	Population ($\bar{x}$ progeny/♀)*	
Phosphorus	21°C	25°C
Absent	1.26 a**	1.67 a
Present	2.00 b	3.39 b

* Mean for ten replicates. Averages calculated across relative humidity levels. All means were back transformed from $y = (x + 0.375)^{1/2}$.

**Means within columns followed by a different letter are significantly different [$P \leq 0.01$; Tukey's honestly significant test (Zar, 1984)].

plants held in distilled water (Table 2). The fact that the nitrogen level was essentially the same for leaves associated with both Hoagland solutions, suggested that nitrogen did not affect the mite population in this study. Although the potassium (K) supply was the same in both Hoagland media, this element level increased in leaves of plants held in the Hoagland solution (Table 1), as did the mite population, and remained at a "sufficient" level in leaves from plants held in either the Hoagland solution lacking phosphorus or distilled water (Tables 1 and 2).

With regards to interactions between these elements, Jesiotr et al. (1979) noted a significant increase in *P. ulmi* populations when nitrogen and phosphorus were

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provided to the plant, but no effect when potassium was used. Rodriguez (1964) reported that mite population growth was positively correlated with both nitrogen (N) and phosphorus (P) at "low" to "sufficient" levels, whereas at much higher levels of N and P population densities were depressed. Cannon and Connell (1965), in studies conducted with *Tetranychus atlanticus* McGregor on soybean leaves, observed that "high" levels of phosphorus were associated with increased mite fecundity. In the present study, "high" levels of phosphorus and "sufficient" levels of nitrogen were correlated with increased populations of *P. ulmi*. When both elements were at "sufficient" levels fewer progeny were obtained. Also, an increase in the level of potassium (K) from "sufficient" to "high" was associated with "high" levels of phosphorus, and increased population numbers of *P. ulmi*.

Summer eggs of *P. ulmi* are vulnerable to dessication up to six hours after oviposition, and they will not survive that period in relative humidities lower than 75% (Beament, 1951). However, after the first six-hour period, eggs can survive at 30% or lower RH. Therefore, in the present study, eggs laid under the driest conditions had little chance of surviving through the critical six-hours period (Table 4.).

Table 4. Numbers of European red mite progeny after eight days on rose plants exposed to different levels of relative humidity and temperature.

	Population ($\bar{x}$ progeny/♀)*	
% RH	21°C	25°C
6	0.00 a**	0.00 a
30	0.28 b	1.26 b
60	2.52 c	3.59 c
75	5.34 d	7.35 d
90	2.03 c	2.69 e

* Mean for ten replicates. Averages calculated across phosphorus levels. All means were back transformed from y = (x + 0.375)½.

**Means within coulumns followed by a different letter are significantly different [$P \leq 0.01$; Tukey's honestly significant test (Zar, 1984)].

Nickel (1960) established that for *Tetranychus desertorum* Banks the innate capacity for increase (r_m) at 30°C and 25-30% RH is 0.46/day and that it become 0.36/day at 85-90% RH, reflecting a higher oviposition rate at lower humidities. In the current study, the numbers of progeny/female were determined by the number of eggs laid, since mortality of young was observed only in one case (30%). The highest number of eggs/female were laid at 75% RH (Table 4). Below this level the oviposition rate decreased with decreasing humidity. At 6% RH no eggs were laid and no females survived. At 30% even though some eggs were laid, survival of immatures was low, as the individuals found were either dead larvae or unhatched eggs.

Boudreaux (1958) reported that mites in a low RH atmosphere lay more eggs and at a higher rate, and live longer than do mites ovipositing in a near saturated atmosphere. In this study, the highest average progeny/female occurred at 75%. Above this level there was a decline in the progeny numbers. At extremely high humidity rates (90%), the mean progeny/female was below that obtained at 75%.

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Although the average progeny/female at 60% was equal to that obtained at 90%, the fact that at 60% the population had not reached its peak (Figs. 2 and 3), suggested the relative humidities from 60% to 75% provided the most favorable conditions for ERM population development as measured by the number of eggs laid. Extremely high humidity rates, e.g. 90%, represented a saturation value that, according to Boudreaux, reduced the oviposition rate of this mite.

Looking at the interaction effect of phosphorus and relative humidity treatments, it is evident that the presence or absence of phosphorus exerted a strong influence on population numbers at both temperature levels (Figs. 2 and 3). Treatments receiving phosphorus resulted in the largest number of progeny/female, except at low levels of relative humidity (6% and 30%), where the presence or absence of phosphorus did not make a significant difference in the population numbers.

How relative humidity and phosphorus affect progeny numbers is highly related to the mites' hydric relations. In feeding, mites maintain their water balance (Wharton, 1985). Hence, the drive to maintain this balance may influence the ingestion or imbibition of other nutrients and consequently, determine feeding, growth and/or reproductive rates (Wharton and Arlian, 1972; Crooker, 1985). Mites reacting to a low relative humidity, or feeding from leaves whose cells are less than turgid, ingest more phosphorus with each unit of water imbibed than when the leaves are water replete (Wharton and Arlian, 1972). It is then expected that under certain humidity conditions (60-75% RH), the intake of nutrients will be greater than under higher humidities (90% RH) to compensate for water loss. Therefore, the presence or absence of phosphorus in the experimental nutrient solutions influence egg production and resulting progeny (Rodriquez, 1954).

Results presented herein demonstrate that the population densities of *P. ulmi* were influenced by phosphorus supply. A variation in the phosphorus level from "sufficient" to "high" resulted in a significant difference in the progeny produced on miniature rose plants and presumably, did not affect plant growth or yield when the nutrient was increased from the band of optimal contents ("sufficient" range) to the region of luxury consumption ("high" range).

To recognize the effect of relative humidity on populations of ERM may be an important tool in pest management, especially for strategies where forecasting is involved. Based on the results of the present study, relative humidity conditions from 60% to 75%, and plants with phosphorus fertilization at "high" levels, are favorable conditions for ERM outbreaks. A careful handling of plant nutrition could lead to lower mite populations, thus reducing the need for acaricidal applications, and the chances for development of resistance. Expenses due to both acaricides and fertilizers would be reduced.

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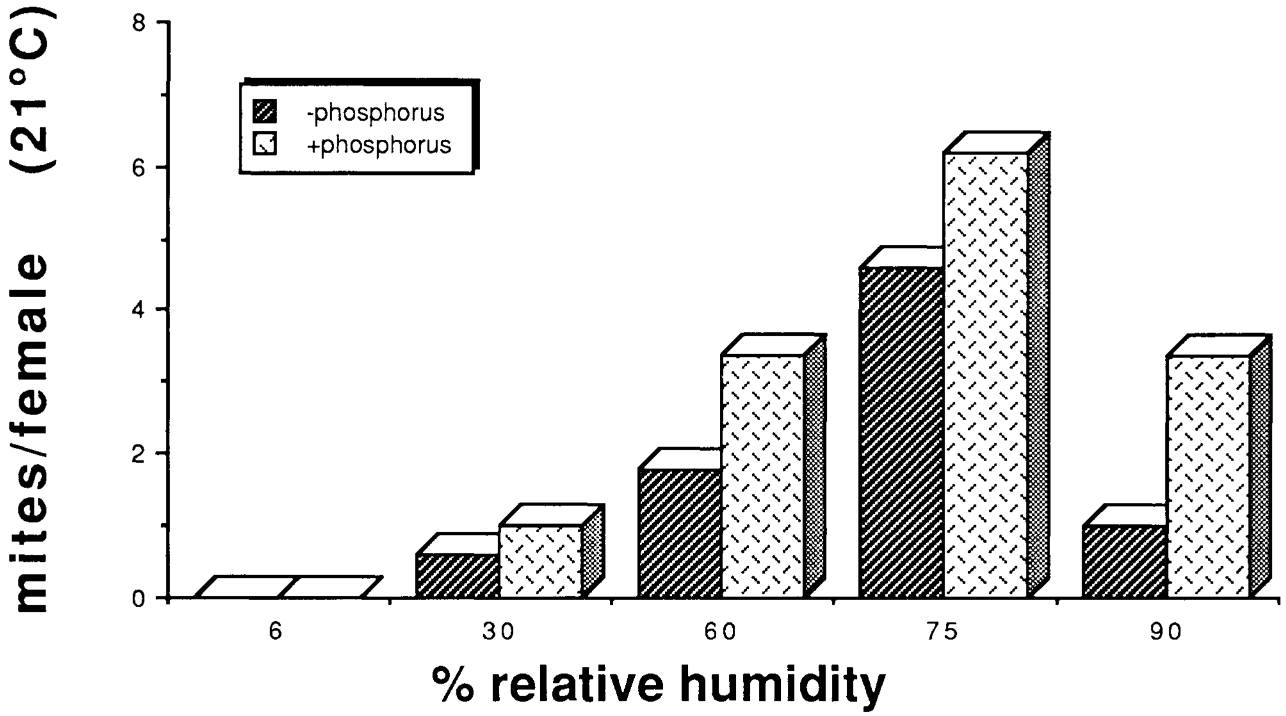

Fig. 2. Combined effect of phosphorus and relative humidity on the number of ERM progenies at 21°C.

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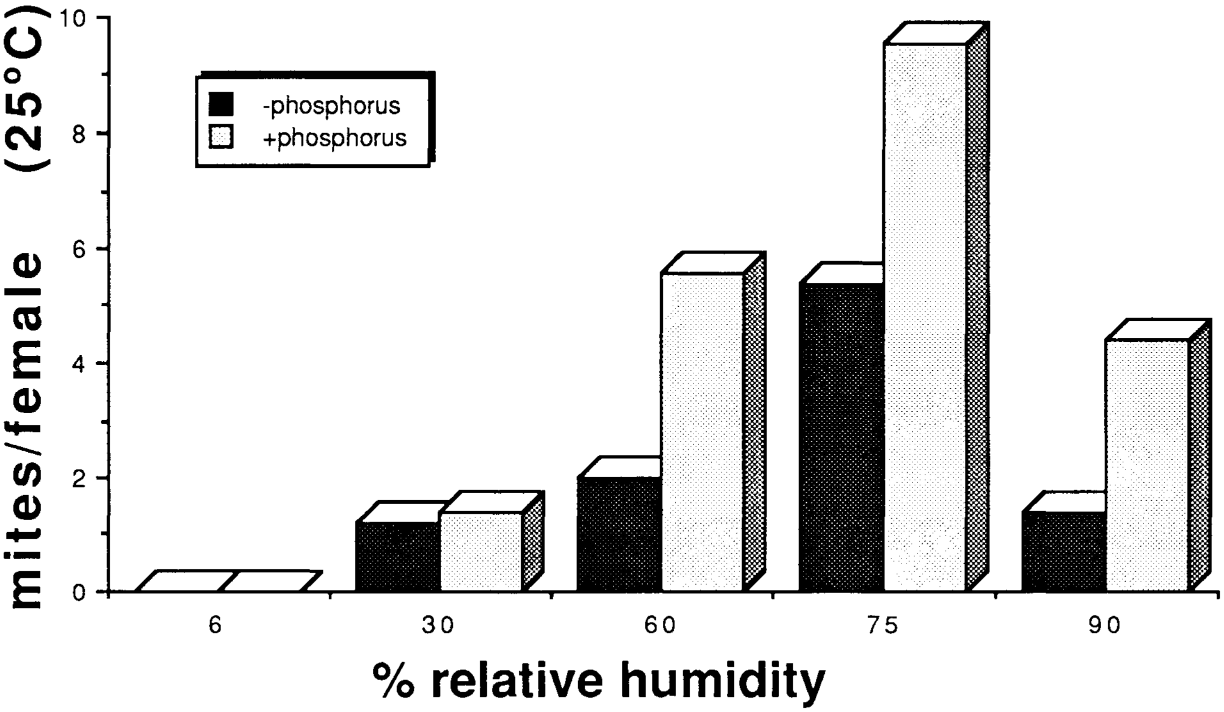

Fig. 3. Influence of phosphorus and relative humidity on ERM progenies at 25°C.

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Table 5. Mean number of progeny per *P. ulmi* female after eight days held on rose plants exposed to different conditions of phosphorus fertilization, relative humidity and temperature.

% RH	Phosphorus			
	Absent		Present	
	21°C	25°C	21°C	25°C
6	0.00 a*	0.00 a	0.00 a	0.00 a
30	0.05 a**	1.19 b	0.07 a	1.37 b
60	1.79 b	1.97 c	3.39 c	5.58 e
75	4.60 d	5.38 e	6.18 e	9.61 f
90	0.95 b	1.88 c	3.39 c	4.38 d

* Average for ten replicates. All means were back transformed from $y = (x + 0.375)^{1/2}$.

**Means within columns followed by a different letter are significantly different ($P \leq 0.01$; Tukey's honestly significant test), [Zar, 1984].

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