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LIFE AND FERTILITY TABLE OF *BACTERICERA COCKERELLI* (HEMIPTERA: TRIOZIDAE), UNDER DIFFERENT FERTILIZATION TREATMENTS IN THE 7705 TOMATO HYBRID

TABLA DE VIDA Y FERTILIDAD DE *BACTERICERA COCKERELLI* (HEMIPTERA: TRIOZIDAE), BAJO DIFERENTES TRATAMIENTOS DE FERTILIZACIÓN EN EL HIBRIDO DE TOMATE 7705

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ABSTRACT

The lifecycle of *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae) was evaluated on tomato hybrid “SUN-7705” using different fertilization schemes each representing a different treatment: Steiner solution (T1), solution with the nitrogen level reduced to 25% (T2), solution with the potassium level reduced to 25% (T3) and solution with the calcium level reduced to 25% (T4). All experiments were carried out under greenhouse conditions during two crop cycles (February-May and May-August, 2012). The lifecycle parameters evaluated in each treatment were: mean life expectancy (e_x), net reproduction ratio (R_o), time of generation (T), intrinsic natural increase ratio (r_m), finite increase ratio (λ), natality (b) and mortality (d). For the experiment carried out during February-May, the greatest values for the (R_o) = 28. (r_m) = 0.069 and (T) = 49.72 were obtained with treatment T1; the greatest value for (b) was obtained with treatment T2 with 0.085 and the greater (d) value was obtained with treatment T3 with 0.023. Treatment T4 presented the smallest values of development evaluated for all population parameters. For the experiment carried out during May-August, the greatest values of (R_o) = 24.78 and (T) = 54.86 were obtained with treatment T1; for the (r_m) parameter, the greatest value was obtained with T3 (0.073) compared to the other treatments; with respect to (b), the greatest value was obtained with treatment T3 with 0.078, and the greatest value for (d) was obtained with treatment T2 with 0.014. Overall, the smallest values for all life parameters evaluated were obtained with treatment T3 regardless the crop cycle studied.

Key words: life table, population parameters, tomato psyllid, 7705 tomato hybrid.

RESUMEN

Se evaluó el ciclo de vida de *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae), bajo diferentes tratamientos de fertilización (T1: Solución de Steiner, T2: Nitrógeno al 25%, T3: Potasio al 25% y T4: Calcio al 25%), en el híbrido de tomate ’SUN-7705’, en condiciones de invernadero en el Colegio de Postgraduados, Campus Montecillo, Texcoco, México, durante dos ciclos de cultivo (Febrero-Mayo y Mayo-Agosto 2012). Los parámetros medidos fueron esperanza media de vida (e_x), tasa neta de reproducción (R_o), tiempo de generación (T), tasa intrínseca de incremento natural (r_m), tasa finita de incremento (λ), natalidad (b) y mortalidad (d), en cada uno de los tratamientos. Se encontró que para el primer ciclo los valores de los parámetros poblacionales más altos se obtuvieron en T1 con (R_o)= 28, (r_m)= 0,069 y (T)= 49,72; el valor más alto para (b) se presentó en T2 con 0,085 y la (d) mayor se presentó en T3 con 0,023; siendo T4 el que presento los valores más bajos de desarrollo en todos los parámetros poblacionales. Para el segundo ciclo los valores más altos de (R_o)=24,78 y (T)=54,86 se obtuvieron con T1 respecto a los otros tratamientos; para el parámetro (r_m), T3 fue el que presento el valor más alto con 0,073 respecto a los otros tratamientos; en cuanto a la (b) el valor más alto se presentó en T3 con 0,078 y la (d) mayor se presentó en T2 con 0,014 respecto a los otros tratamientos, siendo el T3 el que presento en todos los parámetros poblacionales los valores más bajos de desarrollo respecto a los otros tratamientos y en ambos ciclos.

Palabras clave: Híbrido de tomate 7705, parámetros poblacionales, psílido del tomate, tabla de vida.

INTRODUCTION

In Mexico, *B. cockerelli* was first registered in 1947 as a potato (*Solanum tuberosum*) pest in the states of Durango, Mexico, Guanajuato, Michoacan, and Tamaulipas (Pletsch, 1947; Vega-Gutiérrez *et al*., 2008). Currently, it is widely distributed throughout the country, and represents a serious hindrance for the production of crops like pepper (*Capsicum annum* L.), potato (*Solanum tuberosum* L.), tomato (*Solanum lycopersicum* L.), and green tomato (*Physalis ixocarpa* Brot) (Garzon-Tiznado *et al*., 2004, 2005). Besides the damage caused when it sucks on the sap of the host plants, the nymphs inject toxins (Carter, 1939). *B. cockerelli* is considered one of the most serious insect pests of Mexico and parts of the United States of America (Garzón-Tiznado, 2002; Liu & Trumble, 2007; Munyaneza *et al*., 2007). Infestations of *B. cockerelli* on tomato have caused significant fresh tomato market losses in North America, with notable yield reductions up to 50% in California and 80% in Baja California, Mexico (Liu & Trumble 2004, 2006c). Furthermore, *B. cockerelli* vectors a bacterium *Candidatus Liberibacter psyllaurous* (syn. *solanacearum*) that had also caused extensive damage to potato (*Solanum tuberosum* L.) production (Hansen *et al*., 2008; Liefting *et al*., 2008, 2009), due to the destructive disease named potato 'Zebra Chip' (Munyaneza *et al*., 2007, 2008, 2009). This disease causes loss of millions of dollars in the potato industry in Central America, United States, New Zealand and Mexico currently the most effective strategy to control this disease is the application of insecticides, however to improve disease management, knowledge of population dynamics, biology, ecology and geographical distribution of the populations of the insect vector (Munyaneza *et al*., 2007; Gharalari *et al*., 2009) is necessary; this pest possesses a great capacity to increase its population density since the female can lay up to 1400 eggs during its lifecycle (Knowlton & Janes, 1931). Several studies have been done to learn the development and lifecycle of *B. cockerelli* (Pack, 1930; Knowlton & Janes, 1931; Davis, 1937; List, 1939; Pletsch, 1947; Wallis, 1955; Liu *et al*., 2006b; Abdullah, 2008; Yang & Liu, 2009; Yang *et al*., 2010; Vargas-Madríz *et al*., 2011) in different hosts with controlled environments; however, there are few studies of the lifecycle and development of *B. cockerelli* in tomato related with the effect caused by fertilization of the crop. This is necessary since it is known that some of the elements with which the crops are fertilized can also affect the populations of both insects and mites, as in the case of *Trialeurodes vaporariorum* (West.), *Myzus persicae* (Sulzer), *Tetranychus urticae* Koch,

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and *Eotetranychus willamettei* (Ann, 2010; Van Emden, 1966; Ortega-Arenas *et al*., 2006). The application of nutrients to crops can influence oviposition, growth ratios, survival, and reproduction of the insects (Jones, 1976). Phelan *et al*. (1995) mention that an increase in the levels of soluble nitrogen in plant tissue favors a decrease in pest resistance, although it is not a universal phenomenon. The objective of the present work was to determine the effects on the life and fertility table of *B. cockerelli* cohorts in the 7705 tomato hybrid Four different solutions were used with two replicates by treatment, T1: Steiner solution, T2: Steiner solution with the nitrogen level reduced to 25%, T3: Steiner solution with the potassium level reduced to 25%, T4: Steiner solution with the calcium reduced to 25%, during two crop cycles to observe their development of life.

MATERIALS AND METHODS

The experiment was conducted under greenhouse conditions at the Colegio de Postgraduados, Campus Montecillo, Texcoco, the State of Mexico, during two crop cycles, February to May and May to August, 2012. The data collection of daily temperature and relative humidity was taken from the weather station located in the Colegio de Postgraduados, Campus Montecillo. The tomato variety used in this study was the hybrid: "SUN-7705", which are grown frequently by tomato farmers in Mexico because of their good agronomic behavior, *i.e*., very long fruiting periods (indeterminate development) and long postharvest shelf life (De la Cruz-Lázaro *et al*., 2009; Martínez *et al*., 2013).

Bactericera cockerelli **Colonies**

The tomato variety was seeded in planting trays; 20 plants of the variety were selected for the study. Seedlings were transplanted into polyethylene bags containing 2 kg of 50% Canadian Growing Mix 1VM and 50% Tezontle (porous volcanic rock) when the plants were 31 d old. Plants were moved to growth chambers (62 cm long × 95 cm wide × 95 cm high) framed with wooden boards and covered with plain weave mesh to exclude insects, especially *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae). The materials were maintained under a 14:10 h L:D with temperatures ranging from 10 to 25 °C.

No insecticides were used while rearing *B. cockerelli* on the variety of tomato. *Bactericera cockerelli* fourth and fifth instars were collected from the "Rio Grande" tomato variety grown in growth chambers of the Biological Control Greenhouse in the Colegio de Postgraduados and later taken to the experimental greenhouse. These insects were cultured for 7 generations on the tomato variety mentioned above. Subsequently these *B. cockerelli* were maintained for 4 generations in new growth chambers on the variety "SUN-7705" and this was done to avoid parasites or depredation of any kind. The plants were irrigated with a modified Steiner nutrient solution to keep breeding that would be used in the experiment.

The durations of the nymphal and adult stages of *B. cockerelli* were determined on the variety of tomato in the greenhouse. Possible presence/absence of "*Candidatus Liberibacter solanacearum*" and its effects on the life and fertility table on the different stages of insect was not measured. The *B. cockerelli* colony, 65 adults in their reproductive stage were taken randomly to guarantee a cohort of 100 eggs on 1 d in each growth chamber. After 24 h, the adults were removed out and the number of eggs laid was recorded. This was later adjusted to 100 eggs. Four growth chambers were set up for each treatment with two replicates by treatment, the compositions of the solutions used each treatment are shown in Table 1. Four different solutions were used: T1 is the Steiner solution, T2 is the Steiner solution with the nitrogen level reduced to 25%, T3 is the Steiner solution with the potassium level reduced to 25%, T4 is the Steiner solution

Table 1. Nutrient solution used in the research of life table of *B. cockerelli* in the greenhouse (Montecillo, the State of Mexico. Cycles February-May, May-August, 2012).

Elements	T1 (Steiner Solution)	T2 (N 25%)	T3 (K 25%)	T4 (Ca 25%)
	Ppm			
N	167	41.75	167	167
Ca	179	179	179	44.8
K	276	276	69	276
P	31	31	31	31
Mg	46	46	46	46
S	141	141	141	141
Fe	3	3	3	3
Mn	1.14	1.14	1.14	1.14
Cu	0.13	0.13	0.13	0.13
Zn	0.48	0.48	0.48	0.48

ppm = parts per million

with the calcium level reduced to 25%, with 5 plants per growth chamber, and 65 adults were introduced per chamber. The measured parameters were: average life expectancy (e_x), net reproduction ratio (R_o), time of generation (T), intrinsic natural increase ratio (r_m), finite increase ratio (λ), births (b), and mortality (d) in both cycle.

The nutrient solution used was based on the Steiner (1961) universal solution. Two irrigation times a day of 300 mL of the nutrient solution to each plant. In order to observe the effects of nitrogen (N), potassium (K), and calcium (Ca), their amount was decreased in the aforementioned solution to 25% for 100 liters of water.

RESULTS

The durations of the incubation period for the egg stage of *B. cockerelli* were 14 and 12 days, respectively. In the case of treatment T2, T3, and T4, the durations of the periods were 16, 14, and 12 days, and 12, 13, 14 days, respectively. With regard to the duration of the overlapped nymph stages, it was observed to be 40 and 39 days, respectively, while in T2, T3, and T4, they were 34, 37, and 34 days, and 33, 34, and 31 days, respectively. The adult development stages were: T1, 51 and 52 days; T2, 46 and 50 days; T3, 47 and 51 days; and T4, 48 and 49 days, respectively. The durations of the whole lifecycle (egg-adult) were: T1, 77 and 81 days; T2, T3, and T4, 70, 74, and 70 days; and 76, 76, and 73 days, respectively (Table 2).

In the life table, the functions (n_x) of each of the treatments (100%, nitrogen, potassium, and calcium at 25%) were graphed to obtain the corresponding survival curves (Fig. 1 A and B). It can be observed that for all T1, T2, T3, and T4, in the first 23 days in both cycles, there was a moderate mortality in the egg stage of *B. cockerelli*. There greatest mortality was in the nymph 1 and 2 stages, followed by a relative low mortality in the adult stage and in cycle duration. Treatment T1 differs in the curves by effect of the treatments T2, T3, and T4, showing a lower mortality in the stages of the insect as well as in cycle duration, it being longer in T1 than in any of the other treatments in both cycles.

With regard to mean life expectancy (e_x), high values were observed in both cycles under treatment T1, mainly because in this treatment, the population of *B. cockerelli* lived longer than in the rest of the treatments (Table 3).

Table 2. Duration of the egg, nymph, and adult stages of *B. cockerelli* under different fertilization treatments in 7705 tomato hybrid (Montecillo, the State of Mexico. Cycles February-May, May-August, 2012).

Stages	T1	T2	T3	T4	Stages	T1	T2	T3	T4
February-May Cycle					May-August Cycle				
Days					Days				
Egg	14	16	14	12	Egg	12	12	13	14
Nymph 1	17	18	17	16	Nymph 1	15	15	16	14
Nymph 2	17	18	14	14	Nymph 2	11	14	14	15
Nymph 3	18	20	14	15	Nymph 3	14	15	15	16
Nymph 4	18	18	15	18	Nymph 4	16	17	15	17
Nymph 5	22	19	19	21	Nymph 5	21	17	20	18
Adult	51	46	47	48	Adult	52	52	53	51
Egg-Adult	77	70	74	70	Egg-Adult	81	76	76	73

Note: The time of development from the egg to adult is not the sum of the different stages because do not necessarily at the end of one stage indicate the star of the next stage.

Table 3. Mean life expectancy of *B. cockerelli* under different fertilization treatments in 7705 tomato hybrid (Montecillo, the State of Mexico. Cycles February-May, May-August, 2012).

	T1	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**
DAYS	February-May Cycle				May-August Cycle			
(X)	(e_x)	(e_x)	(e_x)	(e_x)	(e_x)	(e_x)	(e_x)	(e_x)
0	53.24	40.10	43.69	40.90	52.14	39.75	41.69	41.08
5	48.24	35.10	38.69	35.90	47.14	34.75	36.69	36.08
10	43.24	30.10	33.69	30.90	42.14	29.75	31.69	31.08
15	41.53	28.79	34.18	31.66	41.44	33.18	31.60	30.66
20	38.31	27.16	32.84	28.63	42.28	33.10	34.50	30.20
25	34.15	27.56	32.56	27.87	37.78	32.94	30.00	29.19
30	29.54	24.10	27.56	23.07	32.78	28.23	25.00	24.41
35	24.54	19.10	22.56	18.36	27.78	23.23	20.15	19.57
40	19.54	15.08	17.56	14.28	22.78	18.39	16.11	15.78
45	14.38	11.87	13.48	10.88	17.90	14.73	13.24	12.37
50	12.38	9.41	10.72	8.16	15.20	11.93	11.23	9.78
55	10.46	5.91	7.40	6.32	12.04	9.08	9.71	8.04
60	8.01	3.71	4.60	4.06	9.91	5.86	7.37	5.78
65	5.17	1.72	2.80	1.79	8.01	3.25	6.21	3.05
70	2.44	0	1.17	0	4.69	1.75	3.10	1.00
75	0.50	0	0	0	1.86	0	0	0

(X)= age interval in time units, (e_x)= mean life expectancy of the individuals of the population at the beginning of interval x.

In the fertility table, the following parameters were analyzed: net reproduction ratio (R_o), intrinsic natural increase ration (r_m), time of generation (T), finite increase ratio (λ), natality (b), and mortality (d), obtained from each of the treatments T1, T2, T3, and T4, condensed in Table 4. For a greater precision of the intrinsic natural increase ratio (r_m), the Lotka equation (Σ exp (-rmx) lx mx = 1) was used to fit the value of r_m through trial and error (Vera *et al*., 2002).

The greatest value for the reproduction ration (R_o) of *B. cockerelli* was obtained in treatment T1, followed by treatments T2, T3, and T4, this latter being the one with the lowest value, and thus the least favorable for the reproduction of *B. cockerelli* in both cycles. With regard to the intrinsic natural increase ratio (r_m), treatments T1 and T2 had higher values than did treatments T3 and T4, favoring a population increase in the February-May cycle; however, in the May-August cycle, the highest value of (r_m) was obtained from T3, it being greater than the other treatments and the one that most favored an increase in population. Regarding time of generation (T), the highest value was obtained in T1 for both cycles, thus making this treatment the one that most benefitted the generational development of the insect. With regard to the finite increase ratio (λ) for the February-May cycle, treatments T1 and T2 showed higher values than did the other treatments. This indicates that these treatments favorably increased the population of *B. cockerelli*. In the case of the May-August cycle, the finite increase ratio (λ) was greater in T3 than in any of the other treatments, indicating that this treatment can favorably increase the population of the insect. Regarding the results for natality (b) in the February-May cycle, the highest value was observed in treatment T2, and for the May-August cycle, the treatment with the highest natality (b) value was T3. Mortality (d) in the February-May cycle was greatest in T3, and in the May-August cycle, it was in T2. This indicates that in these treatments, the survival of the insects was less favorable (Table 4).

The fertility of *B. cockerelli* in all four cohorts showed that in T1, the insect began its reproduction at 30 and 35 days old; in T2 at 32 and 30 days; in T3 at 31 and 29 days; and in T4 at 31 and 30 days, respectively (Figs. 2 A and B).

Treatment T1 showed a beginning of reproduction of *B. cockerelli* at 30 and 35

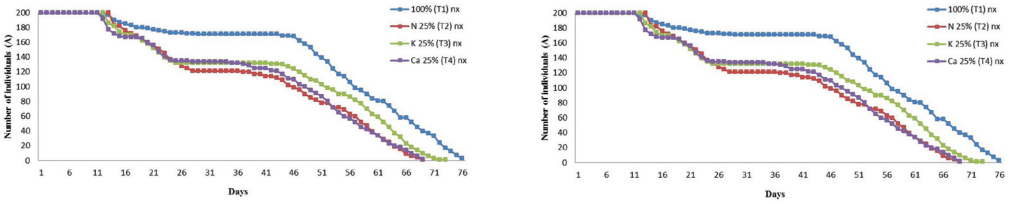

Figure 1. Survival curves (Number of individuals= n_x) of *B. cockerelli* under different fertilization treatments in 7705 tomato hybrid (Montecillo, the State of Mexico. Cycles (A) February-May, (B) May-August, 2012).

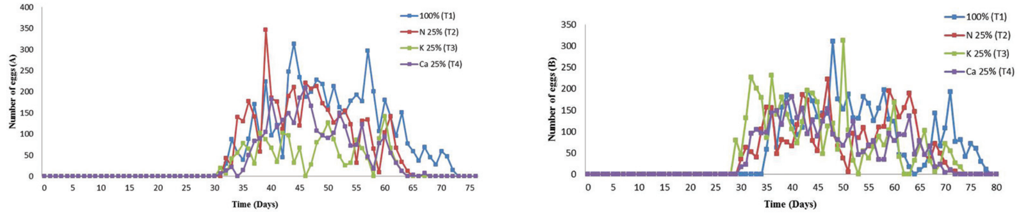

Figure 2. Fertility of *B. cockerelli* under different fertilization treatments in 7705 tomato hybrid (Montecillo, the State of Mexico. Cycles (A) February-May, (B) May-August, 2012).

days of age, respectively. In this treatment, a greater fertility and a greater number of females was observed than in any of the other treatments in both cycles. However, the highest average number of eggs per female in the February-May cycle was that of T3, and in the case of the May-August cycle, it was that of T1 (Table 5).

Table 4. Reproduction parameters of *B. cockerelli* under different fertilization treatments in 7705 tomato hybrid (Montecillo, the State of Mexico. Cycles February-May, May-August, 2012).

Cycles	7705 Hybrid	(R_o)	(r_m)	(r_m) exact	(T)	(λ)	natality (b)	mortality (d)
February-May	T1	28	0.067	0.069	49.72	1.06	0.082	0.015
May-August	T1	24.78	0.060	0.064	52.86	1.06	0.069	0.009
February-May	T2	21.49	0.066	0.068	46.30	1.06	0.085	0.019
May-August	T2	20.03	0.059	0.063	50.51	1.06	0.073	0.014
February-May	T3	9.73	0.047	0.050	47.44	1.04	0.070	0.023
May-August	T3	20.7	0.068	0.073	44.37	1.07	0.078	0.010
February-May	T4	7.68	0.042	0.045	47.61	1.04	0.058	0.016
May-August	T4	11.15	0.049	0.054	48.51	1.05	0.061	0.012

(R_o)= Reproduction ratio, (r_m)= intrinsic natural increase ratio, (T)= time of generation, (λ)= finite increase ratio, (b)= natality, (d)= mortality.

Table 5. Accumulated fertility of *B. cockerelli* under different fertilization treatments in 7705 tomato hybrid (Montecillo, the State of Mexico. Cycles February-May, May-August, 2012).

Cycles	7705 Hybrid	Females x growth chamber (1 and 2)	Eggs growth chamber (1)	Eggs growth chamber (2)	Accumulated sum	Average eggs per female
February-May	T1	92	3160	2779	5939	64.55
May-August	T1	72	2558	2397	4955	68.81
February-May	T2	59	1947	2352	4299	72.86
May-August	T2	61	2092	1915	4007	65.68
February-May	T3	65	2841	2406	5247	80.72
May-August	T3	71	1885	2448	4333	61.02
February-May	T4	70	1574	1353	2927	41.81
May-August	T4	66	1450	2163	3613	54.74

DISCUSSION

The susceptibility of the development of the psyllid varied in function of the treatments that were administered in each of the reproduction chambers. In general, there was a lower tolerance to the development of the psyllid in T4. Regarding the duration of the incubation period for the egg stage of *B. cockerelli* in the February-May and May-August, 2012 cycles in the 7705 tomato hybrid, a variation was observed in the development behavior of the egg, both in cycles and in treatments. For T1 they were 14 and 12 days, for T2 they were 16 and 12 days, for T3 they were 14 and 13 days, and for T4 they were 12 and 14 days, respectively. These results agree with those reported by Vargas-Madríz *et al*. (2011) who pointed out that the duration of the incubation period of the eggs of *B. cockerelli*, grown on "Charanda F1" variety, is 7 and 13 days in the period from October to December, and in the "Rafaello" variety it is 8 and 10 days in the period from January to March. The do not, however, agree with the results reported by Abdullah (2008) who mentions that the incubation period for the egg stage was from 6 to 8 days; while Yang & Liu (2009), reported that it was 5 days in eggplant and 5.9 days in bell pepper. Yang *et al*. (2010) mentioned that under laboratory conditions, the development of the egg was in 6.5 days, while in the field it was 4.4 days. Ortega-Arenas *et al*. (2006) reported a significant increase ($p \leq 0.05$) in the number of eggs of white fly *Trialeurodes vaporariorum* (West.) when increasing the supply of nitrogen. Likewise, they point out that N concentration influenced the ratio of oviposition in the same species. These results agree with those observed in the present work, given that treatments T1, T3, and T4 had a greater number of hatched eggs than did the initial cohort of 200 eggs per treatment in the reproduction chamber. This is regarding T2, where there were fewer hatched eggs, which indicates that by increasing the amount of nitrogen in the other treatments, the number of hatched eggs also increases.

With regard to the duration of the overlapping nymph stages, it was observed that in T1 they were 40 and 39 days; T2, 34 and 33 days; T3, 37 and 33 days; and T4, 34 and 31 days, respectively. These results agree with those reported by Vargas-Madríz *et al*. (2011), who reported that the duration of the nymph stages in "Charanda F1" tomato varieties was 32 and 42 days, and in "Rafaello" it was 31 and 41 days, respectively, for the October to December and January to March periods. However, they do not agree with the results reported by Pack (1930), Knowlton & Janes (1931), who mentioned that the time of development, was from all is 2 to 21 days. On the other hand, Yang & Liu (2009), indicate that nymph development in egg plant was 19.1 days, while in bell pepper it was 20.2 days. Yang *et al*. (2010) mentioned that nymph development in the field was 15.9 days, and under laboratory conditions it was 15.2 days. Asghar (2011) stated that nymph development in Agria and Marfona varieties of potato, nymph development was 22.3 and 18.2 days, respectively. These results are similar to those reported by Adkisson (1958), who found approximately three times more *Anthonomus grandis* larvae in cotton that had received high fertilizer doses than in unfertilized systems. The mentioned results agree with those found in the present study, given that T1 was the treatment that showed a greater number of nymphs than any other treatment. Likewise, Ortega-Arenas *et al*. (2006) mentioned that the number of white fly *Trialeurodes vaporariorum* (West.) nymphs increased significantly ($p \leq 0.05$) as the nitrogen supply increased. These results agree with those found in the present research since in T1, T3, and T4 there was a greater number of nymphs than in T2. This indicates that increasing nitrogen (T1) can increase the number of nymphs in a population of *B. cockerelli*.

With regard to the duration of the adult stage, the observations were: T1, 51 and 52 days; T2, 46 and 52 days; T3, 47 and 53 days; and T4, 48 and 51 days, respectively. These results agree with those reported by Vargas-Madríz *et al*. (2011) who mentioned that the duration of the adult stage in "Charanda F1" is 44 and 41 days, and in "Rafaello" it is 45 and 42 days, respectively. As for the egg-adult duration, T1 was 77 and 81 days; T2, 70 and 76 days; T3, 74 and 76 days; and T4, 70 and 73 days, respectively. These results are similar to those reported by Knowlton (1933) who found that *B. cockerelli* adults are capable of surviving for a long period of time (17 to 96 days), and also with those reported by Vargas-Madríz *et al*. (2011) who mentioned that the duration of the whole cycle (egg-adult) in "Charanda F1" was 63 and 69 days and in "Rafaello" it was 68 and 70 days, respectively. Nevertheless, they do not agree with the results reported by Abdullah (2008), who found that the full lifecycle of *B. cockerelli* is 34 days. Yang & Liu (2009) stated that the complete lifecycle in eggplant is 24 days, and in bell pepper it is 26 days. Yang *et al*. (2010) mentioned that that duration from egg to adult of this insect in the field is 22.4 days, and in the laboratory it is 19.6 days. Wallis (1946) indicated that there is often a great variation from one year to the next in the population densities of *B. cockerelli* found in commercial and non-commercial plants.

The results regarding the durations of egg, nymph, adult, and biological cycle do not agree with some research works done on this insect, as previously mentioned. These differences could be due to the different host plants, varieties used, and environmental conditions where the experiments were carried out. With regard to the results of live adults per treatment, Scriber (1984) indicates that there is an increase in the aphid and mite populations when there is nitrogen fertilization. Also, it has been observed that herbivorous insects associated to the *Brassica* crops show an increase in their populations as a response to increases in the levels of N in the soil (Letourneau, 1988). This is related with the results obtained for live adults per treatment, since the treatment that had the lowest number of adults was T2, as compared against T1. In the case of potassium and calcium, Marschner (1992) mentions that plants with a deficiency of these elements are more susceptible than plants with adequate supply of potassium and calcium. This does not agree with the result obtained in this study, since T3 showed more live adults than did T2 and T4. Likewise, T4 showed more live adults than did T2.

There is often a great variation from one year to the next regarding the numbers in *B. cockerelli* populations found in the host plants, both commercial and non-commercial (Wallis, 1946). It is considered a species that develops according to temperature, this is to say, its lifecycle is affected by extremely cold or extremely hot conditions. List (1939) and Pavlista (2002) stated that exposure for one or two hours to temperatures of 32.2 ºC and 38.8 ºC were lethal, decreasing or stopping oviposition, egg hatching, and the survival of nymphs. Another factor that can influence the behavior of *B. cockerelli* is management of plant fertility, which in turn can affect the abundance of this insect. The application of mineral amendments to the crops has been found to influence the survival of insects (Jones, 1976; Clara & Altieri, 2006). A clear example of this was the results obtained in the survival curves of both cycles, since it was observed that in treatments T2, T3, and T4 there was a moderate mortality of *B. cockerelli* eggs in the first 23 days, while in the nymph stages 1 and 2, there was greater mortality, followed by a lower mortality in the adult stage. There was a similar range in life duration in both cycles in the mentioned treatments. These data agree with those reported by Davis (1937), Liu & Trumble (2006a), Yang & Liu (2009), and Vargas-Madríz *et al.* (2011) who mentioned that adult *B. cockerelli* are capable of surviving for a long period of time, from 17 to 96 days. In the case of *Frankliniella occidentalis* populations, Brodbeck *et al.* (2001) stated that the populations of this insect in tomato crops that receive high ratios of nitrogen fertilization were significantly greater. These results are similar to those observed in the present research, since it was observed that in T1, T3, and T4, there were higher values than did T2, which had a low adult population during the cycle.

B. cockerelli is considered a species that develops according to temperature. This is to say, its lifecycle is affected by extremely cold or extremely hot conditions (Knowlton, 1933; List, 1939). Moreover, there is a variation in the size of populations from one year to the next, depending on the host plants (Wallis, 1946). On the other hand, Huber (1980), Marschner (1992), and Meyer & Root (1993) mentioned that mineral nutrients can increase or decrease plant resistance or tolerance to pests, and also that there is a strong interaction between the impact of insects and soil fertility. This was observed in the parameter of mean life expectancy (e_x), for which the highest values in both cycles were obtained in T1, where the population of *B. cockerelli* lived longest. It was also found that the first stages are the ones that show the greatest life expectancy and a natural tendency to decrease the value of this population parameter as the age of the insect increases. These results are similar to those reported in other studies on life tables in species like *Brevicoryne brassicae* (L.) (Rivera, 1990) and *Dactylopius coccus* (Mendez-Gallegos *et al.* 1993), as well as mean life expectancy of *B. cockerelli* in two tomato varieties under greenhouse conditions (Vargas-Madríz *et al.*, 2011). In these studies, it is mentioned that there is a tendency to decrease the value of this population parameter as the age of the insect increases. On the other hand, Huber & Willhelm (1988) mention that mineral nutrition of the plants can be considered as an environmental factor that can be manipulated with relative ease, although it is not frequently recognized. This factor has also always been an important control component of both pests and disease.

An optimum fertilization that supplies a balance of elements can stimulate resistance to insect attack (Clara & Altieri, 2006), like the increase in soluble N levels in plant tissue can reduce pest resistance; although it is possible that this is not a universal phenomenon (Phelan *et al*., 1995). Likewise, management of soil fertility can influence insect oviposition, growth ratio, survival, and reproduction (Jones, 1976). This could be seen in the results obtained for the reproduction ratios (R_o) of both cycles: February to May and May to August, where the highest reproduction values were found in T1 with 28 and 24.78, respectively; while the lowest values were found in T4 with 7.68 and 11.15, respectively. The dose of T4 was the one that least favored the development of *B. cockerelli* in both cycles. With regard to the intrinsic natural increase ratio (r_m) and the finite increase ratio (l), in the February to May cycle the highest values were those of T1 (0.069 and 1.06) and T2 (0.069 and 1.06), and the lowest values were those of T3 (0.050 and 1.04) and T4 (0.045 and 1.04), respectively. The last two were the ones that least favored the increase of this insect. In the May to August cycle, the highest values of (r_m) and (λ) corresponded to T3 (0.073) and (1.07), followed by T1 (0.064) and (1.06), T2 (0.064) and (1.06), and finally the lowest values of these parameters corresponded to T4 (0.054) and (1.05), respectively. With regard to the results of natality (b) and mortality (d) for the February to May cycle, T2 showed the highest natality value (0.085), being greater than the other treatments; the highest mortality was that of T3 (0.023). In the May to August cycle, the treatment with the highest natality was that of T3 (0.078), while T2 was the treatment with the highest value of mortality (0.014). The obtained results agree with the results found by Yang & Liu (2009), who state that the reproduction ratio, the intrinsic natural increase ratio, and the finite increase ratio differ depending on the host plant. On the other hand, the results of R_o obtained in both cycles for T1, T2, and T3 do not agree with those obtained by Yang *et al*. (2010), Asghar (2011), and Vargas-Madríz *et al.* (2011). Despite the low R_o values found in both cycles of this study, those of T4 were similar to those reported by the mentioned authors. In the case of the intrinsic natural increase ratio (r_m), the results obtained agree with those reported by Asghar (2011) and Vargas-Madríz *et al.* (2011) who obtained a natural increase range of *B. cockerelli* from 0.035 to 0.059 in tomato plants and different potato varieties. They do not, however, agree with the results reported by Yang & Liu (2009), and Yang *et al*. (2010) who give higher natural increase values for this insect, with a range from 0.10 to 0.19 in potato, eggplant, and bell pepper. The results obtained for the finite increase ratio (λ) agree with those obtained by Yang & Liu (2009), Yang *et al*. (2010), Asghar (2011), and Vargas-Madríz *et al.* (2011) who reported a value of 1 for this parameter. With regard to the time of generation (T), the highest value in both cycles was that of T1 (49.72 and 52.86), although it did not show an intrinsic natural increase ratio (r_m) lower than the population (0.069 and 0.064). These results for time of generation are similar to those reported by Yang & Liu (2009), Asghar (2011), and Vargas-Madríz *et al.* (2011) who reported ranges for time of generation going from 40 to 50 days, but they do not agree with those reported by Yang *et al*. (2010) who mentioned lower generation values for this insect, both in the field and in the laboratory. It was also observed in the results from both cycles that as the intrinsic natural increase ratio (r_m) increased, the time of generation (T) decreases, and vice versa. These results are similar to those reported in studies on life tables of *Hippodamia convergens* Guérin (Cervantes, 1989), *Brevicoryne brassicae* L. (Rivera, 1990), and *B. cockerelli* (Vargas-Madríz *et al.*, 2011). As for natality (b) and mortality (d) of *B. cockerelli*, in the February to May cycle, the greatest natality was that of T2 and the greatest mortality was that of T3. For the May to August cycle, the greatest natality was that of T3 and the greatest mortality was that of T2. These results agree with those reported by Vargas-Madríz *et al*. (2011), with a similar tendency in both parameters. Regarding the results obtained for the reproduction ratio (R_o), intrinsic natural increase ratio (r_m), and generation time (T), Scott *et al.* (2005) mention that these life parameters differ among themselves in aphids of the *Aphis glycines* Matsumura species, which feed on soy leaves lacking K from those that feed on leaves not lacking K. These authors state that K deficient treatments showed greater significances in these parameters regarding aphids feeding on non-deficient leaves. They did not, however, observe any significant difference in the time mean of generation (T) between the treatments. This agrees with the observations in the May to August cycle, where T3 showed a higher value than T2 or T4. It is worth mentioning that the value obtained for T3 was not greater than that of T1. On the other hand, Marschner (1992) mention that the tissues of plants with low contents of both potassium and calcium are more susceptible than the tissues of plants with normal potassium and calcium levels. This did not reflect on the results of the life parameters of *B. cockerelli* obtained in this study, since T3 and T4 did not show greater values in these parameters, with regard to the treatment with normal levels of potassium and calcium.

Adult *B. cockerelli* reach reproductive maturity within 48 hours after hatching; females are mature right after hatching while males take a day to reach maturity. Oviposition generally begins 2 days after mating according to Guedot *et al*. (2012). Oviposition of psyllids is on the edge or underside of the leaves (Knowlton & Janes, 1931; List, 1939; Pletsch, 1947). The fertility of *B. cockerelli* was observed in four cohorts in the periods from February to May and from May to August, with the following results: in T1, reproduction began after 30 and 35; in T2, at 32 and 30; in T3, at 31 and 29; and in T4, at 31 and 30 days of age, respectively. The longest fertility period was found in T1, as well as the greatest oviposition. These results agree with those reported by Vargas-Madríz *et al*. (2011) who state that *B. cockerelli* begins its reproduction at 34 days of age on the “Charanda F1” variety and at 36 days on “Rafaello” in the October to December cycle in 2009 and the January to March cycle in 2010. These authors mentioned that this insect begins reproduction at 41 days of age in plants under greenhouse conditions. On the other hand, Mittler (1958) commented that the maturity ratio of aphids is more successful in plants with greater nitrogen content. This was seen in the case of *B. cockerelli* in T1 and T3, with regard to T2. However, in T4, this phenomenon was not observed; this last treatment being the one that showed the lowest fertility and oviposition in both cycles. With regard to the period of oviposition, it was 35 days in the February to May cycle, and 43 days in the May to August cycle. These results are similar to those reported by Yang & Liu (2009), who mention that the oviposition period of this insect on eggplant is 53.4 days long, and in bell pepper it lasts 47.0 days. On this, Asghar (2011) mentions that the oviposition period in different potato varieties is within a range from 18.25 to 20.10 days, while Vargas-Madríz *et al*. (2011) mention that the oviposition period of *B. cockerelli* during the October to December cycle in 2009 lasted 42 days, and during the January to March cycle in 2010, it lasted 34 days in tomato varieties under greenhouse conditions. The results obtained for fertility and oviposition do not agree with those reported by Chow *et al.* (2009) who mentioned that nitrogen deficiency in rose bushes favored an increase in pre-oviposition and development time in the *Tetranychus urticae* Koch. mite, while the oviposition ratio increased. The contrary was observed in the present study, since T2 only presented greater values than T4 but not so when compared against T1.

B. cockerelli possesses ample capacity to increase its population density, since the female can lay up to 1400 eggs in its lifetime (Knowlton & Janes, 1931). Most studies report increases in the number of insects as a response to the increase in the nitrogen fertilization ratios (Scriber, 1984). According to Van Emden (1966), the increase in the fecundity and development ratios of the *Myzus persicae* green aphid is strongly linked with the increase in the levels of soluble N in leaf tissues. This is related with the results obtained on accumulated egg fertility, average number of eggs per female, and number of females in the February to May cycle, where the treatment with the greatest fertility was T1, with 5939 eggs per cycle, as well as a greater number of females, with a total of 92. Nevertheless, the highest average of eggs per female was that of T3 with a total 80.72 eggs per female. In the cycle from May to August, the treatment that showed the highest accumulated egg fertility, average eggs per female, and number of females was T1, with a total 4955 accumulated eggs, average eggs per female of 68.81, and 72 females per cycle. The results of accumulated egg fertility obtained in T4 agree with those reported by Vargas-Madríz *et al*. (2011) who mentioned that in the fertility table of *B. cockerelli* in the “Charanda F1” and “Rafaello” tomato varieties for the 2009 and 2010 cycles, accumulated egg sums were found of 3,426 and 3,200 for “Charanda F1”, and 2,142 and 2,099 for “Rafaello”. With regard to the average number of eggs per female, the results obtained are within the ranges reported by Lehman (1930) and Asghar (2011). These authors mentioned that the average number eggs per female can reach from 47.20 to 65. However, the results do not agree with those reported by Abdullah (2008), Liu & Trumble (2006a), Yang & Liu (2009), and Yang *et al*. (2010) who reported higher numbers of oviposition per female, in a range from 147.5 to 1400. On the other hand, the results of females per cohort do not agree with those reported by Vargas-Madríz *et al*. (2011) who mentioned that the number of females for the 2009 and 2010 cycles in “Charanda F1” and “Rafaello” tomato varieties were 117 and 131, and 108 and 118, respectively, evidencing a greater number of females than those reported in this study. According to this, it could be mentioned that T4 least favored the survival and reproduction of the *B. cockerelli* population, also showing lower values for reproduction ratio (R_o), intrinsic natural increase ratio (r_m), time of generation (T), and finite increase ratio (λ). It is possible to infer that calcium probably affects the biology of *B. cockerelli* when the insect reproduces or feeds with this dose of fertilization in the plant. From the results obtained in the four treatments, T1 was found to be the most adequate for the development of *B. cockerelli*, since it showed the highest values for the life parameters evaluated. To this regard, Morales & Carmeli (2001) stated that the preference of oviposition and development of an insect, on a determined host plant, is influenced by age and the environmental conditions in which the crop is grown. Wilson (1994) mentions that adult females of the two spotted mite have a lineal relationship with the nitrogen available in the leaves, and as the concentration of nitrogen increases development is faster and oviposition is greater. These results are similar to those found in the present study, since T1 showed the best development of *B. cockerelli*.

CONCLUSIONS

The lifecycles of *B. cockerelli* in both cycles of the study (February to May and May to August, 2012) were less favorable in the treatment with 25% calcium, lasting 70 and 73 days, respectively. The females can lay an average 2927 and 3613 eggs in the whole cycle, respectively, while each female can lay an average 41.81 and 54.74 eggs in its lifetime. The oviposition timescales of the females were 39 and 43 days, respectively. Moreover, in this same treatment, the mean life expectancy (e_x), ratio of reproduction (R_o), intrinsic natural increase ratio (r_m), and finite increase ratio (λ) were lower than in all the other treatments, it is considered that this element alter / affect the biologic cycle of *B. cockerelli* in both cycles.

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