Developmental Biology and Population Studies on the *Citrus* Psylla *Trioza erytreae* (Del Guercio) *(Hemiptera: Triozidae)*

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Biologie du développement et études des populations du psylle des agrumes *Trioza erytreae* (Del Guercio) *(Hemiptera: Triozidae).*

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RESUME - A une température journalière moyenne de 20,8 °C, les œufs de *Trioza erytreae*, le psylle africain des agrumes, éclosent au bout de 7 jours et le déroulement du cycle larvaire s'effectue en 18 à 23 jours. Les taux d'abondance de population au champ dans la région de Hazyview augmentent ou diminuent quand les rapports de pullulation entre les œufs, les larves et les adultes augmentent ou diminuent dans des proportions 15:13:1. La valeur K entre les comptages d'œufs et de larves a été estimée à 0,55, et entre les larves et les adultes à 0,63. Une mortalité générale (K total) a été enregistrée à 1,18.

Dans la région de Nelspruit, les populations de psylles observées étaient inféodées à des agrumes non traités pendant la plus grand partie de l'année sauf de la mi-novembre à la fin décembre. Par ailleurs, *T. erytreae* a été trouvé régulièrement dans la végétation naturelle sur *Clausena anisata*, une rutacée indigène, en période de développement végétatif de cette espèce, c'est-à-dire de fin octobre à début de décembre, soit à la suite de la poussée printanière normalement enregistrée sur agrumes. L'effet "relais" de *C. anisata* signifie que *T. erytreae* peut se développer abondamment toute l'année lorsque les plants d'agrumes sont cultivés à proximité de massifs forestiers hébergeant *C. anisata*. En conclusion, il convient d'éviter la présence de cette rutacée africaine à proximité des vergers.

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ABSTRACT - At a daily mean temperature of 20.8°C, *Citrus* psylla eggs hatched after 7 days and the nymphal stage was completed within 18 to 23 days. Field populations in the Hazyview area were either rising or declining when the egg/nymph/adult ratios increased above or declined below about 15:13:1 respectively. The K-value between the egg and nymph counts was 0.55 and between the nymph and adult counts 0.63. A general mortality (total K) was 1.18.

In the Nelspruit area, *Citrus* psylla were present on unsprayed *Citrus* trees for most of the year, excepting from mid-November to the end of December. On the other hand, psylla were only present on *Clausena anisata*, an indigenous host plant, when it had developing leaves i.e. between late October and early December. This means that if *Citrus* and *C. anisata* grow near each other, *Citrus* psylla will be able to breed and increase in numbers throughout the year. It is suggested that *C. anisata* should be removed if it grows in the proximity of *Citrus* orchards.

KEYWORDS: *Citrus, Clausena, Psyllidae, Triozidae,* entomology, pests of plants, biology, population changes.

MOTS CLES : *Citrus, Clausena, Psyllidae, Triozidae,* entomologie, ravageur des plantes, biologie, évolution de la population.

Introduction

For many years the *Citrus* psylla, *Trioza erytreae* (Del Guercio) *(Hemiptera: Triozidae)* was considered to be a minor *Citrus* pest (LOUNSBURY, 1897; VAN DER MERWE, 1923). However, its status was raised to that of a major pest after MCCLEAN and OBERHOLZER (1965) reported that the adult is a vector of the greening disease of *Citrus* in South Africa. Trees severely affected with greening are stunted and produce fruit which fail to ripen and, if processed, impart an objectionable bitter-salty flavour (OBERHOLZER *et al.*, 1965). The importance of greening was emphasised when approximately 100 000 sweet orange trees were rendered commercially unprofitable in South Africa (OBERHOLZER *et al.*, 1965).

The *Citrus* psylla is indigenous to Africa and has been found in many countries on the continent, from the Cape Province, South Africa in the south (LOUNSBURY, 1897) to Eritrea, Ethiopia in the north-east (DEL GUERCIO, 1918) and Cameroon in the west (AUBERT *et al.*, 1988). It has also been reported in the islands of St. Helena (WALLACE, 1960), Mauritius (MAMET, 1955), Madagascar (BRENIERE et DUBOIS, 1965) and Réunion (MOREIRA, 1967). This pest seems to be spreading further north and was recently reported in North Yemen (BOVÉ et GARNIER, 1984), Saudi Arabia and the Yemen Arab Republic (BOVÉ, 1986) in the Palearctic region.

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Significant positive correlations were found (VAN DEN BERG *et al.*, 1991a) between numbers of *Citrus* psylla adults, eggs and nymphs in an unsprayed *Citrus* orchard. Furthermore, increases in minimum temperature and minimum relative humidity matched increases in numbers at all stages of the psylla.

The aim of the present work was to study the developmental biology of the *Citrus* psylla and mortality that occurs during the developmental process.

Materials and methods

Developmental biology

10 psylla females were placed on each of 10 *Citrus* seedlings in an insectary at 22 ± 1.5 °C (day, 14 h) and 19 ± 1.5 °C (night, 10h) (mean 20.75 °C) and 80% RH. After 2 h, when eggs had been laid, the psylla were removed and the eggs inspected daily.

Nymphs that hatched were allowed to settle on the young leaves. All but 40 nymphs were removed so that the position of each nymph could be recorded and identified without disturbing them. The position, movement and moulting of each nymph was studied once daily until they reached the adult stage. The sex of each adult was determined microscopically.

Population studies at Burgershall

An experimental orchard 80 x 60 m, containing about 200 *Citrus* trees (Valencia) 1 to 1.5 m high, planted in four rows 15 m apart with 19 500 *Citrus* seedlings of similar height between the trees, was situated on the Burgershall Experimental Farm, Hazyview area, eastern Transvaal (25° 07' S, 31° 05' E). Flush formation was encouraged by irrigating and fertilizing the plants regularly, providing additional nitrogen, and by pruning side branches approximately every second month. No insecticides were used. The experiment was conducted from August 1987 to February 1990, at which time trees and most seedlings were infected with greening. No other *Citrus* or alternative host plants grew within 1 km of the orchard.

To estimate psylla population density, 100 seedlings were marked so that corner trees, 32 border trees and 64 other trees formed a grid with rows about 9 m apart and trees spaced at 6.6 m intervals. At approximately weekly intervals, adults on these trees were counted *in situ*. Thereafter, eggs and nymphs were counted using a 10 x magnifying lens. Egg and nymph numbers in excess of 50 per tree were estimated. This information was used to estimate the mean number of each *Citrus* psylla stage present during a count.

Population studies at Nelspruit

This study was carried out in an experimental *Citrus* orchard at the Institute for Tropical and Sub-tropical Crops, Nelspruit (25° 27' S, 30° 58' E). The orchard consisted of 50, 2-year-old Valencia trees which were irrigated regularly but no pesticides were sprayed on them. Ten of these trees were chosen at random and marked for observation.

Approximately 3 ha of indigenous trees and shrubs were situated 350 m north of the experimental orchard. This vegetation included three host plants of which the false horsewood, *Clausena anisata* (Willd). Hook. f. ex Benth., was the most abundant. 10 false horsewood trees approximately 1 m high were chosen at random and marked.

All stages of the *Citrus* psylla present on the marked *Citrus* and horsewood trees were counted every fortnight from 27 February 1986 to 4 March 1987 as described earlier. At the same time intervals, the presence of developing leaves that could be used as breeding sites by *Citrus* psylla were also recorded.

Results and discussion

Developmental biology

At a daily average temperature of 20.8 °C, *Citrus* psylla eggs hatched after 7 days. There were no statistical differences between developmental times of male and female nymphs (table 1). The nymphal stage was completed within 17 to 23 days (mean just less than 20 days).

The developmental times of eggs and nymphs and the age of psylla leaving the seedlings (VAN DEN BERG and DEACON, 1989) were combined to indicate the time each stage spent on the trees (figure 1). Adults stayed on the trees from less than 1 day to more than 16 days. *Citrus* psylla were thus present on the trees from 25 to more than 46 days.

Table 1. Comparison of the duration of development of 11 males and 22 females *Citrus* psylla nymphs in days.

Instar	Duration in days (± standard error)	
	Males	Females
1	5.0 (±0.1)	5.1 (±0.1)
2	2.3 (±0.1)	2.4 (±0.1)
3	2.6 (±0.2)	2.7 (±0.1)
4	3.2 (±0.1)	3.6 (±0.1)
5	6.3 (±0.2)	6.1 (±0.1)
Total	19.4 (±0.1)	19.9 (±0.1)

There were no significant differences between the means for males and females at $p \leq 0,05\%$.

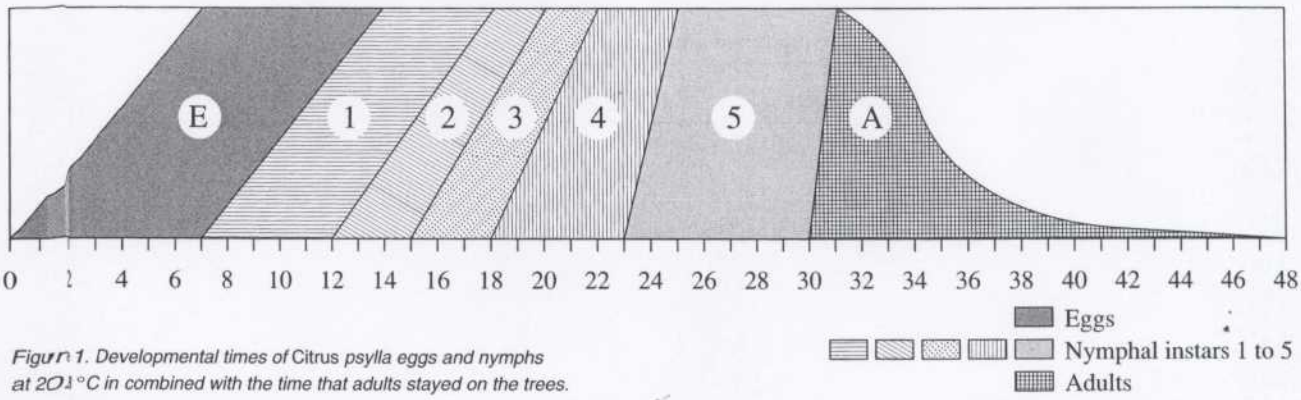

Figure 1. Developmental times of Citrus *psylla eggs and nymphs at 20±1°C in combined with the time that adults stayed on the trees.*

Population studies at Burgershall

From the total weekly counts of *Citrus* psylla present on the 100 marked *Citrus* seedlings at Burgershall over 29 months, three periods where chosen when adults, eggs and nymphs were found to increase in numbers for 8 consecutive weeks. The numbers present during the corresponding weeks of these periods were added together and are presented in figure 2a. Similarly, three 8 week periods when total numbers stayed relatively constant (figure 2b) or decreased (figure 2c) were selected. Figure 2 clearly shows that egg and nymph populations were almost the same size and that adults in all cases were outnumbered by the other stages.

Numbers of *Citrus* psylla at the different stages counted over 29 months are summarized in table 2. When the ratios of eggs, and nymphs to adults increased above about 15:13:1, the population was rising, e.g. 20:17:1 (table 2.2) and 18:14:1 (table 2.1, when also rising slightly). The population was more or less constant when the ratios were about 15:13:1 (table 2.3). When the ratios declined below about 15:13:1, the population was declining (14:10:1, table 2.4). We calculated that about 845 000 eggs, 682 000 nymphs and 48 000 adults were present on this 0.48 ha *Citrus* orchard during an average count.

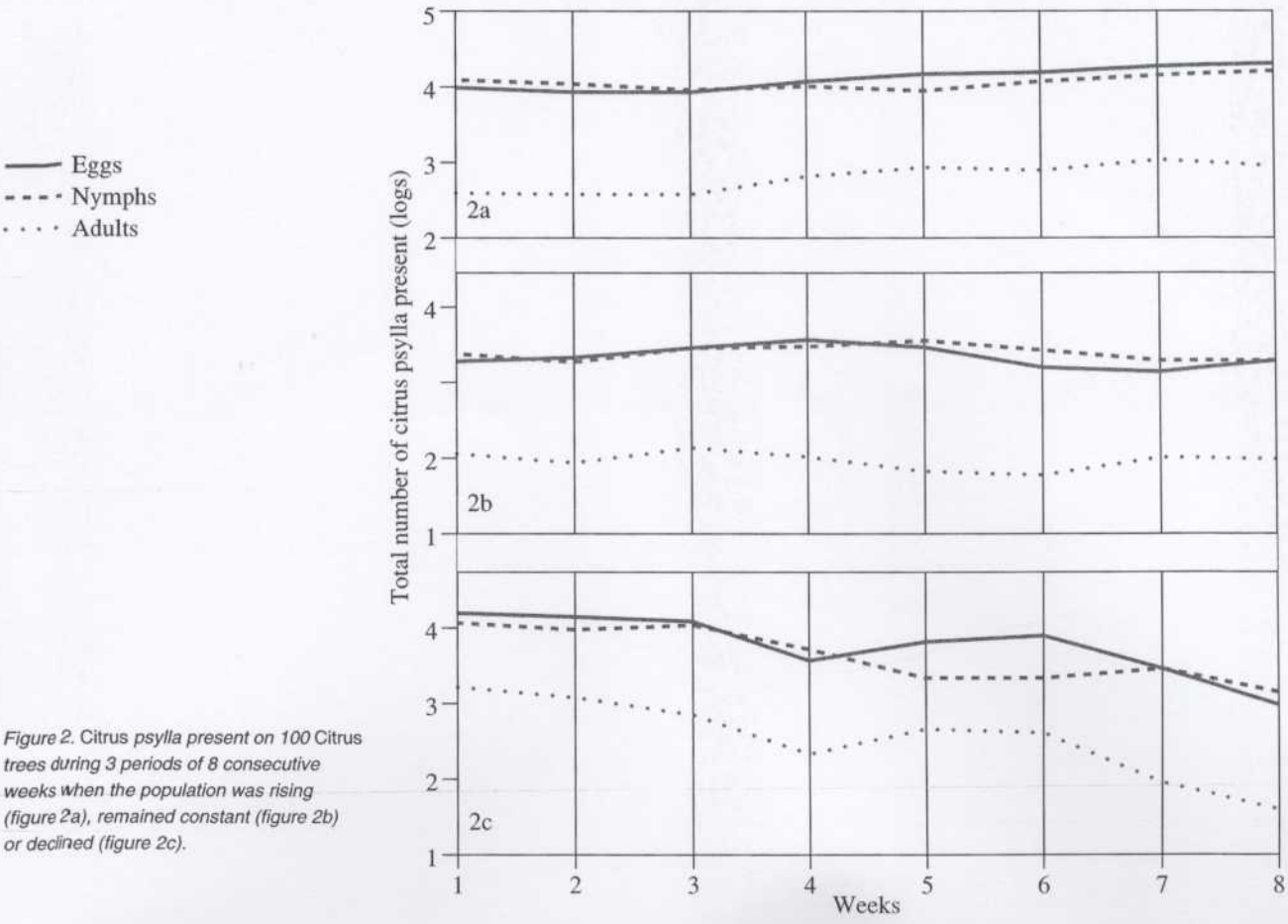

Figure 2. Citrus *psylla present on 100* Citrus *trees during 3 periods of 8 consecutive weeks when the population was rising (figure 2a), remained constant (figure 2b) or declined (figure 2c).*

Table 2. Numbers of *Citrus* psylla eggs, nymphs and adults on 100 *Citrus* seedlings at Burgershall.

Period	Eggs	Nymphs	Adult
1. Total numbers counted over 29 months (population rising slightly)			
Total numbers	531 801	428 934	29 898
Ratio	17.79	14.35	1
2. Three periods of 8 weeks each when population was rising			
Total numbers	129 960	111 071	6 588
Ratio	19.73	16.86	1
3. Three periods of 8 weeks each when population was more or less constant			
Total numbers	37 914	33 066	2 570
Ratio	14.75	12.87	1
4. Three periods of 8 weeks each when population was declining			
Total numbers	70 935	51 304	5 171
Ratio	13.72	9.92	1

To compare the numbers of the different stages each was multiplied by x/y, where x = number of days between counts (= 7) and y = developmental time or average age when adults leave the trees. The developmental time for eggs was determined to be 7 days and that for nymphs 20 days. Adults leave the trees after a mean period of 6 days (VAN DEN BERG and DEACON, 1989). Calculations for the total number of adults, nymphs and eggs counted over 29 months are given in table 3. The K-value between the egg and nymph counts was 0.55 (table 3) and between the nymph and adult counts 0.63 with a generation mortality (total K) of 1.18. The successive percentages of mortality that occurred between eggs and nymphs and nymphs and adults were similar, both above 70 %. This indicates that high mortality occurred throughout the life cycle. These mortalities can be attributed to:

– the infertility of some eggs: according to VAN DEN BERG *et al.*, (1991c) this represents approximately 4.1% of the eggs;
– the effect of low humidity and high temperature (termed saturation deficit) that may sometimes occur on eggs and first instar nymphs;
– predation of all stages;
– paritization of nymphs;
– fungus diseases causing mortality;
– natural mortality.

Population studies at Nelspruit

The total fortnightly numbers of *Citrus* psylla eggs, nymphs and adults counted on *Citrus* from 27 February 1986 to 4 March 1987 are given in figure 3a and those on *C. anisata* in figure 3b. Sharp increases or declines in egg numbers were generally followed by respective increases and collapses in the entire populations (figure 3a and 3b). The egg stage may therefore possibly be used to indicate population increases or declines. However, since the egg stage is very vulnerable when high temperatures are combined with low humidities (GREEN and CATLING, 1971), population fluctuations of the egg stage should be studied with this knowledge and over a long period.

The numbers of psylla on both *Citrus* and *C. anisata* were relatively high over short periods, whereas no individuals were found during certain periods of the year. On *Citrus*, the *Citrus* psylla population remained high during most of the year, except towards the end of November and during December 1986, and at the beginning of March 1987 (figure 3a). On the other hand, the psylla population on *C. anisata* was declining in late February 1986 when the experiment started, and it peaked when trees had developing leaves, i.e. between the end of October and the beginning of December 1986 (figure 3b). Psylla thus peaked on *C. anisata* at the time when psylla numbers were declining or completely absent on *Citrus* trees. This means that if *Citrus* and *C. anisata* grow near each other, *Citrus* psylla will be able to breed and increase their numbers throughout the year. This would not be the case when only one host plant is present. According to VAN DEN BERG and DEACON (1988) *Citrus* psylla adults are able to disperse to a distance of at least 1.5 km. Furthermore, VAN DEN BERG *et al.*, (1991b) found that there was continuous movement of *Citrus* psylla between an unsprayed *Citrus* orchard and adjacent indigenous vegetation. It is therefore evident that in areas where *Citrus* is grown near *C. anisata*, the *Citrus* psylla population will probably be higher than in areas where either *Citrus* or *C. anisata* grows. This suggests that *C. anisata* should be removed if it grows in the proximity of *Citrus* orchards, which supports earlier recommendations (VAN DER MERWE, 1923; VAN DEN BERG *et al.*, 1991b, 1992).

Table 3. Population change and age-specific mortality of the *Citrus* psylla, *Trioza erytreae* in a *Citrus* orchard over 29 months.

	Eggs	Nymphs	Adults
Total numbers	531 801	428 934	29 898
Chance of being counted	7/7	7/20	7/6
Relative number	531 801	150 127	34 881
Population	1 000	282	66
Number of dying in interval	718	216	Total = 934 dead
% Mortality	71.8	21.6	Total = 93.4 % dead
Successive % mortality	71.8	76.6	
Log population	3	2.45	1.82
K-value	0.55	0.63	Total: K = 1.18

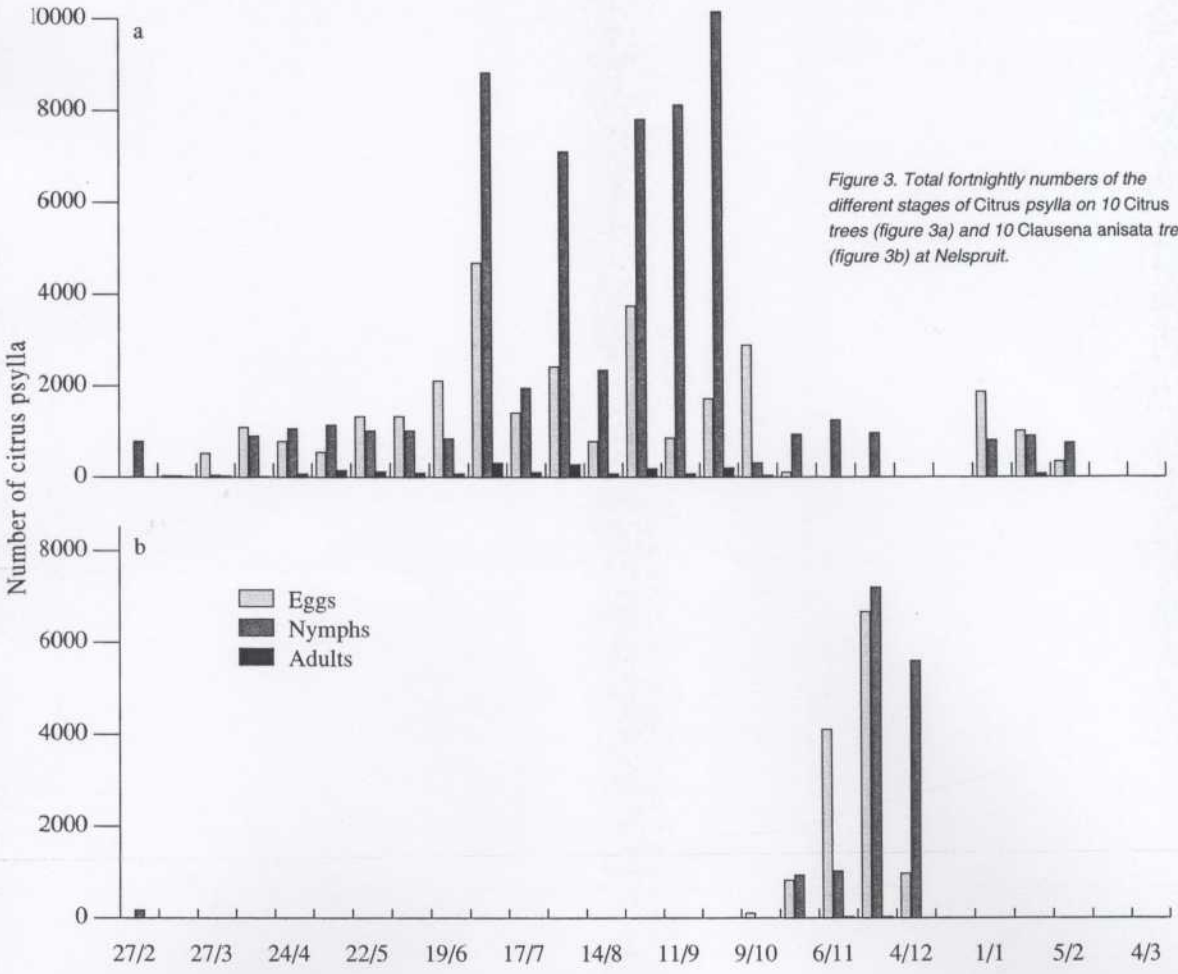

Figure 3. Total fortnightly numbers of the different stages of Citrus *psylla on 10* Citrus *trees (figure 3a) and 10* Clausena anisata *trees (figure 3b) at Nelspruit.*

Conclusions

In a *Citrus* orchard, populations of the *Citrus* psylla seemed to be rising or declining when the ratios of eggs, and nymphs to adults increased or declined above about 15:13:1 respectively.

If *Citrus* is grown near indigenous horsewood trees, *Clausena anisata*, *Citrus* psylla could breed and increase their numbers throughout the year. This suggests that *C. anisata* should be removed if it grows in the proximity of *Citrus* orchards.

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Biología del desarollo y estudios de las poblaciones del psylla de los cítricos *Trioza erytreae* (del Guercio) (Hemiptera: Triozidae).

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RESUMEN - A un promedio de temperatura diaria de 20,8 °C las larvas de *Trioza erytreae*, el psylla africano de los cítricos nacen a los 7 días y el ciclo larvario se cumple en 18 a 23 días. Los niveles de abundencia de población en el campo en la región de Hazyview aumentan o disminuyen cuando las razones de pululaciones entre huevos, larvas y adultos aumentan o disminuyen en las proporciones 15:13:1. El valor K entre la cuenta de huevos y de larvas ha sido estimada a 0,55 y entre las larvas y los adultos a 0,63. Una mortalidad general (total) ha sido notada a 1,18.

En la región de Nelspruit, las poblaciones de psylla observadas eran infeudadas a cítricos sin tratamiento la mayor parte del año salvo desde la mitad de noviembre hasta el fin de diciembre. Por otro lado, *Trioza erytreae* ha sido regularmente encontrado en la vegetación natural sobre *Clausena anisata*, una rutácea indígena, en período de desarollo vegetativo de esa especie, es decir desde el fin de octubre a principio de diciembre, o sea después del desarollo primaveral normalmente observado en los cítricos. La sustitución momentanea de los cítricos por *Clausena anisata* significa que *Trioza erytreae* puede desarollarse abundamente todo el año cuando los cítricos son cultivados cerca de bosques con *Clausena anisata*. En conclusión, es conveniente evitar la presencia de esta rutácea africana a proximidad de los huertos.

PALABRAS CLAVES : *Citrus, Clausena, Psyllidae, Triozidae*, entomología, plaga de plantas, biología, evolución de la población.