

# The development of the citrus psylla, *Trioza erytreae* (Del Guercio) (Homoptera: Psyllidae), on *Citrus limon* and four indigenous host plants

by

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## SUMMARY

The nymphal development of the citrus psylla, *Trioza erytreae* (Del Guercio) was followed on five different host plants in the family Rutaceae. Development was compared on *Citrus limon* (rough lemon) and four indigenous hosts, namely, *Vepris undulata*, *Clausena anisata*, *Fagara capensis* and *Calodendrum capense*. The suitability of these hosts for development of the psyllids was gauged (i) by the sizes attained by the nymphs, (ii) by the durations of the nymphal instars and (iii) by the mortalities of the nymphs on each host plant. It was concluded that *V. undulata* and *Cl. anisata* were most suitable for development of *T. erytreae* and that these plants are probably among the original indigenous hosts. *Ci. limon* and *F. capensis* were less suitable for development but still adequate, whereas *Ca. capense* was found to be entirely unsuitable.

## INTRODUCTION

The citrus psylla, *Trioza erytreae* (Del Guercio), is a pest of commercial citrus and is only known from Africa, Madagascar, St. Helena and Mauritius (Anon., 1967). Citrus is an introduced crop in Africa and therefore *T. erytreae* must have invaded citrus secondarily from some indigenous host plant or plants. Both Harris (1936) and Van der Merwe (1941) have noted that *T. erytreae* is found on several different species of indigenous host plants within the family Rutaceae, indicating that this psyllid is oligophagous (see Thorsteinson, 1960; Schoonhoven, 1968). Van der Merwe records further that all varieties of citrus are attacked and that among indigenous hosts *Vepris undulata*, *Clausena anisata* (*inequalis*) and *Fagara capensis* have been found to be infested and that they "are probably among the original food plants".

This paper, which should be read in conjunction with the companion paper (Moran, 1968, *vide infra*), is an attempt to establish which is the original indigenous host plant or plants of *T. erytreae* in southern Africa. The development of the immature stages of *T. erytreae* on citrus and four indigenous hosts is used as a criterion of host plant suitability. Data are presented on the mortalities, instar durations and sizes realized by the immature stages of *T. erytreae* on the different hosts. (The responses of the adult insects to these hosts, is the subject of the companion paper, *vide infra*). The reservoir of citrus psylla in the vegetation surrounding citrus orchards may be responsible for the

rapid reinfestation of the crop, very soon after insecticides have been applied. Therefore, an understanding of the indigenous reservoir of *T. erytrae* has a direct bearing on the planning and execution of effective control measures against this pest in citrus orchards.

## MATERIAL AND METHODS

A culture of *T. erytrae* was maintained on potted seedlings in an environment room under controlled conditions of fluctuating temperature, humidity and light, as described by Moran & Blowers (1967). All the data contained in this investigation were derived from experiments conducted in the environment room at a temperature regime of four hour degrees Centigrade per day above 20°C and 38 hour degrees Centigrade per day below 20°C. Females of *T. erytrae*, together with several males, were confined in perforated plastic bags on seedlings and left to lay for 24 hours. After this time all the psyllids were removed from the plants. As each nymph hatched it was given a number and its position recorded on a map of the leaf. Each nymph was measured daily using a micrometer eyepiece in a stereo-microscope, and records obtained of instar durations and size increases at the moult and inter-moult periods. Measurements were made of nymphal lengths and breadths as these give the best indication of size increases in these extremely flat insects. In the account that follows, only lengths of the nymphs are given for nymphal breadths add nothing to the general conclusions drawn.

Means, standard deviations and standard errors were calculated for each set of data points. The standard errors given with each set of data in the tables, were used to determine whether or not size differences or durations were significantly different. In any particular case, an average was calculated for the two means in question and the null hypothesis made that the two means were not significantly different. Three standard errors were then added to or subtracted from the means and if the resultant figures, in each case, did not overlap the average of the means then the null hypothesis was rejected. Actual probabilities were not calculated but where two means are said to be significantly different  $p$  in every case is less than 0.001.

The development of immature stages of *T. erytrae* on five different host plants in the family Rutaceae was compared. The host plants used were *Citrus limon* (L.) Burm. f. (rough lemon) and the indigenous species, *Vepris undulata* (Th.) Verdoorn et Sm., *Clausena anisata* (Willd.) Hook. f. ex Benth., *Fagara capensis* Thunb., and *Calodendrum capense* (L. f.) Thunb. In each set of experiments several seedlings were used to eliminate possible effects of individual plant variation. All the seedlings used were flushing vigorously and were watered and fertilized regularly.

The choice of these host plants was dictated by the following considerations. Phillips (1951) lists 21 genera in the family Rutaceae. Of these, 12 genera comprise small leafed, ericoid species, occurring mostly in exposed heath communities, and these are unsuitable as hosts for *T. erytrae*. Of the nine broad-leafed genera, which would be likely hosts of *T. erytrae*, four genera are either not represented in South Africa, or are very locally distributed. The situation with the remaining five genera in the family is as follows: (a) the genera *Clausena* and *Calodendrum* are each represented by only one species in South Africa, namely, *Clausena anisata* and *Calodendrum capense*; (b) the genus *Vepris* has two South African species of which *V. undulata* was chosen for study because it is most common and widespread in distribution; (c) there are four species of *Fagara* in South Africa and of these *F. capensis* was chosen as it is the most common and widespread; *F. davyi* is also a fairly widely distributed plant, and although it might be a very suitable host for *T. erytrae* it was not considered in this investigation because it

does not occur locally; (d) lastly, *Teclea natalensis* is also a possible host of *T. erytreae* but was excluded because it too was not available locally.

## RESULTS

### The effect of host plant on the sizes attained by the nymphs of *T. erytreae*

The lengths of the nymphs of *T. erytreae* on each of the five host plants, at the start and end of the instars, together with standard errors and the number of readings on which the calculations are based, are contained in Appendix 1. Table 1 gives an extract of these data.

TABLE 1. — Mean lengths (in mm) of *T. erytreae* nymphs at the end of each instar, when reared on five different host plants.

Host Plant	1st Instar	2nd Instar	3rd Instar	4th Instar	5th Instar
<i>Citrus limon</i> . . . . .	0.37	0.50	0.73	1.04	1.54
<i>Vepris undulata</i> . . . . .	0.41	0.52	0.75	1.07	1.60
<i>Clausena anisata</i> . . . . .	0.39	0.53	0.76	1.09	1.62
<i>Fagara capensis</i> . . . . .	0.40	0.54	0.74	1.05	1.55
<i>Calodendrum capense</i> . . . . .	0.38	0.50	0.69	1.04	1.56

Eggs of *T. erytreae* were measured and it was found that eggs of similar size (mean lengths  $0.28 \pm 0.001$  mm, based on 60 measurements) were laid on all the host plants. The data in Appendix 1 show, however, that there was a notable difference in the length of the first stage nymphs on emergence from each of the five different host plants. Although these differences are very small, it does suggest that the developing embryos in the eggs were gaining differing amounts of nutriment from each of the plants, and that sizes of the psyllids on emergence were dependent on the species of host plant. Although clearly requiring further evidence, this assumption is not implausible in view of the suggested absorptive function of the egg stalk in *T. erytreae* (Blowers & Moran, 1967).

Table 1 and Appendix 1 show that the differences in length of the first instar nymphs at the end of the instar, on the five different host plants, became more pronounced during the later instars. The sizes attained by the later instar nymphs of *T. erytreae* reared on *Ci. limon* and *Ca. capense* were very similar, and in all cases (except for the fifth stage on *Ca. capense*, the measurements of which were based on only one individual), were less than the sizes attained on the other three host plants. Nymphs reared on *F. capensis* were as large at the end of the first, second and third instars as their counterparts on *Cl. anisata* and *V. undulata*, but those on the latter two plants were larger in the last two instars. These size differences, although very small, were statistically significant.

The citrus psylla did not survive to the adult stage when reared on *Ca. capense*. Of the adults which did survive on the other four host plants, those from *F. capensis* were

smaller than those from *Ci. limon*, and both groups of adults were much smaller than the adults from *V. undulata* and *Cl. anisata*. Adults reared from nymphs on *V. undulata* were slightly larger than those from *Cl. anisata*. The actual measurements of the adults from these four host plants are presented in Table 2.

TABLE 2. — Lengths (in mm) of *T. erytreae* adults, measured immediately after the moult to the adult stage, from insects reared on four different host plants.

	<i>Citrus limon</i>		<i>Vepris undulata</i>		<i>Clausena anisata</i>		<i>Fagara capensis</i>	
	♂	♀	♂	♀	♂	♀	♂	♀
No. readings . . . . .	32	36	10	13	9	17	0	8
Minimum length . . . . .	1.88	1.88	2.19	2.56	1.88	2.06	—	1.88
Maximum length . . . . .	2.50	2.50	2.50	2.88	2.56	2.63	—	2.25
Mean length . . . . .	2.17	2.24	2.39	2.66	2.26	2.36	—	2.13
Standard error . . . . .	0.03	0.03	0.04	0.03	0.07	0.04	—	0.04

#### The effect of host plant on nymphal instar durations in *T. erytreae*

The mean instar durations of the immature stages of *T. erytreae* on the five rutaceous host plants, together with maximum and minimum durations, standard errors, and the number of readings on which the calculations were based, are recorded in Appendix 2. Table 3 presents an extract of these data.

TABLE 3. — Mean developmental durations (in days) of the immature stages of *T. erytreae*, from insects reared on five different host plants. The mean total developmental durations are also given.

	Egg	1st instar	2nd instar	3rd instar	4th instar	5th instar	Mean Total
<i>Citrus limon</i> . . . . .	9.5	7.6	4.4	4.1	4.4	7.3	37.0
<i>Vepris undulata</i> . . . . .	11.0	4.1	3.2	3.9	3.9	6.2	31.5
<i>Clausena anisata</i> . . . . .	9.0	7.0	3.3	3.6	3.6	6.9	33.2
<i>Fagara capensis</i> . . . . .	10.6	5.1	3.4	4.0	4.9	8.2	36.0
<i>Calodendrum capense</i> . . . . .	10.1	10.4	7.8	5.0	5.0	9.0	45.0

The durations of the egg stage were significantly different (see standard errors in Appendix 2) when the eggs were allowed to develop on different host plants. Table 3 shows that the shortest duration for the egg stage was recorded for eggs laid on *Cl. anisata* (9.0 days), and the longest incubation period was recorded from eggs laid on *V. undulata* where the mean egg duration was 11.0 days.

The data in Table 3 and Appendix 2 show also that the mean durations of the egg stage, on different host plants, were inversely related to the mean durations of the first instar. Thus, except for the case of *Ca. capense* which is an unsuitable host, the longer the duration of the egg stage, the shorter the duration of the first stage. This suggests that the first stage nymphs may have been emerging from the eggs at a different stage of maturity, depending upon the host plant on which they were laid. These data lend further support to the supposition, already outlined from information on the sizes of the first stage nymphs on emergence, that substances of importance to the development of the embryonic psyllids were entering the eggs through the egg stalks.

The instar durations of second to fifth instars of *T. erytrae*, recorded in Table 3 and Appendix 2, showed considerable variation depending upon the host plant on which the psyllids were reared. The developmental durations on *Ci. limon* and *F. capensis*, and the mean total durations, were very similar, but were significantly longer than those for insects reared on *V. undulata* and *Cl. anisata*. The developmental durations of the citrus psylla reared on *V. undulata* and *Cl. anisata* were very similar during the later instars although the mean total development time was significantly shorter on *V. undulata* than on *Cl. anisata*. Instar durations on *Ca. capense* were excessively prolonged.

#### Nymphal mortalities of *T. erytrae* on different host plants

Records were kept of the numbers of losses and deaths among the nymphs of *T. erytrae* on the five different host plants. A death was recorded when the corpse of the psyllid nymph was found shrivelled in its mapped position on the leaf; a loss was recorded when the insects were not found and were presumed to have dropped off the plant and died. Losses were recorded only when a thorough search of the plant failed to reveal the missing nymph. These data are presented in Table 4.

TABLE 4. — Percentage deaths and losses recorded for nymphs of *T. erytrae* on five different host plants. For further explanation see text.

	No. of readings	% Losses	% Deaths	Total %
<i>Citrus limon</i> . . . . .	90	6.9	3.6	10.5
<i>Vepris undulata</i> . . . . .	29	6.6	3.3	9.9
<i>Clausena anisata</i> . . . . .	39	36.0	0	36.0
<i>Fagara capensis</i> . . . . .	20	45.0	15.0	60.0
<i>Calodendrum capense</i> . . . . .	76	45.0	55.0	100.0

The percentages of losses and deaths recorded in Table 4 are an indication of the suitability of the different plants as hosts to *T. erytrae*. The greatest number of losses and deaths was recorded for nymphs reared on *Ca. capense* and this host was so unsuitable for the development of *T. erytrae* that none of the nymphs survived to maturity. The number of deaths recorded for insects reared on *F. capensis* was higher than the almost negligible percentage of deaths recorded on the other three hosts. No

deaths were recorded from *Cl. anisata* although the percentage of losses was high. The percentage of losses recorded in this case, and in the case of *F. capensis* is misleading because, in these instances, almost all the losses occurred within the first few days after emergence from the eggs. The newly emerged first stage nymphs showed considerable wandering activity before settling down finally in one position on the leaf. The leaves of *Cl. anisata* and *F. capensis*, on the new flush where the insects fed, were extremely small; the insects had difficulty in finding a suitable flat section of the leaves on which to settle, and consequently losses were high.

### CONCLUSIONS

The development of the immature stages of *T. erytrae* was compared on the rough lemon, *Ci. limon*, and on four indigenous host plants. The sizes attained by the nymphs, and the instar durations of the insects, may be used as criteria to gauge the suitability of the five different host plants for the development of *T. erytrae*.

Size measurements of the nymphs of *T. erytrae* showed that these insects grew significantly larger on the two indigenous hosts, *V. undulata* and *Cl. anisata*, than they did on *Ci. limon*, *F. capensis* or *Ca. capense*. Larger adults were produced on *Ci. limon* than on *F. capensis* or *Ca. capense*. Therefore, if size in *T. erytrae* is a criterion of host food plant suitability, *V. undulata* and *Cl. anisata* are most suitable, followed in order by *Ci. limon*, *F. capensis* and *Ca. capense*.

These conclusions were verified by measurements of the instar durations of the nymphs on the five different host plants. Development was significantly faster on *V. undulata* (mean development time, 31.5 days) than it was on *Cl. anisata* (mean development time, 33.2 days). Development was found to be slower than this on *F. capensis* and *Ci. limon* (mean development time 36 and 37 days, respectively) and development of the immature stages was excessively prolonged on *Ca. capense* (mean development time, 45 days). Developmental durations were also far more consistent (as gauged by the standard errors in each case) when the insects were reared on *V. undulata* or *Cl. anisata* compared with those on the other three host plants.

The percentage of deaths recorded for the immature stages on *V. undulata*, *Cl. anisata* and *Ci. limon*, (3.3 per cent, 0 per cent, and 3.6 per cent, respectively) was very low, as compared with 15 per cent deaths on *F. capensis* and 55 per cent deaths recorded on *Ca. capense*. In the case of *Ca. capense* this high mortality coupled with losses of individuals during the experiment, resulted in only one individual, out of a total of 76 first stage nymphs, reaching maturity. This insect died as it moulted to the adult stage and it is clear that *Ca. capense* was totally unsuitable for development of *T. erytrae* and that it can be disregarded as a potential indigenous host.

It is tempting to suggest, although no evidence has been presented to support this conclusion, that the observed differences in sizes and instar durations of the immature stages of *T. erytrae* on different host plants, reflect simple differences in the nutritional properties of the host plants. This suggestion is supported by Lowe's (1967) observations on the growth of aphids on the leaves of *Vicia faba*. Lowe noted that *Aulacorthum solani* grew larger on certain areas of the leaves than on other areas and he has ascribed this to nutritional differences within the leaf. It is probable, therefore, that nutritional differences in the host plants would be pronounced and account for the differential effects noted in the development of the immature stages of *T. erytrae*. This simple interpretation, however, is complicated by the fact that the nymphs of *T. erytrae* showed

considerable wandering activity on the leaves of *F. capensis* and *Ci. limon* whereas they remained in one position during their entire development on *V. undulata* and *Cl. anisata*. The wandering activities of the nymphs might explain the extended instar durations and smaller sizes of the nymphs on *F. capensis* and *Ci. limon*. This does not seem very likely, because it does not explain the significant differences in total instar durations between *T. erytreae* nymphs reared on *V. undulata* and *Cl. anisata* when there was no wandering activity during development. It would seem that these differences must reflect a difference in nutritional properties of the host, or some other more subtle factor such as phloem turgor pressure or nitrogen concentrations in the cell sap (Wearing & Van Emden, 1967; Wearing, 1967).

Collectively, these results indicate that the indigenous host, *V. undulata*, was most suitable for the development of *T. erytreae* and that either this plant or *Cl. anisata* or both, are among the original host plants of this insect. These two hosts are often heavily infested with natural populations of *T. erytreae* in the field (unpublished observations). *T. erytreae* also develops very adequately on *Ci. limon* and must have been well preadapted to this host at the time of the introduction of citrus to southern Africa. The indigenous host plant *F. capensis* was almost as suitable as *Ci. limon* for the development of *T. erytreae*.

Further discussion of these results, and a consideration of the economic implications of these findings, is pointless without taking into account the responses of the adults of *T. erytreae* to *Ci. limon* and the four indigenous hosts. This aspect is dealt with in the companion paper (Moran, 1968).

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## APPENDIX 1

Minima, maxima and mean lengths (in mm) of *Trioza erytrae* nymphs, at the start and end of each instar, when reared on rough lemon (*Citrus limon*) and four indigenous host plants.

*T. erytrae* nymphs reared on *Citrus limon*.

Lengths at the start of each instar					
	1st	2nd	3rd	4th	5th
No. Readings . . . . .	99	86	78	74	73
Minima . . . . .	0.25	0.44	0.63	0.94	1.38
Maxima . . . . .	0.34	0.50	0.75	1.13	1.63
Means . . . . .	0.32	0.48	0.71	1.01	1.50
Standard errors . . . . .	0.002	0.002	0.004	0.004	0.01
Lengths at the end of each instar					
	88	78	75	72	68
No. Readings . . . . .	88	78	75	72	68
Minima . . . . .	0.33	0.46	0.66	1.00	1.38
Maxima . . . . .	0.41	0.56	0.75	1.13	1.66
Means . . . . .	0.37	0.50	0.73	1.04	1.54
Standard errors . . . . .	0.001	0.001	0.003	0.004	0.01



*T. erytreae* nymphs reared on *Vepris undulata*.

Lengths at the start of each instar					
	1st	2nd	3rd	4th	5th
No. Readings . . . . .	29	22	26	24	25
Minima . . . . .	0.31	0.47	0.67	0.96	1.38
Maxima . . . . .	0.38	0.53	0.78	1.09	1.63
Means . . . . .	0.35	0.51	0.70	1.03	1.49
Standard errors . . . . .	0.004	0.004	0.006	0.007	0.02

Lengths at the end of each instar					
	30	27	14	24	25
No. Readings . . . . .	30	27	14	24	25
Minima . . . . .	0.41	0.50	0.71	1.00	1.44
Maxima . . . . .	0.42	0.56	0.78	1.13	1.71
Means . . . . .	0.41	0.52	0.75	1.07	1.60
Standard errors . . . . .	0.003	0.004	0.008	0.007	0.01

*T. erytreae* nymphs reared on *Clausena anisata*

Lengths at the start of each instar					
	1st	2nd	3rd	4th	5th
No. Readings . . . . .	37	30	29	27	26
Minima . . . . .	0.29	0.46	0.66	0.94	1.42
Maxima . . . . .	0.38	0.54	0.78	1.16	1.66
Means . . . . .	0.32	0.50	0.72	1.06	1.53
Standard errors . . . . .	0.004	0.003	0.006	0.01	0.01

Lengths at the end of each instar					
	30	29	27	26	26
No. Readings . . . . .	30	29	27	26	26
Minima . . . . .	0.34	0.51	0.71	1.00	1.53
Maxima . . . . .	0.44	0.56	0.79	1.17	1.75
Means . . . . .	0.39	0.53	0.76	1.08	1.62
Standard errors . . . . .	0.004	0.004	0.004	0.008	0.01

*T. erythrae* nymphs reared on *Fagara capensis*.

Lengths at the start of each instar					
	1st	2nd	3rd	4th	5th
No. Readings . . . . .	14	13	14	10	9
Minima . . . . .	0.29	0.50	0.71	0.97	1.38
Maxima . . . . .	0.34	0.56	0.78	1.04	1.56
Means . . . . .	0.33	0.53	0.73	1.01	1.47
Standard errors . . . . .	0.004	0.006	0.006	0.009	0.02

Lengths at the end of each instar					
	11	12	11	9	8
No. Readings . . . . .	11	12	11	9	8
Minima . . . . .	0.38	0.53	0.71	1.03	1.50
Maxima . . . . .	0.41	0.56	0.78	1.09	1.59
Means . . . . .	0.40	0.54	0.74	1.05	1.55
Standard errors . . . . .	0.005	0.003	0.006	0.009	0.01

*T. erythrae* nymphs reared on *Calodendrum capense*.

Lengths at the start of each instar					
	1st	2nd	3rd	4th	5th
No. Readings . . . . .	80	7	4	2	1
Minima . . . . .	0.28	0.44	0.66	0.97	1.44
Maxima . . . . .	0.34	0.51	0.69	1.00	1.44
Means . . . . .	0.31	0.47	0.68	0.99	1.44
Standard errors . . . . .	0.002	0.01	0.008	0.02	—

Lengths at the end of each instar					
	9	4	3	1	1
No. Readings . . . . .	9	4	3	1	1
Minima . . . . .	0.34	0.50	0.66	1.04	1.56
Maxima . . . . .	0.41	0.50	0.71	1.04	1.56
Means . . . . .	0.38	0.50	0.69	1.04	1.56
Standard errors . . . . .	0.006	—	0.01	—	—



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APPENDIX 2

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Minima, maxima and mean developmental durations (in days) of the immature stages of *T. erytrae*, from insects reared on rough lemon (*Citrus limon*) and four indigenous host plants. The mean total developmental durations are also given.

Instar durations of *T. erytrae* on *Citrus limon*.

	Egg	1st	2nd	3rd	4th	5th	Mean Total
No. Readings . . . . .	127	97	78	73	71	68	67
Minima . . . . .	8	4	2	3	2	5	31
Maxima . . . . .	13	15	11	7	7	13	48
Means . . . . .	9.5	7.6	4.4	4.1	4.4	7.3	37.0
Standard errors . . . . .	0.09	0.19	0.18	0.12	0.11	0.18	0.52

Instar durations of *T. erytrae* on *Vepris undulata*.

	Egg	1st	2nd	3rd	4th	5th	Mean Total
No. Readings . . . . .	31	27	27	26	25	25	25
Minima . . . . .	11	4	3	3	3	6	31
Maxima . . . . .	12	5	4	4	4	7	34
Means . . . . .	11.0	4.1	3.2	3.9	3.9	6.2	31.5
Standard errors . . . . .	0.03	0.05	0.08	0.07	0.07	0.08	0.14

Instar durations of *T. erytrae* on *Clausena anisata*.

	Egg	1st	2nd	3rd	4th	5th	Mean Total
No. Readings . . . . .	39	30	29	28	26	26	26
Minima . . . . .	9	6	3	3	3	6	31
Maxima . . . . .	9	9	5	5	5	9	37
Means . . . . .	9.0	7.0	3.3	3.6	3.6	6.9	33.2
Standard errors . . . . .	—	0.14	0.10	0.11	0.11	0.14	0.27

Instar durations of *T. erytreae* on *Fagara capensis*.

	Egg	1st	2nd	3rd	4th	5th	Mean Total
No. Readings . . . . .	24	15	15	13	9	9	9
Minima . . . . .	10	4	2	3	4	7	33
Maxima . . . . .	11	6	5	5	6	11	40
Means . . . . .	10.6	5.1	3.4	4.0	4.9	8.2	36.0
Standard errors . . . . .	0.10	0.12	0.19	0.16	0.23	0.47	0.71

Instar durations of *T. erytreae* on *Calodendrum capense*.

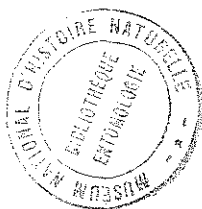
	Egg	1st	2nd	3rd	4th	5th	Mean Total
No. Readings . . . . .	84	8	4	3	1	1	1
Minima . . . . .	8	7	6	3	5	9	45
Maxima . . . . .	14	17	10	7	5	9	45
Means . . . . .	10.1	10.4	7.8	5.0	5.0	9.0	45.0
Standard errors . . . . .	0.15	1.28	0.85	1.15	—	—	—

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