

**Some Ecological Factors Affecting Population Growth
of the Rust-Red Flour Beetle *Tribolium castaneum*
Herbest (Coleoptera : Tenebrionidae)
I : Space and Temperature**

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ABSTRACT. The effect of surface area (space) on the growth of 2 populations of an initial size of 5 and 10 female *Tribolium castaneum* per container in a fixed weight of wheat flour at 28°C and 31°C was investigated for 9 months. Growth rates of these populations were similar at both temperatures. The population density was oscillating at 28°C and more or less regular at 31°C.

Flour beetles such as *Tribolium castaneum* Herbest are well-known pests of flour mills (Chapman 1928), and the entire life cycle (5.78 weeks) is completed in the flour habitat. A heavy beetle infestation spoils flour, making it grey and smelly as a result of accumulation of faeces, excretions and corpses.

Laboratory investigations of population growth fundamentals were performed under controlled environmental conditions (Ricklefs 1979). However, these studies were limited to specific conditions seldom found in nature. In field studies, the observations were limited to correlations of population phenomena with environmental variables and frequently, have involved large errors in the estimation of the different parameters.

Population density is an important factor controlling longevity, but its effect is complicated and in no case fully understood. In earlier studies, more crowded populations showed marked inhibition of growth. Park *et al.* (1965), working with *T. castaneum* and *T. confusum* proved that intraspecific competition, in all its forms, causes an increased rate of mortality; mortality being usually heavier among the young and directly influencing the recruitment of new reproductive members.

Maximum population growth for *T. castaneum* occurred at 29°C and 70%

relative humidity (Park 1962) and the highest mortality rate at 34°C. Space may regulate population, but the state or value of this environmental factor may be altered significantly by the organism (Williams 1980).

In *T. castaneum* all mobile developmental stages show preference to inhabit the upper layer of flour. Therefore, the area of the surface, rather than the volume of the medium, may affect population growth in this species. The present work investigates the influence of space, expressed as surface area, upon population growth of *T. castaneum* at two different temperatures, one of which allows maximum population growth (Park 1962).

Material and Methods

A colony of *T. castaneum* was maintained in the laboratory at room temperature ($27 \pm 2^\circ\text{C}$) using wheat flour as food and habitat. Experiments were conducted at 2 different temperatures, $28 \pm 1^\circ\text{C}$ and $31 \pm 1^\circ\text{C}$. At each temperature, two densities of females, 5 and 10 per container (referred to hereinafter as 5-F and 10-F groups respectively), were reared in a fixed weight (2.1 gm) of fresh wheat flour according to Park's (1962) modified method. For each density, the experiments were conducted in glass containers of 3 different sizes (diameter \times height: 1.4×4.0 , 3.0×1.5 , and 5.4×0.4 cm) providing surface areas of 1.8, 7.1 and 22.9 cm², respectively.

The population densities were determined monthly for 9 months in these containers, a period equivalent to 5 generations. Each experiment was repeated 3-5 times. Monthly, *T. castaneum* adults, pupae and larvae were sieved, counted and replaced with the eggs in the same weight of new fresh flour [The sieve mesh, size 0.001 mm, did not allow the eggs (0.01 - 0.02 mm long) to be sieved down with the rejected flour].

The mean and standard error were calculated for each group in each experiment. The data were compared using the Student's t-test and the analysis of variance (F-ratio).

Results

Population growth at 28°C

During the first month, a remarkable increase ($P < 0.001$) in size occurred in all populations (Fig. 1A,B). This increase was 2.5 - 4 times the initial size (5 or 10 females) except for the 5-F group reared in the 1.8 cm² space where the increase amounted to 8 times the initial size. In the 5-F groups, population size after 2 months became nearly similar ($P > 0.05$, where P values are based on Student's t-test) (Table 1). Population growth during the following 2 months was directly proportional to space, being the highest ($P < 0.01$) in the largest space. In the latter space, population size remained at the same level ($P > 0.05$) except at 7 months

when a drop in size occurred. In the 7.1 cm² space, although population size was smaller ($P < 0.01$) during the seventh month, a gradual increase ($P < 0.01$) occurred during the eighth and ninth months. In the smallest space, fluctuation in population size ($P < 0.01$) during the fifth to ninth months occurred with the largest size being at the last month (Fig. 1A). However, at the end of the experiment, all 5-F groups reared in the different spaces had nearly the same population size ($P > 0.05$).

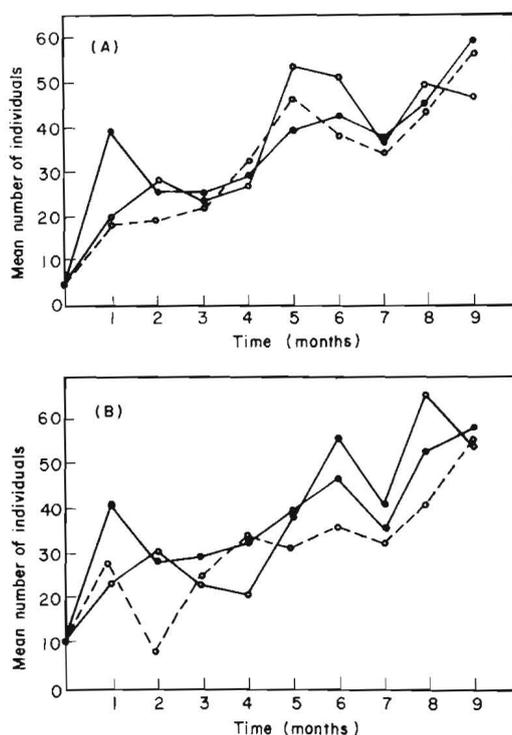


Fig. 1. *T. castaneum* population growth at 28°C, in 3 spaces 1.8 cm² ●—●, 7.1 cm² ○---○, 22.9 cm² ○—○. (A) Original population density of 5 females (B) Original population density of 10 females.

In the 10-F groups, the initial increase ($P < 0.01$) during the first month in population size was followed by a marked decrease ($P < 0.01$) during the second month in those reared in 1.8 and 7.1 cm² spaces. On the other hand, the population reared in 22.9 cm² continued to grow ($P < 0.01$) during that month. However, by

the third month, all populations were similar in size ($P > 0.05$) (Table 1). Population growth continued ($P < 0.01$) in the group reared in the 1.8 and 22.9 cm² spaces (except for a drop at the seventh month) reaching its maximum during the eighth and ninth months. On the other hand, population size in the 7.1 cm² space increased during the fourth month with no significant change ($P > 0.05$) during the fifth to eighth months. However, a marked increase in population size occurred during the ninth month ($P > 0.01$). At the end of the experiment, all 10-F groups reared in the different spaces had nearly the same population size ($P > 0.05$).

When the population sizes at the end of the experiment were compared in the 5-F and 10-F groups, reared in the different spaces, they were found to be nearly similar ($P > 0.05$).

Population growth at 31°C

Population growth was generally gradual and more regular than that observed at 28°C (Fig. 2A,B). In the 5-F groups, maximum population size in the 1.8 cm² space was reached after 4 months ($P > 0.01$) and remained nearly at the same level ($P > 0.05$) until the end of the experiment (Table 2). In the 22.9 cm² space, maximum population size was reached after 5 months, and despite the fluctuations observed in the seventh and eighth months ($P < 0.01$), the maximum size was regained in the last month ($P > 0.05$). In the 7.1 cm² space, the population continued to grow during the sixth month ($P < 0.01$), remained at the same level for 2 months ($P > 0.05$) and reached the maximum size on the ninth month ($P < 0.01$). At the end of the experiment, the population sizes varied in the different spaces, the largest being in the 7.1 cm² ($P < 0.001$) and the smallest in the 1.8 cm² ($P < 0.01$).

In the 10-F groups, the gradual population growth in the 7.1 and 22.9 cm² reached its peak after 6 and 7 months respectively ($P < 0.01$) with no significant change during the following months ($P < 0.05$) until the end of the experiment (Fig. 2B). In the 1.8 cm² space, population growth was less regular than in the larger spaces. After a gradual increase in size during the first 3 months ($P < 0.01$), the population decreased ($P < 0.01$) during the fourth month, remained unchanged during the fifth month ($P > 0.05$) and then increased again ($P > 0.01$) reaching a peak size during the last 3 months ($P > 0.05$) (Table 2). At the end of the experiment, the population size of all of the 10-F groups in the 3 spaces was similar ($P > 0.05$).

Growth rate

When the growth rates in all of the 5-F and 10-F groups reared at 28 and 31°C in the different spaces were compared (analysis of variance), they were found to be nearly similar (F-ratio = 0.03 - 2.79) (Table 3).

Table 1. Mean number of mobile *T. castaneum* individuals reared from two initial densities of 5 and 10 females in three different spaces of wheat flour for 9 months at 28°C.

Period in months	Mean (\pm SE) population density from an initial density of					
	Five females			Ten females		
	1.8 cm ²	7.1 cm ²	22.9 cm ²	1.8 cm ²	7.1 cm ²	22.9 cm ²
1	38 \pm 1.27 d*,e	16 \pm 0.32 a	17 \pm 0.32 a	40 \pm 5.77 e,f	28 \pm 3.50 b,c	22 \pm 3.50 b,c
2	25 \pm 2.57 b	17 \pm 2.89 a,b	26 \pm 2.57 c	27 \pm 1.90 c	7 \pm 1.90 i	32 \pm 2.89 c,d
3	26 \pm 1.60 b,c	20 \pm 0.95 b	22 \pm 1.90 b	30 \pm 2.57 b,c	25 \pm 2.89 b,c	21 \pm 2.57 b
4	28 \pm 1.90 c	32 \pm 0.95 c	25 \pm 2.89 b,c	33 \pm 4.18 c	35 \pm 3.85 d	20 \pm 3.21 a,b
5	35 \pm 1.27 d	46 \pm 2.89 f	53 \pm 2.57 g,h	40 \pm 3.85 e,f	32 \pm 2.57 c,d	37 \pm 1.90 d,e
6	42 \pm 0.95 f	35 \pm 2.23 d	50 \pm 0.95 g	45 \pm 5.14 f	37 \pm 3.50 d	58 \pm 1.90 h
7	36 \pm 1.90 d,e	32 \pm 0.32 c,d	36 \pm 2.57 d,e	36 \pm 3.50 d,e	32 \pm 2.23 c,d	41 \pm 1.61 e,f
8	45 \pm 2.23 f	43 \pm 0.95 f	49 \pm 2.23 g	55 \pm 2.89 g,h	41 \pm 3.21 d,e	71 \pm 0.64 j
9	58 \pm 0.32 g,h	55 \pm 2.89 g,h	46 \pm 2.57 f,g	61 \pm 5.14 g,h	52 \pm 1.57 g,h	58 \pm 1.90 h

* Figures with similar letters (a-i) are not significantly different ($P > 0.05$); those with different letters are statistically different ($P < 0.01 - P < 0.001$).

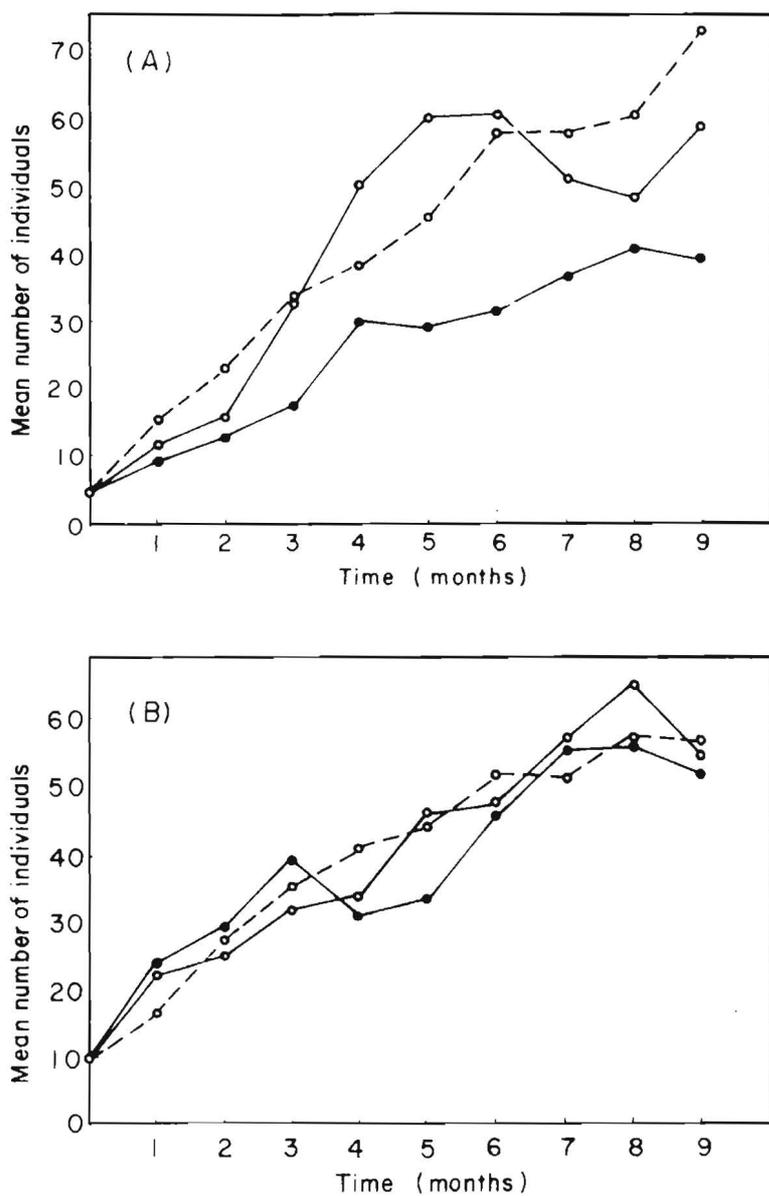


Fig. 2. *T. castaneum* population growth at 31°C and in 3 spaces 1.8 cm² ●—●, 7.1 cm² ○---○, 22.9 cm² ○—○. (A) Original population density of 5 females (B) Original population density of 10 females.

Table 2. Mean number of mobile *T. castaneum* individuals reared from two initial densities of 5 and 10 females in three different spaces of wheat flour for 9 months at 31°C.

Period in months	Mean (\pm SE) population density from an initial density of					
	Five females			Ten females		
	1.8 cm ²	7.1 cm ²	22.9 cm ²	1.8 cm ²	7.1 cm ²	22.9 cm ²
1	9 \pm 1.27 a*	16 \pm 1.59 b	11 \pm 1.59 a	22 \pm 1.90 c	16 \pm 2.57 b,c	21 \pm 2.23 c
2	12 \pm 1.27 a,b	22 \pm 1.59 c,d	15 \pm 1.90 b,c	28 \pm 1.90 d	27 \pm 1.90 c,d	25 \pm 2.89 d
3	14 \pm 1.9 a,b	35 \pm 0.95 e	32 \pm 2.57 d,e	39 \pm 1.90 e,f	35 \pm 2.57 d,e	33 \pm 2.89 d,e
4	30 \pm 1.27 d	38 \pm 0.95 e,f	50 \pm 1.27 f,g	30 \pm 2.57 d	42 \pm 2.57 e,f	35 \pm 0.63 e
5	30 \pm 1.27 d	45 \pm 1.9 f	59 \pm 1.9 h	32 \pm 2.89 d	45 \pm 1.59 f	47 \pm 2.89 f
6	33 \pm 1.9 d,e	56 \pm 2.23 g	60 \pm 2.23 h	46 \pm 1.27 f	51 \pm 4.49 f,g	48 \pm 3.21 f,g
7	36 \pm 2.89 d,e	59 \pm 3.21 g,h	51 \pm 2.89 f,g	56 \pm 2.23 g,h	50 \pm 3.21 f,g	59 \pm 3.21 g,h
8	42 \pm 1.9 e,f	60 \pm 4.49 g,h	48 \pm 2.57 f,g	56 \pm 1.59 g,h	59 \pm 2.89 g,h	65 \pm 2.57 h
9	40 \pm 3.85 d,e	72 \pm 1.27 i	56 \pm 1.27 g,h	51 \pm 1.27 g	54 \pm 1.43 g	55 \pm 2.89 g,h

* Figures with similar letters (a-h) are not significantly different ($P > 0.05$); those with different letters are statistically different ($P < 0.01 - P < 0.001$).

Table 3. Analysis of variance of growth rates of two *T. castaneum* population densities (5 and 10 females) reared in wheat flour at 28°C and 31°C and in three spaces (1.8, 7.1 and 22.9 cm²).

Source of Variation	Degrees of Freedom	Mean Square	F-ratio
Space	2	164.1	0.79
Temperature	1	313.5	1.51
Initial density	1	171.3	0.82
Space and temperature	2	580.7	2.79
Space and initial density	2	283.6	1.36
Temperature and initial density	1	7.3	0.03
Space, temperature and initial density	2	104.5	0.50
Residual	96	208.2	—

Discussion

The growth rates of the *T. castaneum* population of 2 different initial sizes reared in 3 different spaces were similar. These results are in agreement with those of Park (1948) who found that space (volume) of universe) did not greatly affect the pattern of population growth in *T. castaneum* and *T. confusum*. However, in the present work, the surface area rather than the total volume of flour (volume of the universe) was different. In the present study, population growth was oscillating at 28°C but at 31°C, it was more regular. However, the growth rate was similar at both temperatures. These results are not in full agreement with Park's (1962) conclusion that 29°C was the optimum growth temperature for *T. castaneum*.

In the present investigation, variation in the initial population density and temperature also did not influence the growth rate of *T. castaneum*. In experimental studies of flour beetles, the population density of the flour beetle is seen to increase, as the birth rate exceeds the death rate in the culture. At this stage, cannibalism probably acts to stabilize the population size. This cannibalistic process is complex and is responsible for most of the mortality of these flour beetles (Park *et al.* 1965).

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References

- Chapman, R.N.** (1928) The quantitative analysis of environmental factors, *Ecology* **9**: 111-122.
- Park, T.** (1948) Experimental studies of interspecies competition I. Competition between populations of the flour beetles, *Tribolium confusum* Duval and *T. castaneum* Herbst. *Ecol. Monogr.* **18**: 265-307.
- Park, T.** (1962) Beetles, competition and populations, *Science* **138**: 1369-1375.
- Park, T., Mertz, D.B. Grodzinski, W. and Prus, T.** (1965) Cannibalistic predation in populations of flour beetles, *Physiol. Zool.* **38**: 289-321.
- Ricklefs, R.E.** (1979) *Ecology*, Prentice-Hall Inc., London, pp. 434-479.
- Williams, F.M.** (1980) *Conceptual foundations of ecological dynamics*, Univ. Park, PA., U.S.A., (unpublished).

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بعض العوامل البيئية المؤثرة على نمو
مجموعات من خنفساء الدقيق ذات
الصدأ الأحمر ترايوليام كاستانيام
١ - الفراغ ودرجة الحرارة

أحمد الوزير هجرس

قسم علم الحيوان - كلية العلوم - جامعة المنصورة - مصر

لقد تم فحص تأثير حجم المكان محتسباً كمساحة سطحية على نمو مجموعتين من خنفساء الدقيق ترايوليام كاستانيام بدأنا بحجم أولى خمسية أو عشرة إناث وضعت في حجم ثابت من دقيق القمح عند درجة حرارة ٢٨م أو ٣١م لمدة ٩ شهور.

لقد أثبتت النتائج أن معدلات النمو لهذه المجموعات تكون متماثلة عند درجتي الحرارة المذكورتين بينما تتذبذب كثافة المجموعات عند درجة حرارة ٢٨م إلا أن الزيادة تكون أكثر انتظاماً عند درجة حرارة ٣١م.