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Effect of food concentration on the development, growth, reproduction and total life span of Simocephalus expinosus Koch (Cladocera: Daphniidae)

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ABSTRACT

Simocephalus expinosus, a North African species, was collected from a seasonal pond and reared in the laboratory at three different food concentrations of Saccharomyces cerevisiae (12 x 10^5cells/ml, 65 x 10^4cells/ml, 5 x 10^4cells/ml), in order to examine the effects of food depressions on the embryonic development, adult period, total life span, growth and reproduction under ambient room temperature. Culture media and food were renewed each day. Data were recorded during its entire life cycle. The results demonstrate that low food level exerted a negative influence on the embryonic development. It increases with decreasing resource level, while the trend was reversed as food concentration rose. When raised under low food conditions, S. expinosus had a significantly lower growth rate and lower reproductive rate. Therefore, in the field, populations of S. expinosus, under insufficient food level could suppress any reproduction and any growth phenomenon, leading to its decline and its disappearance. The results indicated that food availability affects neither adult stage, nor total life span of S. expinosus.

Key words: *Simocephalus*, food quantity, life history, reproduction, growth.

INTRODUCTION

Cladocerans are prominent among zooplankton of freshwater bodies, and as such play an important role in the trophic level dynamics [1]. In natural biotopes, population dynamics of the cladocerans which live in the small bodies of water as ponds, are subjected to the variations of environmental conditions, such as temperature [2-5], predation [6-9], population density [10-12] and food quality [13-14].

Food quantity may be another factor that can affect the population dynamics and the cladocerans life history traits. In natural waters, food quantity constitues a key factor in the strucure, abundance and zooplankton diversity [15-16]. In addition, a wide number of papers of laboratory studies, demonstrate the negative effect of food depletions on the reproduction and growth. For example, many species of *Daphnia* responds to food depressions by curtailing growth and reproduction [17-18] and, in extreme conditions, cladocerans may produce resting eggs before their disappearance from the plankton [3, 19-23]. For the better understanding how food depletions could induce the disappearance of the cladocerans from the plankton, an experimental study on the influence of food level on the life history traits will be necessary to give more knowledge. Therefore, this study is undertaken in the laboratory, under conditions of abundant and limiting food supply in order to measure some life history parameters of the cladoceran *Simocephalus expinosus* Koch, recorded in Northeast Algeria [24-26].

MATERIALS AND METHODS

S. expinosus in this study had been reared in the laboratory with *Saccharomyces cerevisiae*. Animals were obtained from a temporary pond ; Joanonville (36°52.82' N, 7°45.42' E). A clone was established from a single female

isolated from the culture, and should therefore have been genetically identical. Water used in stock and experimental cultures was collected from the same pond where they come from and then filtered through a 0.45 µm to remove bacteria, algae and fine detritus. Animals were grown at three different food concentrations corresponding to low, intermediate and high food level. Experiments were performed at ambient room temperature. In the low food level, a neonate born within 16 h period was placed in test vessels containing 20 ml of filtered pond water and the food at 5 x 10^4cells/ml of *S. cerevisiae*. In the intermediate and high food levels, neonates not older than 16 h were placed individually in tubes, each containing 20 ml of filtered pond water and the food at 65 x 10^4cells/ml and 12 x 10^5 cells/ml respectively. Preliminary experiments showed that the concentration of 5 x 10^4cells/ml represents the threshold of the growth and reproduction of *S. expinosus*. Each experiment started with more than 10 replicates. Every second day, neonates were examined and the entire food medium was changed. Room temperature which was measured every day at 12 a.m.was about 19.99 ± 0.61 °C. The following characters were noted : embryonic development time (the time from laying an egg into the brood chamber to the release of neonate) ; adult period (the time from primiparous instar to the death of the adult animal), total life span (juvenile phase + adult phase) [27], growth rate [28] and reproductive rate [29]. Means were compared using one way analysis of variance. All analyses were performed with Minitab.

RESULTS

The duration of embryonic development was shortened at high food concentration and lengthened at low food concentration (Table 1). The analysis of variance shows that the differences between means are significant (Table 2).

Table 1. Effect of food concentration on the duration of embryonic devlopment of *Simocephalus expinosus* cultured in the laboratory
(Mean ±SD). Number of observations in parenthesis

Food concentrations (cells/ml)	Embryonic development (days)
5 x 10^4	4,0000 ± 0,7303 (16)
65 x 10^4	3,4706 ± 0,5145 (17)
12 x 10^5	3,2381 ± 0,4364 (21)**

*** = $p < 0.001$*

Table 2. One way ANOVA testing for the effect of food concentration on the duration of embryonic development of *Simocephalus expinosus*

Source of variance	DF	SS	MS	F Ratio	P
Factor	2	5,381	2,691	8,55	0,001
Error	51	16,045	0,315		
Total	53	21,426			

DF: degrees of freedom, SS: sum squares, MS: mean squares.

The duration of the adult phase increases with increasing food concentration. By contrast, the total life span decreases when food level increases (Table 3). However, differences between means are not significant (Table 4).

Table 3. Duration of adult phase and total life span of females of *Simocephalus expinosus* cultured under three food concentrations in the laboratory
(Mean ±SD). Number of observations in parenthesis

Food concentrations (cells/ml)	Adult phase (days)	Total life span (days)
5 x 10^4	8,850 ± 5,122 (20)	26,350 ± 5,008 (20)
65 x 10^4	9,478 ± 6,251 (23)	23,043 ± 6,321 (23)
12 x 10^5	11,240 ± 6,869 (25)	22,920 ± 7,103 (25)

Table 4. One way ANOVA testing the difference in the adult phase and total life span of *Simocephalus expinosus* in relation with food concentration

	Source of variance	DF	SS	MS	F Ratio	P
Adult phase						
	Factor	2	70,9	35,5	0,93	0,402
	Error	65	2490,8	38,3		
	Total	67	2561,8			
Total life spane						
	Factor	2	158,5	79,3	2,01	0,143
	Error	65	2566,5	39,5		
	Total	67	2725,0			

DF: degrees of freedom, SS: sum squares, MS: mean squares.

Data revealed that both growth rate and reproductive rate increase significantly for females cultured under high food level than those cultured under low food level (Table 5, 6).

Table 5. Mean growth rate and reproductive rate of *Simocephalus expinosus* cultured in the laboratory under three different food concentrations

(Mean ±SD). Number of observations in parenthesis

Food concentrations (cells/ml)	Growth rate	Reproductive rate
5 x 10^4	0,036000 ± 0,005026 (20)	3,619 ±1,320 (16)
65 x 10^4	0,057391 ± 0,004490 (23)	8,809 ± 4,567 (17)
12 x 10^5	0,072400 ± 0,005228 (25) ***	10,809 ± 7,747 (21) **

*** = $p < 0.001$, ** = $p < 0.01$*

Table 6. One way ANOVA testing for the influence of food concentration on the growth rate and reproductive rate of *Simocephalus expinosus*

	Source of variance	DF	SS	MS	F Ratio	P
Growth rate						
	Factor	2	0,0147426	0,0073713	303,35	0,000
	Error	65	0,0015795	0,0000243		
	Total	67	0,0163221			
Reproductive rate						
	Factor	2	483,7	241,8	7,91	0,001
	Error	51	1560,2	30,6		
	Total	53	2043,8			

DF: degrees of freedom, SS: sum squares, MS: mean squares.

DISCUSSION

It is well known that food depletion affects the growth of Daphniid cladocerans [17, 18, 30]. In the present study, data revealed that *S. expinosus* had a significantly earlier embryonic development when reared at abundant food concentrations. The previous works on many cladocerans indicate embryonic development to be temperature dependent [27, 31-33], but independent from ressource levels [34-35] which did not agree with our results, possibly linked to the differences in culture medium. However, similar results have been observed on *Daphnia parvula* [15], on *Daphnia laevis* [30] and on *Daphnia pulicaria* and *Daphnia hyalina* [36]. Such rapid development should be advantageous in unstable environments where food ability fluctuates.

According to the results of this study, animals show a higher growth rate as well as higher reproductive rate under abundant food conditions and inversely as food conditions drop. The low food level exerted a negative influence on the age at maturity (juvenile period) of this species [37] ; i.e., with decreasing food level, a longer time is required to reach maturity. Therefore, low food conditions affect the growth rate by causing an increase in the juvenile period. Higher growth rate is obtained at high food level. This was due to a decrease in the age at which females started to reproduce. At higher food level, more energy is available for growth and reproduction [38]. Such a response is consistent with those reported for *Daphnia hyalina* [13], *Daphnia parvula* [15], *Daphnia pulex* [18, 39], *Daphnia laevis* [30] and *Daphnia pulicaria* and *Daphnia hyalina* [36]. Lower growth rate at diminished food could be affected also by smaller size of matured females. Indeed, decreased growth rate in relation to smaller size of females was found for *Daphnia hyalina* [13], *Daphnia pulex* [18] and *Daphnia laevis* [30].

Unsurprisingly, reproductive output of *S. expinosus* declined with resource depressions which could be due to the longer embryonic development time. In addition, under threshold food concentration used in this study, females would not able to reproduce and would supress any reproduction phenomenon. Similar outcomes on the reproduction rate to decrease with increasing embryonic devlopment were reported previously for *Daphnia* [13, 19, 40]. Lower reproductive rate could be attributed to the reduced fecundity due to the lower number of neonates produced by poorly fed females. Thus, many authors state that food depletions affect the fecundity of cladocerans [15, 36, 41].

The overall result of this study showed that, when raised at the higher food level, females of *S. expinosus* matured quikly. The early onset of maturity is reflected into higher growth rate while, the early embryonic development time is reflected into higher reproductive rate. In general, the results of the present study show that food depressions affect the growth and reproduction of *S. expinosus*. Therefore, when analysing the importance of different factors regulating the population dynamics of *S. expinosus* in the field, food concentrations should be taken into account.

Based on the above, some speculations on the mecanisms regulating seasonal populations dynamics of *S. expinosus* can be made. The conditions of food deficiency induce lower growth rate as well as lower reproductive rate. In the field, an insufficient food supply could suppress any growth and any reproduction phenomenon, which leads to its disappearance from the plankton, two or three months before ponds dry up. Further studies will be needed to provide more clarification on the population dynamics of this species.

CONCLUSION

It appears clearly evident from the results of our experiments, that food availability is considered as a key factor among others that determine the growth and reproduction of *S. expinosus*. The conditions of low food resource reduce the growth of *S. expinosus* by causing an increase in the juvenile period, while they reduce the reproductive rate by an increase in the embryonic development time. Therefore, in exteme conditions of food depressions, natural populations of *S. expinosus* could neither grow nor reproduce leading to its disappearance from the plankton.

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