E.Ü. Su Ürünleri Dergisi 2006
E.U. Journal of Fisheries & Aquatic Sciences 2006
Cilt/Volume 23, Sayı/Issue (1-2): 113–116

ISSN 1300 - 1590
http://jfas.ege.edu.tr/

The Effect of Food (S*cenedesmus acuminatus* (von Lagerheim) R. H. Chodat) Densities and Temperature on the Population Growth of the Cladoceran *Ceriodaphnia quadrangula* (O. F. Muller, 1785)

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Özet: ***Cladoceran Ceriodaphnia quadrangula (O.F. Muller, 1785)'nın populasyon artışı üzerine sıcaklık ve besin (Scenedesmus acuminatus*** (von Lagerheim) R. H. Chodat***) yoğunluğunun etkisi.*** Bu çalışmada, *Ceriodaphnia quadrangula*'nın populasyon artışı üzerine sıcaklık (20, 25 ve 30 ºC) ve farklı besin (*Scenedesmus acuminatus*) yoğunluğunun (15, 30, 45, 60 ve 75x10^4 h/ml) etkisi incelenmiştir. Deneme 16 aydınlık:8 saat karanlık ışık uygulamasında gerçekleştirilmiştir. Deneme başında, farklı besin yoğunlukları içeren her bir tüpe 1 adet 24 saatten genç birey konulmuş, birey sayısı ve büyüme hızı 25 gün süre ile belirlenmiştir. En yüksek birey sayısı (21,433±0,750 birey/ml) ve büyüme hızı (0,240±0,004) 25 ºC'de 45x10^4 h/ml'de belirlenmiştir. Besin yoğunluğunun artması, *Ceriodaphnia quadrangula*'nın birey sayısı ve büyüme hızını arttırmıştır. Farklı besin yoğunluklarının birey sayısına etkisi istatistiki olarak önemli (P<0,05), 20-25 ºC arasındaki sıcaklığın önemsiz (P>0,05) olduğu bulunmuştur.

Anahtar Kelimeler: *Ceriodaphnia quadrangula, Scenedesmus acuminatus*, besin yoğunluğu, sıcaklık, populasyon yoğunluğu.

Abstract: In this study, the effect of the different concentration of *Scenedesmus acuminatus* (15, 30, 45, 60 and 75 x 10^4 cell ml^{-1}) and temperature (20, 25 and 30 ºC) on the population growth of *Ceriodaphnia quadrangula* were investigated. The experiment carried out a photoperiod of 16 hours light:8 hours dark In the beginning of the experiments, 1 individual <24 h old were put on each vessel, number of the individual, growth rates were determined during 24 days. The peak population density and the growth rate were obtained at 45 x 10^4 cells ml^{-1} at 25 ºC. Increasing the food concentration was increased number of individual and growth rates in *Ceriodaphnia quadrangula.* The effect of different food concentration on number of the individual were statisticaly significant (P<0,05), temperature between 20 and 25 ºC were found insignificant (P>0,05).

Key Words: *Ceriodaphnia quadrangula*, *Scenedesmus acuminatus,* food concentration, temperature, population density.

** Bu çalışma S.D.Ü. Bilimsel Araştırma Projeleri Yönetim Birimi tarafından desteklenmiştir (SDUAF -849 YDL).*

Introduction

Freshwater zooplanktons are mainly composed of protozoans, rotifers, cladocerans and copepods. Cladocerans, in term of biomass, are often the dominant groups (Benider et al., 2002). The most important environmental factors controlling cladocerans growth and reproduction are temperature, food quantity and quality. Cladocerans by virtue of their small size and short generation times, respond rapidly to changes in algal food density (Nandini et. al., 1998; Nandini and Sarma, 2000; Nandini and Sarma 2003). One the most important variable affected by changing food level is the population growth rate. The effects of food on the dynamics of cladoceran species have been a well-researched issue (Jana and Pal, 1983; Gliwicz and Guisande, 1992; Boersma and Vijverberg, 1996; Nandini and Rao, 1998; Ovie and Egborge, 2002; Rose et al., 2000; Benider et al., 2002; Nandini and Sarma, 2000; Nandini and Sarma, 2003; Alva-Martinez et al., 2004). However, most studies have focus on *Daphnia* species and few studies have appeared on dynamics of smaller cladocerans such as *Ceriodaphnia*, *Moina* and *Simocephalus* (Jana and Pal, 1985; Ramirez et.al., 2002; Rose et al., 2002; Abrantes and.Goncalves, 2003). Especially, little information is available on the effect of food level and temperature on *C. quadrangula* in growing culture. Therefore, the aim of the present work was determined effect of food level and temperature on *C. quadrangula* using population growth to asses performance.

Materials and Methods

The *Ceriodaphnia quadrangula* was isolated from the lake Karacaören-Antalya-Turkey, and maintained for at least 6 months prior to experimentation. For routine maintenance as well as the experiments, we used well water. *Scenedesmus acuminatus* was cultured in 6 l bottles using Bold's basal medium. Algae in the log phase of growth was centrifuged and resuspended in well water. The density of this stock concentrate was determined using "neubauer" counting chamber. An initial test was conducted to determine the food concentrations (15 x 10^4, 30 x 10^4, 45 x 10^4 60 x 10^4 and 75 x 10^{4}cells ml-1) and temperature (20 °C, 25 °C and 30°C). In a preliminary, the population did not grow 30°C and a food concentration of 75 x 10^{4}cells ml^{-1} . For the population growth experiments, we were designed based on the results of the pilot study, which indicated that 15 x 10^4, 30 x 10^4, 45 x 10^4 ve

60 x 10^4 cells ml^{-1} at 20 °C and 25°C temperature. Experiments were conducted pH 7.0-7.5 and photoperiod of 16h light:8h dark. The experimental design for each algal density and two temperature consist of 24 (= 4 food level x 2 temperature x 3 replicate) test tube of 30 ml capacity containing 10 ml well water. The initial density of *C. quadrangula* was 0.1 ind. ml^{-1} (3 animals per tube). Everyday we counted the number of living individual animals in each experimental tube and transferred them to test tube containing fresh medium at the appropriate food levels. The experiments were terminated after 25 days depend on the all test groups, by which time most replicates showed a declining trend.

Based on the data collected, we derived the rate of population increase (r) using the following equation: $r = (\ln Nt - \ln N_0)/ t$, where N_0 = initial population density and Nt = population density after time t (Nandini and Sarma, 2000). Statistical analyses were performed using SPSS 9.0 for window software (SPSS Inc, Chicago, IL, USA). Differences in population density and the population growth rate between treatments were tested using Anova. Data were analysed by two-way analysis of variance (Anova), and multiple comparisons among made Duncan's multiple range test. The significance level was at $P<0.05$.

Results

Data on the population density of *C. quadrangula* in relation to food concentration at two temperatures are show in figure 1, column A and B. Food concentration had a significant effect on the population density of *C. quadrangula* ($p<0.05$) at two temperatures. The population density of *C. quadrangula* showed low increase at 15 x 10^4 cells $ml^{-1}$and 30 x 10^4 cells ml^{-1} regardless of temperature ($P<0.05$ 2-way Anova table 1). The lowest population density recorded at low food concentration of 15 x 10^4cells ml^{-1}. The peak population density was at food level of 45 x 10^4 cells ml^{-1} at each temperature. However, no significant difference in *C. quadrangula* population density was found between 45 x 10^4 cells ml^{-1} and 60 x 10^4 cells ml^{-1}. Temperature differences did not result in significant difference in the population density. However, *C. quadrangula* showed an improved population density at 25 °C temperature regardless of food concentration ($P < 0.05$).

Table 1. Maximum population density and rate of population growth of *C. quadrangula* in relation to different concentration of *S. acuminatus* at two temperatures. Values represent mean ± standard error based on three replicate recordings.

Temperature	Food concentrations (cells ml^{-1})	Maximum population density (ind. ml^{-1})	Rate of population growth (day^{-1})
20 °C	15x10^4	7.666±0.416a	0.191±0.002a
	30x10^4	12.433±1.563b	0.212±0.004b
	45 x10^4	20.400±0.346c	0.231±0.001c
	60 x10^4	19.700±0.700c	0.229±0.001c
25 °C	15x10^4	8.633±0.550a	0.199±0.002a
	30x10^4	13.066±1.700b	0.217±0.003b
	45x10^4	21.433±0.750c	0.240±0.004c
	60x10^4	20.100±1.135c	0.237±0.004c

Similarity, food concentration had a significant effect ($p<0.05$) on the population growth rate (r), with the increase in food levels leading to increased r values (Fig. 1, column A and B). The lowest r values were obtained at 15 x 10^4 cells ml^{-1}food level while the highest was 0.240 ± 0.004 at 25 °C, at 45 x 10^4 cells $ml^{-1}$of *S. acuminatus* concentration (Table 1).

The population growth rates for animals fed the two lowest food concentrations were significantly smaller ($p<0.05$) than the population growth rate of animals fed the highest food concentrations at two temperatures. However, no significant difference in the r values were found between at food levels cells ml^{-1} 45 x 10^4 cells ml^{-1} and 60 x 10^4 cells ml^{-1}.

Discussion

Micro-algal density and temperature are major factors affecting the rate of cladocerans development in cultures (Benider et al., 2002; Ovie and Edborge, 2002; Rose et al., 2002). However, the population growth could vary depend on the cladoceran body size and species (Nandini and Sarma, 2003). The effect of varying food concentrations on cladocerans may be quantified using population growth studies and life-table demography aspects. Furthermore, population growth studies provide information on the effect of food level on individuals of various generations simultaneously occurring in growing culture (Bocanegra et. al., 2002; Nandini and Sarma, 2003). The results presented here support the findings of previous studies conducted using Ceriodaphnia species on the effect of food quantity on the population growth. The increasing population density of cladoceran with increasing food concentration, up to a level, is common in laboratory conditions (Nandini and Sarma, 2003). In the present study, food concentration has a significant effect on population density and population growth rate. The peak population density of *C. quadrangula* occurred at 45x10^4 cells ml^{-1} food concentration at 25 °C (Table 1). A further increase in food level did not result in a higher peak population density. In the study determining population growth of some genera of cladocerans in relation to algal food (*Chlorella vulgaris*) levels, Nandini Sarma (2003) have recorded the peak population density value 17.1± 0.4 for *C. dubia* at food concentration from 0.05 to 1.6 x 10^6 cells ml^{-1}. Cladocerans have r values in the range of 0.01-1.5 depend on the species, food type, temperature levels etc. (Nandini Sarma 2003). Using the life table demography approach, Nandini Sarma (2000) have recorded r values ranging from 0.17-0.23, for *Ceriodaphnia cornuta* at food concentration from 0.5 to 45 x 10^6 cells ml^{-1}. The peak r value in the present study was show similarity to theirs value. The current study has demonstrated that animals provided with low food level showed statistically significant ($p<0.05$) reductions in population growth rate than those provided with high level food. The results of this study agree with those Kluttgen et al., 1996; Repka, 1998; Rose et al., 2000) who found that cladocerans given abundant food displayed significantly higher rates of population growth rate than those given limited food. Stemberger and Gilbert (1985),

states that smaller rotifer species are well adapted to low food levels while larger species cannot survive and reproduce under these conditions as their the threshold food hypothesis. Our results are confirm to this hypothesis for *C. quadrangula* small cladoceran. *C. quadrangula is* well not adapted to high food (at 75 x10^4 cells ml^{-1} as initial tests) level. In the present study, above 45 x 10^4 cells ml^{-1} food level the r values were approximately constant and no significant difference at each temperature. However, several reasons have been adduced for the inhibitory properties of algal feed at high densities. It was stated that too high algal densities result in overfeeding, obstruction of the filtration apparatus and suffocation of animals to death. The similarity observed for *C. quadrangula* the r values at high levels could be due to a combination of these factors. Relatively little work has been done to define temperature effects on cladocerans over the wide variation of regimes which can be experienced in cultures. (Benider et al., 2002; Nandini and Rao, 1998). The initial tests show that *C. quadrangula* did not growth at 30 °C. In the present study, optimum temperature is at 25 °C for the culture of *C. quadrangula*.

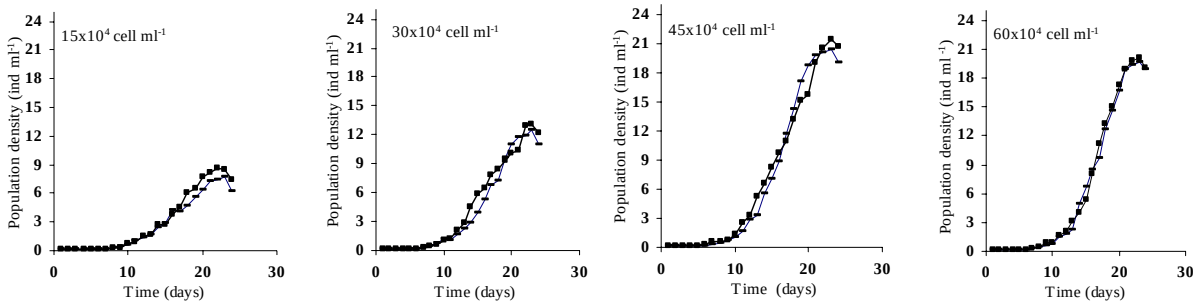

Figure 1. Population density of *C. quadrangula* in relation to algal food density at 20°C (▬) and 25 °C (■) temperature.

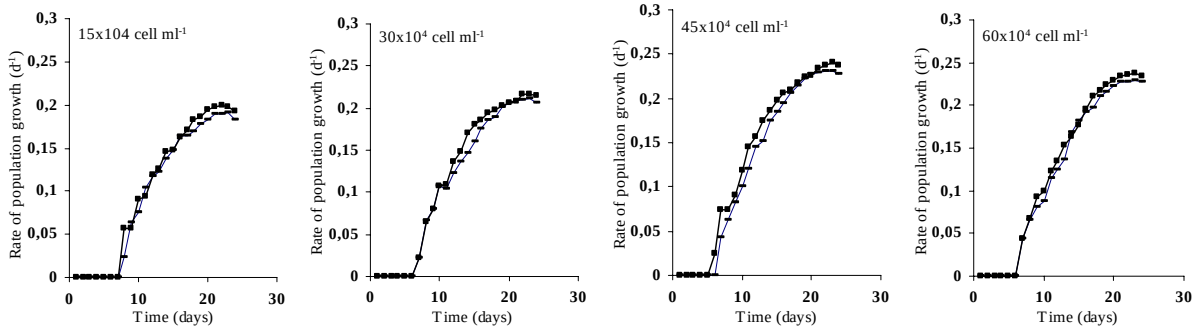

Figure 2. Population growth rate of *C. quadrangula* in relation to algal food density at 20°C (▬) and 25 °C (■) temperature.

In conclusion, the present study was determined the best levels of *S. acuminatus* cells and temperature required for *C. quadrangula* in growing culture. Both food concentration and temperature vary under natural conditions and can be controlled when maintaining cladocera cultures. Knowledge of the combined impact of these two factors is, for example toxicology tests, for researchers growing experimental organisms.

This information's on the effect of food level and temperature on *C. quadrangula* can be useful for efficient aquaculture practices, and ideally for ecosystem modelling.

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