**Research Article****Effect of dietary diversification on the growth and reproduction of copepods, cladocerans, and rotifers**Md. Milon Sarker, Sadia Momota Hena¹, Md. Al-Amin, Mohammad Ariful Islam Sumon

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Received: 08 March 2026

Revised: 17 May 2026

Accepted: 08 July 2026

Keywords: Copepods, Cladocerans, Rotifers, *Scenedesmus* sp., Growth rate.**ABSTRACT**

Zooplankton plays a vital role in the successful propagation of aquaculture, as they contain nutrients those are essential for fish and shellfish larvae. However, the optimization of zooplankton culture using appropriate dietary strategies remains a challenge for sustainable larval aquaculture. In this regards, the present study examined the influence of the microalga *Scenedesmus* sp. on the growth performance of copepods (*Cyclops* sp. and *Diaptomus* sp.), cladocerans (*Diaphanosoma* sp. and *Moina* sp.), and a rotifer (*Brachionus* sp.). Five experiments were conducted with six dietary treatments, including live *Scenedesmus* sp., powdered *Scenedesmus* sp., their combination, live or powdered *Scenedesmus* sp. combined with baker's yeast, and baker's yeast alone. The growth performance of most of the zooplankton taxa was significantly affected by the dietary diversification. The combination of the live *Scenedesmus* sp. and baker's yeast diet consistently showed the best results, suggesting that this mixed diet may be the most suitable feeding strategy for successful zooplankton culture.

Introduction

Meeting the rapidly increasing demand for animal protein from the growing global population, aquaculture has become a cornerstone, as capture fisheries are no longer able to meet this demand (Mzula et al., 2021). As the global population is expected to reach nearly 10 billion by 2050, and production from capture fisheries has remained unchanged for the past two decades, aquaculture has become the primary driver to meet this rising demand (Béné et al., 2015; Boyd et al., 2022). At present, nearly half of the total fish and 43% of the seafood consumed globally are supplied by aquaculture, and this share is projected to rise by approximately 10% by 2032 (Anderson et al., 2017; FAO, 2024). Despite this potential, one of the major bottlenecks in this

sector is the limited availability of high-quality fish and shellfish larvae (Hu et al., 2018; Ritu et al., 2024).

During the early developmental stages, fish and shellfish larvae lack a fully functional digestive system (Kolkovski, 2001), and their nutritional requirements remain highly specific and complicated (Hamre et al., 2013). Deficiencies in essential micronutrients or macronutrients may cause stunted growth, poor feed efficiency, and mass mortality (Olivotto et al., 2003; Karlsen et al., 2015). To address these limitations, live foods, especially zooplankton, can be suitable sources of larval nutrition as they are highly palatable, easily digestible, and rich in nutrients necessary for successful larval rearing (Conceicao et al., 2010; Das et al., 2012).

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Among all the zooplankton genera, copepods are known for their superior nutritional profile (Shields et al., 1999; Rasdi and Qin, 2018), with high concentrations of proteins, digestive enzymes, and essential polyunsaturated fatty acids (PUFAs), which closely align with the physiological requirements of the fish larvae (Radhakrishnan et al., 2020). These elements are very essential for increasing larval stress tolerance, visual development, and successful metamorphosis (Kanazawa, 1997; Satoh et al., 2009). Furthermore, the diversification in naupliar size across different copepodite stages, along with their distinctive swimming behaviour, makes them more visible and increases their ingestion rate by fish larvae (Støttrup, 2000). In freshwater ecosystems, *Cyclops* and *Diatomus* often dominate zooplankton communities due to their rapid growth and high survival rates (Watras, 1983; El-Khodary et al., 2020). Cladocerans are also an important zooplankton group due to their rich nutritional composition, high filtration efficiency, and rapid biomass production (Nandini and Sarma, 2003). Among cladocerans, *Diaphanosoma* and *Moina* are the most promising candidates for bridging the gap between initial feeding and the weaning stage (Khatoon et al., 2013). *Diaphanosoma* spp. are characterized by fast reproduction and a high capacity for lipid retention, which enhances larval survival (Suhaimi et al., 2022). Similarly, *Moina* spp. are frequently used in larval rearing because of their high protein content (often exceeding 50% of dry weight), ease of mass culture, and short embryonic developmental period (Loh et al., 2012). Additionally, their erratic movement enhances their visibility to predators, thereby increasing the efficient energy transfer to the fish larvae (Mayer and Wahl, 1997).

Despite the advantages of copepods and cladocerans, rotifers (specifically the genus *Brachionus*) have gained considerable interest in larval culture as a "starter diet" due to their microscopic size and slow, planktonic movement, which make them easily accessible to larvae with tiny mouth gapes and limited mobility (Yanes-Roca et al., 2024; Akter et al., 2013). Additionally, rotifers are capable of surviving at high

densities and often serve as efficient bioencapsulators for essential amino acids and minerals (Matsunari et al., 2012; Loka et al., 2016). They facilitate the first transition to exogenous feeding and gradually prepare larvae to consume the comparatively complex live feeds, such as copepods and cladocerans (Radhakrishnan et al., 2020).

The growth performance and biochemical composition of zooplankton depend on the quality and quantity of their food source (Ritu et al., 2023a; Hena et al., 2025a). Green microalgae contain essential nutrients, such as proteins, lipids, and carbohydrates, and long-chain polyunsaturated fatty acids (LC-PUFAs) like EPA and DHA (Batista et al., 2013; Nagappan et al., 2021). These components play an important role in improving maturation rates, fecundity, and hatching success of zooplankton (Arendt et al., 2005; Nielsen et al., 2021). Therefore, the appropriate selection of microalgal species with high nutritional value is essential for the successful mass culture of zooplankton.

Among green microalgae, *Scenedesmus* sp. has gained interest due to its high concentrations of proteins, lipids, and essential amino acids (Dineshbabu et al., 2019; Gorzelnik et al., 2023). In addition to its rich macronutrient profile, *Scenedesmus* sp. is also an important source of carotenoids, including β -carotene, astaxanthin, and lutein, which can accumulate up to 2.30% of its dry weight (Přibyl et al., 2015; Ritu et al., 2023b). Its rapid proliferation rate and high antioxidant productivity enhance its suitability for zooplankton culture. Though several studies have explored the effects of *Scenedesmus* cell densities on some specific taxa such as *Diaphanosoma excisum* (Ovie and Ovie, 2008), *Moina micrura* (Ovie and Egborge, 2002), and *Brachionus calyciflorus* (Kennari et al., 2008), research on the optimization of diet delivery in various forms and combinations is still limited.

The successful mass culture of zooplankton is often hindered by the diverse dietary requirements of different species. Some studies have recently investigated the effects of combining microalgae with baker's yeast or powdered diets to improve culture performance of various zooplankton groups, such as copepods,

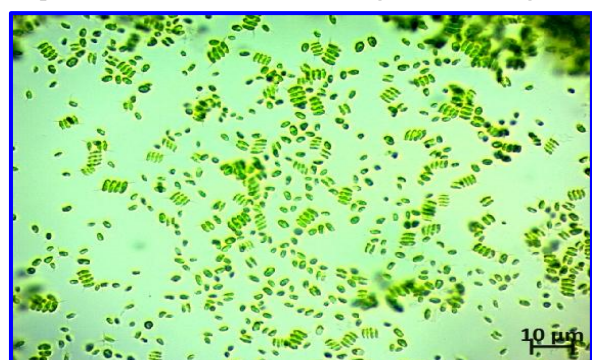
cladocerans, and rotifers (Ritu et al., 2023a; Ahmed et al., 2024; Hena et al., 2025a). However, a significant knowledge gap remains regarding the comparative efficacy of live versus powdered *Scenedesmus* sp., particularly when used in combination with other dietary supplements across a broad spectrum of zooplankton taxa. To date, no comprehensive study has evaluated the simultaneous rearing of copepods (*Cyclops* sp. and *Diaptomus* sp.), cladocerans (*Moina* sp. and *Diaphanosoma* sp.), and rotifers (*Brachionus* sp.) using these varying dietary formats of *Scenedesmus*. Therefore, this study aims to examine the effects of different dietary forms and combinations of *Scenedesmus* sp. on the growth, reproduction, and nutritional value of five zooplankton genera.

Materials and Methods

Culture of *Scenedesmus* sp. and its powder preparation

The microalga *Scenedesmus* sp. (Fig. 1A) was obtained from the Laboratory of Plankton Research, Department of Fisheries Management, Bangladesh

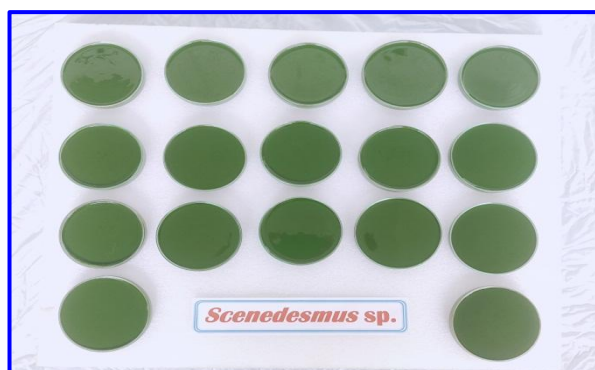
Agricultural University, Mymensingh. Mass culture was subsequently carried out in conventional Bold Basal Medium (BBM) under controlled conditions at $25 \pm 2^\circ\text{C}$, with a light intensity of $120 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$, a 12 h light: 12 h dark photoperiod, and continuous aeration in 10 L glass carboys (Fig. 1B). BBM was prepared using the chemicals as follows (Sarker et al., 2025): $250 \text{ mg L}^{-1} \text{ NaNO}_3$, $75 \text{ mg L}^{-1} \text{ MgSO}_4 \cdot 7\text{H}_2\text{O}$, $25 \text{ mg L}^{-1} \text{ NaCl}$, $75 \text{ mg L}^{-1} \text{ K}_2\text{HPO}_4$, $175 \text{ mg L}^{-1} \text{ KH}_2\text{PO}_4$, $25 \text{ mg L}^{-1} \text{ CaCl}_2 \cdot 2\text{H}_2\text{O}$, $4.42 \text{ mg L}^{-1} \text{ ZnSO}_4 \cdot 7\text{H}_2\text{O}$, $1.44 \text{ mg L}^{-1} \text{ MnCl}_2 \cdot 4\text{H}_2\text{O}$, $0.71 \text{ mg L}^{-1} \text{ MoO}_3$, $1.57 \text{ mg L}^{-1} \text{ CuSO}_4 \cdot 5\text{H}_2\text{O}$, $0.49 \text{ mg L}^{-1} \text{ Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $11.40 \text{ mg L}^{-1} \text{ H}_3\text{BO}_3$, $50.00 \text{ mg L}^{-1} \text{ EDTA}$, $31.00 \text{ mg L}^{-1} \text{ KOH}$, and $4.98 \text{ mg L}^{-1} \text{ FeSO}_4 \cdot 7\text{H}_2\text{O}$. To prepare the algal powder, biomass was harvested during the exponential growth phase via centrifugation. The resulting *Scenedesmus* sp. paste (Fig. 1C) was oven-dried at 40°C and subsequently pulverized into a fine powder (Fig. 1D).



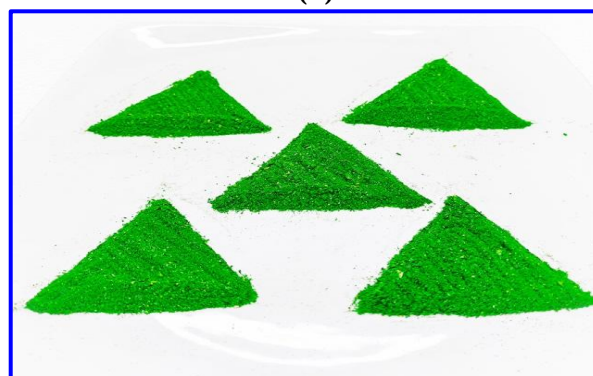
(A)



(B)



(C)



(D)

Fig. 1. (A) Pure cells, (B) mass culture, (C) concentrated paste, and (D) dried powder of the green microalga *Scenedesmus* sp.

Collection and stock culture of zooplankton

Zooplankton were collected from ponds adjacent to the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, using a 50- μ m mesh plankton net. Immediately following collection, the samples were screened and cleaned to remove the unwanted organisms. After repeated screening and cleaning, the concentrated zooplankton were resuspended in tap water, transferred to a multi-well culture plate, and isolated under a stereo microscope (Stemi 305, Carl Zeiss, Germany). Isolated

zooplankton, including copepods (*Cyclops* sp. and *Diaptomus* sp.), cladocerans (*Diaphanosoma* sp. and *Moina* sp.), and rotifers (*Brachionus* sp.) (Fig. 2A–2E), were transferred to the respective glass beakers (1000 mL) for the maintenance of zooplankton stock culture. The green microalga *Scenedesmus* sp. was given as food to the isolated zooplankton thrice a day (8:00 am, 2:00 pm, and 8:00 pm). To maintain population stability, zooplankton stocks were transferred to clean beakers with fresh tap water at 7-day intervals throughout the experimental period.

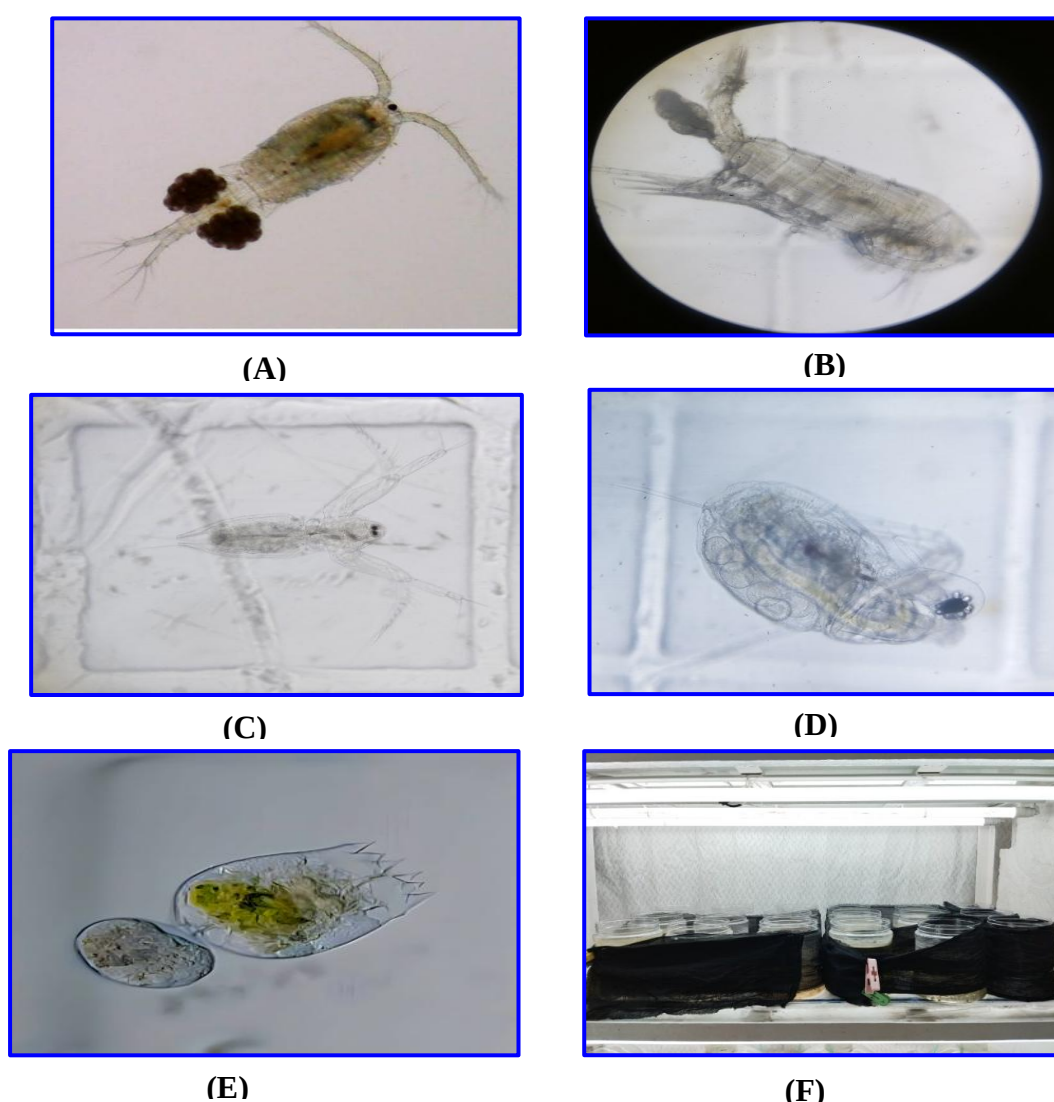


Fig. 2. Isolated zooplankton: (A) *Cyclops* sp., (B) *Diaptomus* sp., (C) *Diaphanosoma* sp., (D) *Moina* sp., and (E) *Brachionus* sp.; and (F) setup of zooplankton culture experiments.

Experimental design and feeding protocol

The study included five distinct experiments, each conducted on a single zooplankton species (*Cyclops* sp., *Diaptomus* sp., *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp.). In each experiment, zooplankton growth and reproductive response were evaluated under six distinct dietary regimes: live *Scenedesmus* sp. (T₁), powdered *Scenedesmus* sp. (T₂), a mixture of live and powdered *Scenedesmus* sp. (T₃), live *Scenedesmus* sp. combined with baker's yeast (T₄), powdered *Scenedesmus* sp. combined with baker's yeast (T₅), and baker's yeast alone (T₆) (Table 1; Fig. 2F). Each treatment had three replications. Zooplankton were cultured in 2 L glass jars containing 1.8 L tap water, with an initial stocking density of 1000 individuals L⁻¹ for each experiment. Each experiment was continued for 10 days, with diets administered three times daily at 08:00, 14:00, and 20:00 h. Microalgal cell density was determined once daily before the first feeding using a Sedgewick–Rafter counting chamber under a compound microscope (B-510BT, OPTIKA, Italy) at 40× magnification. Powdered *Scenedesmus* sp. and baker's yeast were weighed, suspended in distilled water, homogenized by gentle stirring, and filtered through a 30 µm mesh net before being supplied to the cultures.

Estimation of population density, growth rate and fecundity

To estimate the zooplankton population density (individuals L⁻¹), a 10 mL sample was collected from

each replica, fixed with 4% buffered formalin, and quantified using a Sedgewick–Rafter (S-R) counting chamber under a microscope (B-510BT, OPTIKA, Italy) at 10x magnification.

The population growth rate (day⁻¹) of zooplankton was calculated according to Krebs (1985): Population growth rate (day⁻¹) = (Ln N_t – Ln N₀) / t; where N₀ is the initial population density, N_t is the population density after time t, and t is the culture duration. The value of the population growth rate was attained from the mean of 5-7 values calculated during the zooplankton's exponential growth phase in each experiment.

To estimate the fecundity (eggs female⁻¹), 10 mL of the cultured sample from each replica during each experiment was taken on a Petri dish and fixed with the solution of 4% buffered formalin. Egg-bearing females were examined very carefully under a stereomicroscope (Stemi 305, Carl Zeiss, Germany), and the number of eggs was counted. The egg sacs were disrupted utilizing an inoculating loop, if required.

Statistical analysis

All the data were gathered, noted, and kept on MS Office (analyses were conducted using SPSS software (version 25.0; IBM Corp., Armonk, NY, USA).

Table 1. The layout and feeding ration of the zooplankton culture experiments.

Treatments	Types of feed	Feed quantity
T ₁	Live <i>Scenedesmus</i> sp.	10.0 × 10 ⁵ cells mL ⁻¹
T ₂	Powdered <i>Scenedesmus</i> sp.	0.2 g L ⁻¹
T ₃	Live <i>Scenedesmus</i> sp. + Powdered <i>Scenedesmus</i> sp.	5.0 × 10 ⁵ cells mL ⁻¹ + 0.1 g L ⁻¹
T ₄	Live <i>Scenedesmus</i> sp. + Baker's yeast	5.0 × 10 ⁵ cells mL ⁻¹ + 0.1 g L ⁻¹
T ₅	Powdered <i>Scenedesmus</i> sp. + Baker's yeast	0.1 g L ⁻¹ + 0.1 g L ⁻¹
T ₆	Baker's yeast	0.2 g L ⁻¹

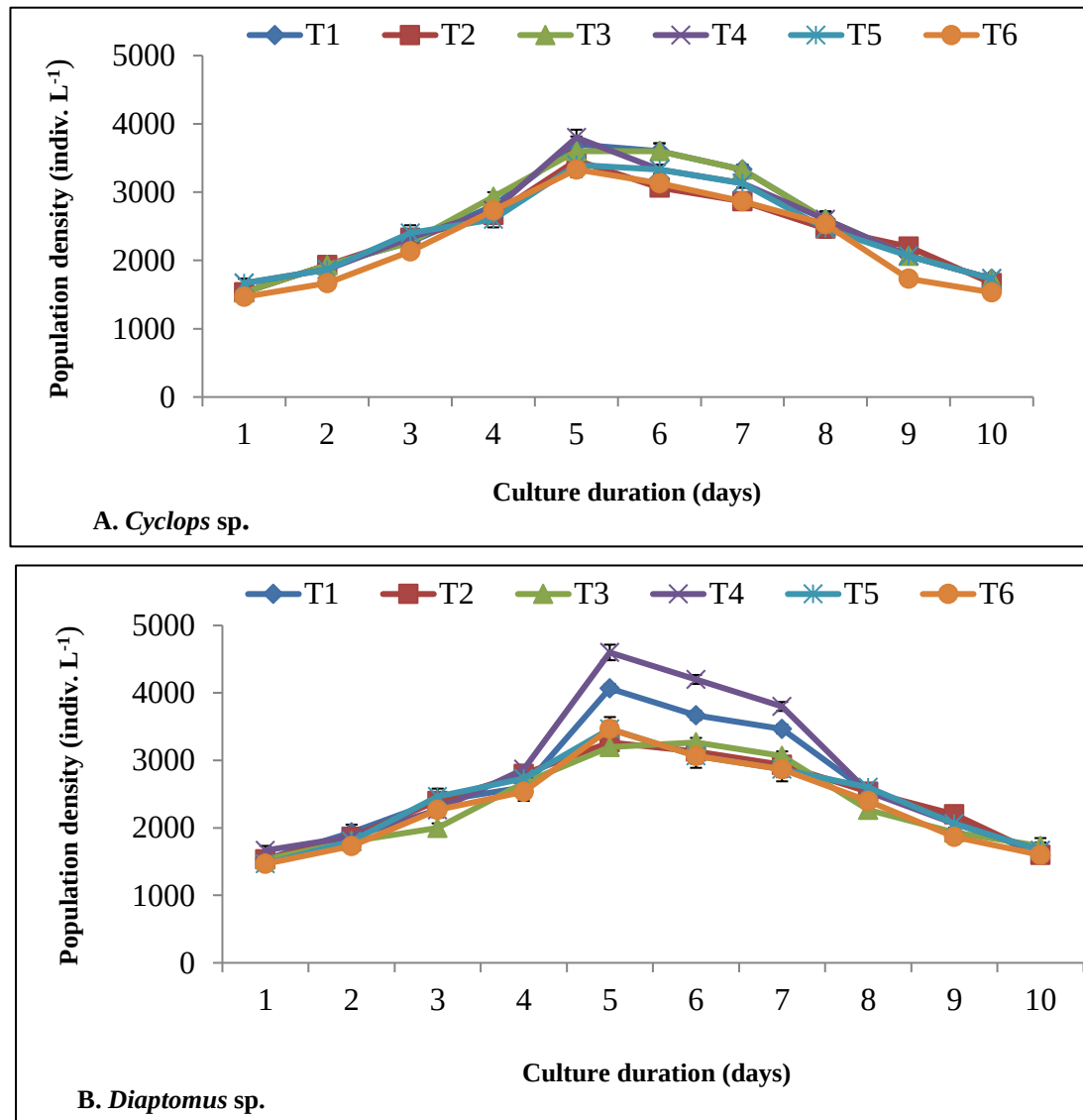
Results

Effect of different diets on the population density of zooplankton

The temporal variation in population density of the copepods (*Cyclops* sp. and *Diaptomus* sp.), cladocerans (*Diaphanosoma* sp. and *Moina* sp.), and rotifers (*Brachionus* sp.) under different dietary treatments is presented in Fig. 3. In all treatments within each experiment, population density increased rapidly during the early culture period, reaching peak values on day 5 for *Cyclops* sp. and *Diaptomus* sp., day 6 for *Brachionus* sp., and day 7 for *Diaphanosoma*

sp. and *Moina* sp., followed by a gradual decline toward the end of the experiment.

Dietary treatments showed a significant effect ($p < 0.05$) on the maximal population density of *Diaptomus* sp., *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp., as well as on the mean population density of *Diaphanosoma* sp. and *Brachionus* sp. In contrast, the maximal and mean population densities of *Cyclops* sp. were not significantly affected by diet ($p > 0.05$). Similarly, no significant difference was observed in the mean densities of *Diaptomus* sp. and *Moina* sp. under all dietary treatments ($p > 0.05$).



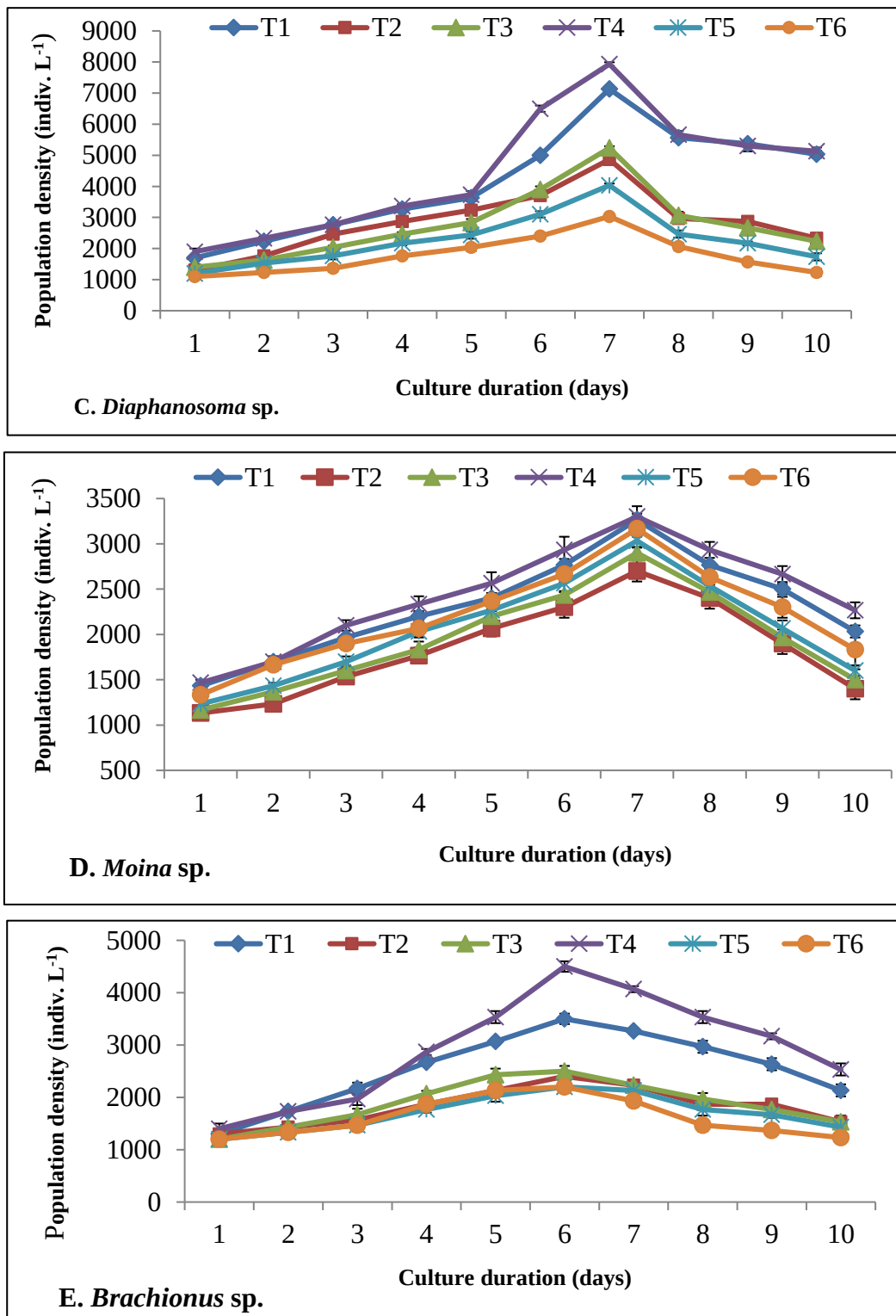


Fig. 3. Daily population density (indiv. L⁻¹) of (A) *Cyclops* sp., (B) *Diaptomus* sp., (C) *Diaphanosoma* sp., (D) *Moina* sp., and (E) *Brachionus* sp. in response to different diets (T₁ = live *Scenedesmus* sp., T₂ = powdered *Scenedesmus* sp., T₃ = live *Scenedesmus* sp. + powdered *Scenedesmus* sp., T₄ = live *Scenedesmus* sp. + baker's yeast, T₅ = powdered *Scenedesmus* sp. + baker's yeast, and T₆ = baker's yeast). Data are presented as mean ± standard deviation (n = 3).

For *Cyclops* sp., both maximal and mean population densities were statistically similar among all dietary treatments, although numerically higher values were consistently observed in T₄ (live *Scenedesmus* sp. + baker's yeast) (Fig. 4 and 5). In *Diaptomus* sp., maximal population density was significantly higher in T₄ compared with all other treatments, while mean density in T₄ was comparable to T₁ but exceeded those recorded in the remaining diets (Fig. 4 and 5).

In *Diaphanosoma* sp., both maximal and mean population densities differed significantly among diets, with T₄ yielding the highest values, followed by T₁, whereas the lowest densities were consistently

observed in T₆ (baker's yeast alone). T₂ and T₃ did not differ significantly from each other for either parameter (Fig. 4 and 5).

For *Moina* sp., maximal and mean population densities were significantly higher in T₄ and T₁, followed by intermediate values in T₆ and T₅, while the lowest densities were observed in T₂ and T₃ (Fig. 4 and 5). Similarly, *Brachionus* sp. exhibited the highest maximal and mean population densities under T₄, which were significantly greater than those recorded in all other treatments, except for partial overlap among T₃, T₂, T₅, and T₆ (Fig. 4 and 5).

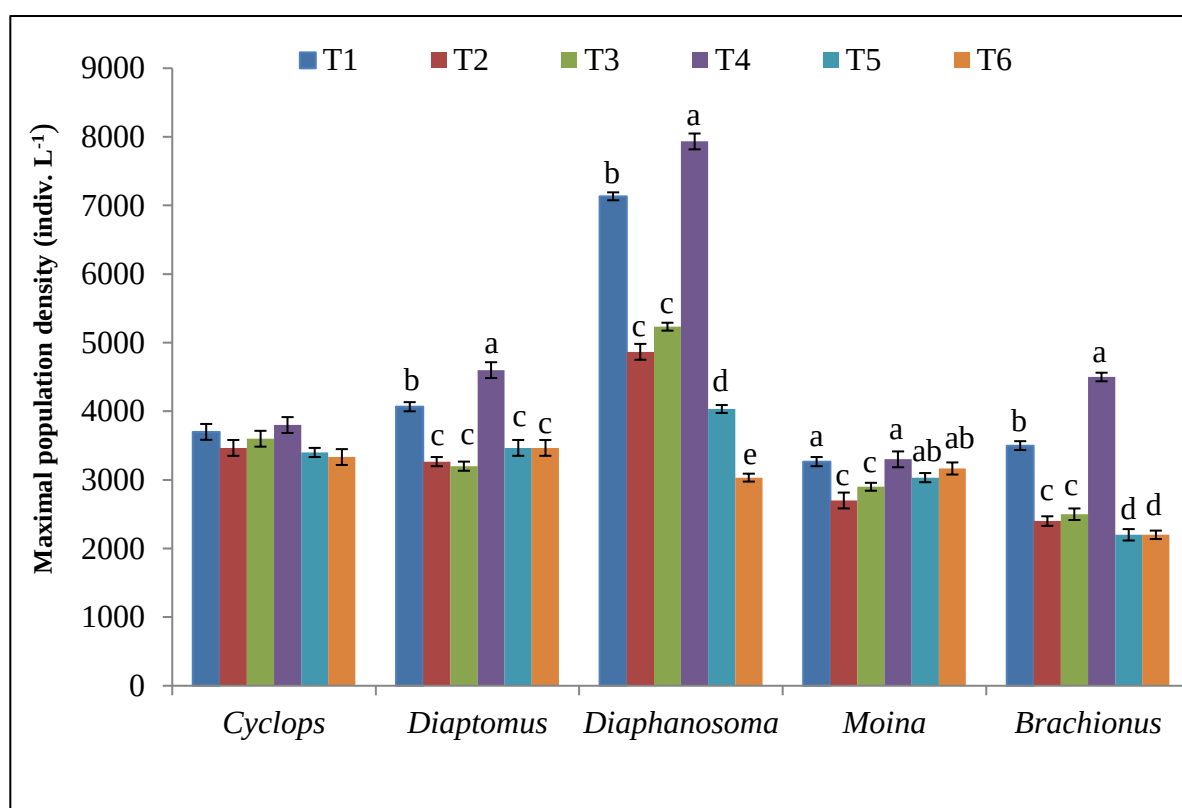


Fig. 4. Maximal population density (indiv. L⁻¹) of *Cyclops* sp., *Diaptomus* sp., *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp. in response to different diets (T₁ = live *Scenedesmus* sp., T₂ = powdered *Scenedesmus* sp., T₃ = live *Scenedesmus* sp. + powdered *Scenedesmus* sp., T₄ = live *Scenedesmus* sp. + baker's yeast, T₅ = powdered *Scenedesmus* sp. + baker's yeast, and T₆ = baker's yeast). Data are presented as mean ± standard deviation (n = 3). Means with different superscripts are significantly different ($p < 0.05$).

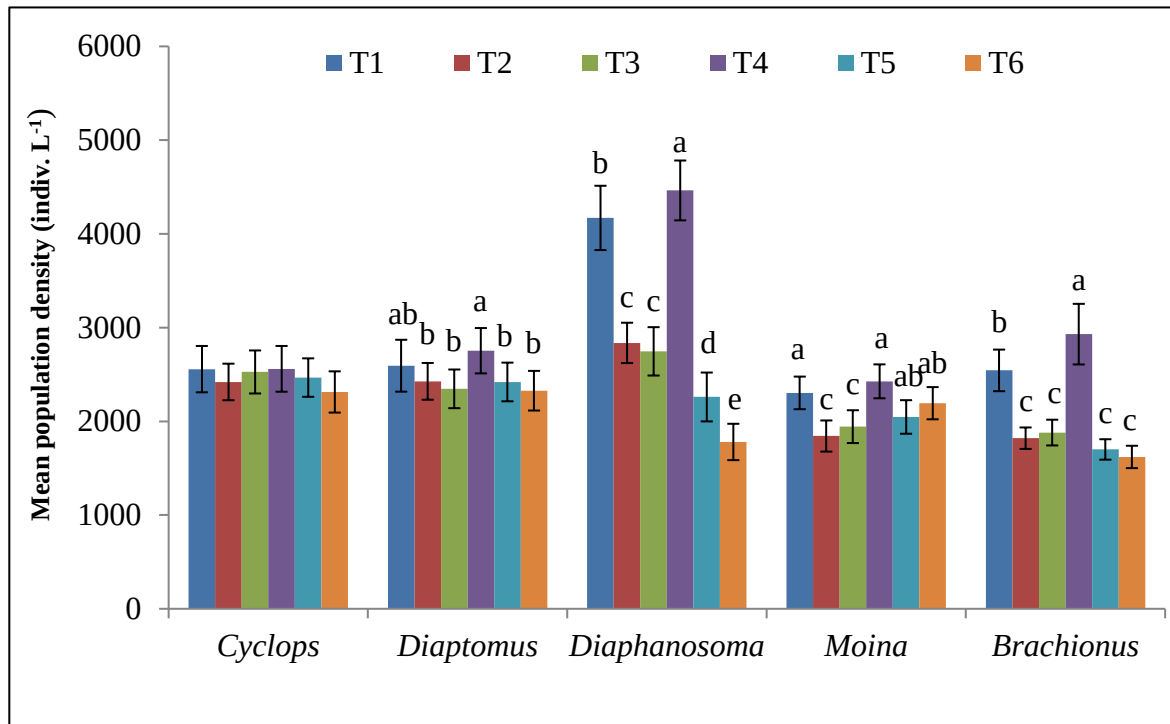


Fig. 5. Mean population density (indiv. L⁻¹) of *Cyclops* sp., *Diaptomus* sp., *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp. in response to different diets (T₁ = live *Scenedesmus* sp., T₂ = powdered *Scenedesmus* sp., T₃ = live *Scenedesmus* sp. + powdered *Scenedesmus* sp., T₄ = live *Scenedesmus* sp. + baker's yeast, T₅ = powdered *Scenedesmus* sp. + baker's yeast, and T₆ = baker's yeast). Data are presented as mean ± standard deviation (n = 10). Means with different superscripts are significantly different (p < 0.05).

Effect of different diets on the growth rate of zooplankton

Dietary treatments significantly influenced the growth rate of *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp. (p < 0.05), whereas no significant dietary effect was detected in case of *Cyclops* sp. and *Diaptomus* sp. (p > 0.05).

For *Cyclops* sp., the highest growth rate was recorded in T₄ (0.325 ± 0.048 day⁻¹), which did not differ significantly from T₁, T₂, T₃, or T₅, but was significantly higher (p < 0.05) than T₆ (Fig. 6). Similarly, *Diaptomus* sp. exhibited its maximum growth rate in T₄ (0.333 ± 0.045 day⁻¹), which was statistically comparable to T₁, but significantly exceeded the growth rates than those observed in T₂, T₃, T₅, and T₆ (p < 0.05). No significant difference was observed among T₂, T₃, T₅, and T₆ (Fig. 6).

In contrast, *Diaphanosoma* sp. showed a clear dietary response, with the highest growth rate in T₄ (0.369 ± 0.049 day⁻¹), followed sequentially by T₁, T₂, T₃, T₅, and T₆. Growth rates of the zooplankton differed significantly among the treatments offered different diets (p < 0.05), except between T₂ and T₃ (Fig. 6).

In case of *Moina* sp., T₄ resulted in the highest growth rate (0.235 ± 0.028 day⁻¹), which was statistically similar to T₁ but significantly higher than T₂, T₃, T₅, and T₆ (p < 0.05). No significant difference was detected between T₂ and T₃, or between T₁ and T₆ (Fig. 6).

A comparable trend was observed in case of *Brachionus* sp., where T₄ produced the highest growth rate (0.267 ± 0.015 day⁻¹), followed by T₁. Growth rates in T₂ and T₃ were statistically similar, as were those in T₅ and T₆, but all were significantly lower than T₁ and T₄ (p < 0.05) (Fig. 6).

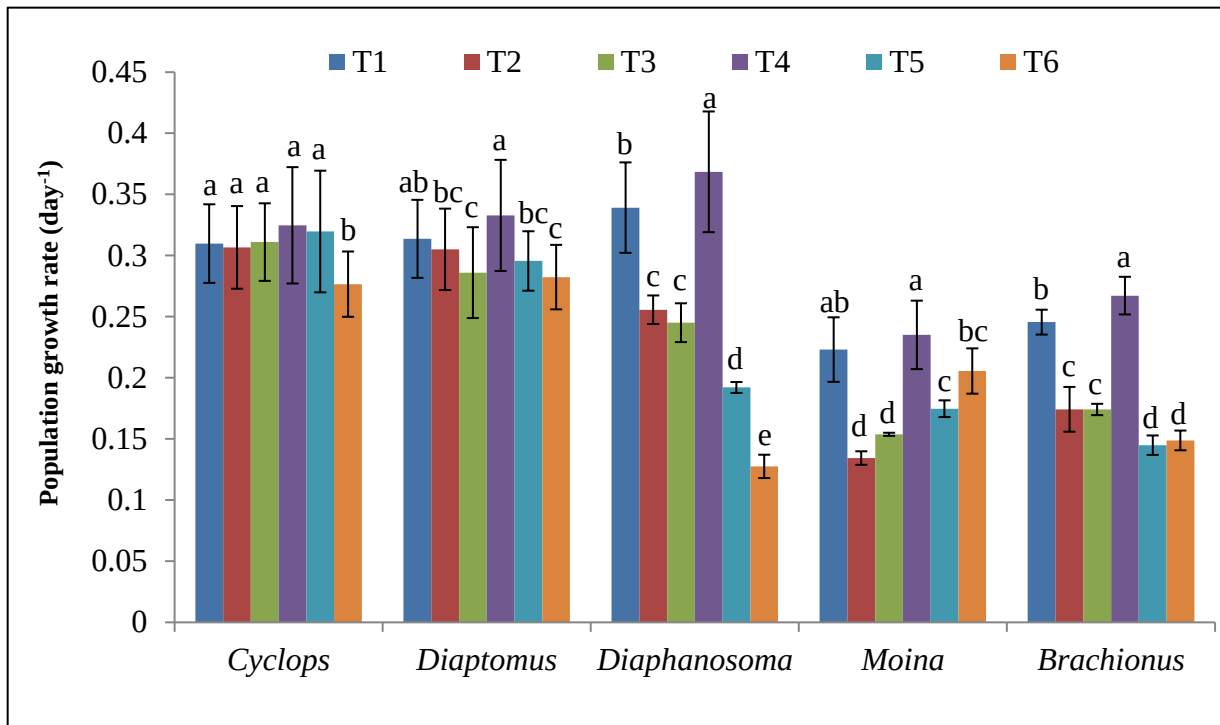


Fig. 6. Population growth rate (day^{-1}) of *Cyclops* sp., *Diaptomus* sp., *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp. in response to different diets (T₁ = live *Scenedesmus* sp., T₂ = powdered *Scenedesmus* sp., T₃ = live *Scenedesmus* sp. + powdered *Scenedesmus* sp., T₄ = live *Scenedesmus* sp. + baker's yeast, T₅ = powdered *Scenedesmus* sp. + baker's yeast, and T₆ = baker's yeast). Data are presented as mean $\pm$ standard deviation ($n = 3$). Means with different superscripts are significantly different ($p < 0.05$).

Effect of different diets on the egg production rate of zooplankton

Egg production rates of the studied zooplankton species were significantly affected by dietary treatments ($p < 0.05$). For *Cyclops* sp., the highest egg production was observed in T₄ (46.33 ± 1.86 eggs female⁻¹), followed by T₁, T₃, T₂, T₅, and T₆. Egg production did not differ significantly between T₃ and T₂, and between T₅ and T₆, but each value was significantly lower than T₄ ($p < 0.05$) (Fig. 7). In *Diaptomus* sp., T₄ also resulted in the highest egg production rate (22.43 ± 1.16 eggs female⁻¹). Treatments T₁, T₃, T₅, and T₆ showed statistically similar values, whereas T₂ produced significantly fewer eggs ($p < 0.05$) (Fig. 7). For *Diaphanosoma* sp.,

maximum egg production occurred in T₄ (7.16 ± 0.55 eggs female⁻¹), which was statistically comparable to T₁, T₂, and T₃, but significantly higher than T₅ and T₆ ($p < 0.05$) (Fig. 7). Egg production in *Moina* sp. was highest in T₄ (6.78 ± 0.68 eggs female⁻¹). Values recorded in T₁ and T₆ did not differ significantly, while T₂ yielded the lowest egg production and differed significantly from all other treatments ($p < 0.05$) (Fig. 7). Similarly, *Brachionus* sp. exhibited the highest egg production rate in T₄ (2.43 ± 0.10 eggs female⁻¹), which was statistically similar to T₁ but significantly higher than T₂, T₃, T₅, and T₆ ($p < 0.05$). No significant difference was observed among T₂, T₃, and T₅, and between T₅ and T₆ (Fig. 7).

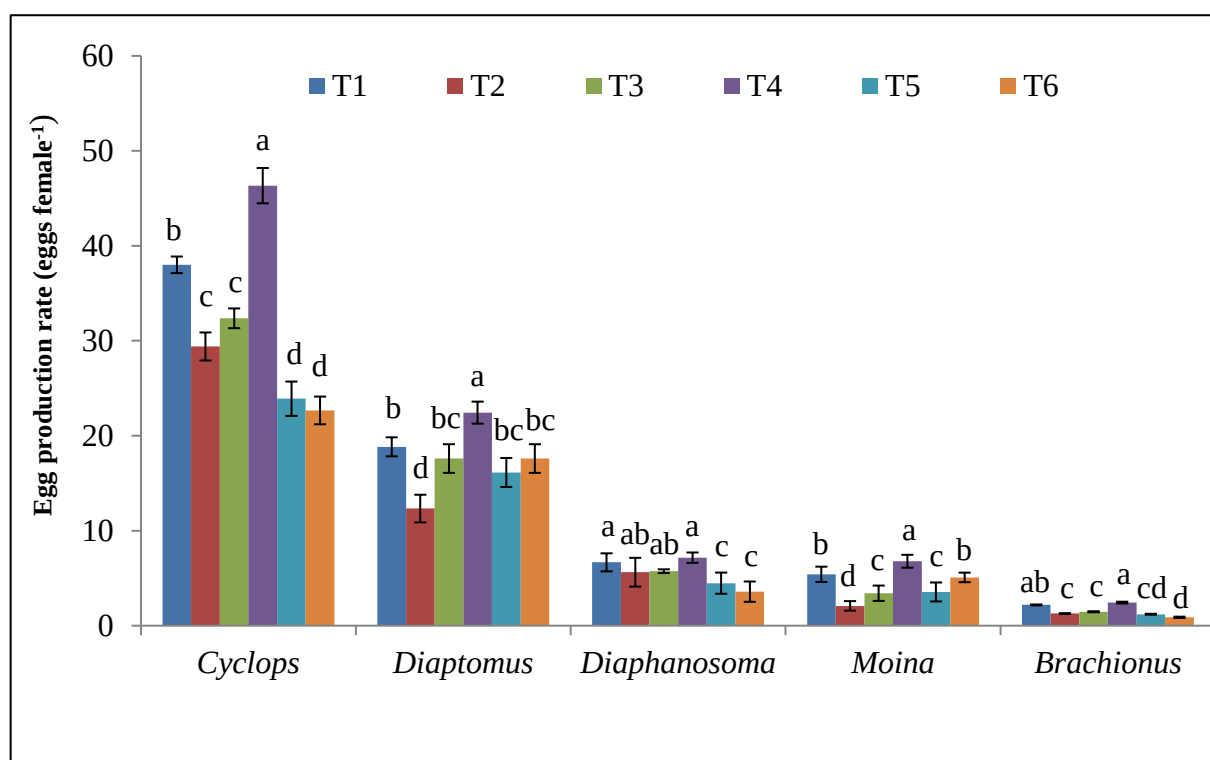


Fig. 7. Maximal egg production rate (eggs female⁻¹) of *Cyclops* sp., *Diaptomus* sp., *Diaphanosoma* sp., *Moina* sp., and *Brachionus* sp. in response to different diets (T₁ = live *Scenedesmus* sp., T₂ = powdered *Scenedesmus* sp., T₃ = live *Scenedesmus* sp. + powdered *Scenedesmus* sp., T₄ = live *Scenedesmus* sp. + baker's yeast, T₅ = powdered *Scenedesmus* sp. + baker's yeast, and T₆ = baker's yeast). Data are presented as mean ± standard deviation (n = 3). Means with different superscripts are significantly different ($p < 0.05$).

Discussion

The growth performance and reproductive success of zooplankton primarily depend on the quality and quantity of available dietary inputs (Ritu et al., 2023a; Hena et al., 2025a). The present study demonstrated that the dietary regime significantly influences maximal population density, growth rate, and egg production across copepods, cladocerans, and rotifers. Although the role of microalgae in aquaculture has been well established (Khatoon et al., 2013; Sarker et al., 2025), the present findings showed that not only the algal species selection but also the physical forms (live versus powdered) and composition (single versus mixed) of the diet greatly influence zooplankton productivity.

Across all treatments, the population exhibited a sigmoid growth pattern, with a short lag phase, a rapid exponential phase, and a subsequent decline towards the end of the culture period. The beginning of the exponential growth phase occurred earlier in copepods than in cladocerans and rotifers, indicating that life history traits, feeding efficiency, and reproductive strategies are different among various zooplankton taxa. The peak population densities were observed between the 5th and 7th days of culture, which is close to the earlier reports on copepods cultured with *Monoraphidium littorale* (Ritu et al., 2023a) and cladocerans reared on *Haematococcus*-based diets (Hena et al., 2025a). This consistent temporal pattern indicates that once the minimum nutritional requirements are fulfilled, the growth kinetics of

zooplankton largely depend on the species-specific biological characteristics. After reaching peak density, the population declined, possibly due to nutrient depletion, accumulation of metabolic waste, and density-dependent stress.

The main finding of this study was the superior growth performance of zooplankton fed on a combined diet of live *Scenedesmus* sp. and baker's yeast, which consistently showed the best results among all of the conducted experiments. Generally, live microalgae are considered a suitable feed source for zooplankton because of their appropriate cell size, high digestibility, and balanced supply of essential nutrients and vitamins (Ahmed et al., 2024). However, the better growth performance in the mixed diet indicates the interactive effect between the live microalgae and yeast. Baker's yeast generally offers a concentrated and readily absorbable energy source, which reduces the energy cost associated with continuous filtration and digestion of microbial cells. Furthermore, yeast enhances the supply of amino acids and other nutrients to zooplankton, thereby promoting faster growth and improving reproductive performance. Similarly, Hena et al. (2025b) demonstrated that the combined diet of live microalgae and baker's yeast enhanced population growth and egg production by increasing the supply of easily absorbable energy and supporting rapid metabolic turnover. Additionally, the synergistic effects of a combined diet (live *Monoraphidium littorale* and baker's yeast) have also been reported in copepods by Ritu et al. (2023a). Yeast supplementation with different algal species has been consistently shown to enhance growth and reproductive performance in various zooplankton taxa.

Live *Scenedesmus* sp. alone showed the second-highest growth and reproductive performance among all diets tested. The favourable cell size and enriched biochemical composition collectively promoted higher population growth and egg production. Powdered *Scenedesmus* sp. also demonstrated significantly better results than baker's yeast when

used alone, indicating its potential as an alternative diet where live microalgae are not available. This observation is consistent with earlier studies by Peña-Aguado et al. (2005) and Akter et al. (2013), who reported that dried algal diets contain sufficient nutritional value to support zooplankton growth and reproduction and are superior to solely yeast-based diets. On the other hand, the possible reasons behind the relatively poor performance of baker's yeast as a sole feed may include its rigid mannoprotein-rich cell wall, limited digestibility, and deficiency of essential polyunsaturated fatty acids, which are important for the growth and reproduction of zooplankton (Coutteau et al., 1990; Nagata and Whyte, 1992; Hena et al., 2025b).

Despite these limitations, baker's yeast minimizes the reliance on large-scale microalgal culture systems and thus reduces zooplankton production costs. When incorporated with live microalgae, yeast can provide higher zooplankton yields while enhancing economic feasibility (Hena et al., 2025a and 2025b; Ritu et al., 2023a). Taken together, the present findings suggest that live *Scenedesmus* sp., especially when supplemented with baker's yeast, represents a nutritionally balanced and economically viable dietary strategy for the mass culture of copepods, cladocerans, and rotifers.

Conclusion

The study demonstrated that the growth and reproductive success of zooplankton depend not only on the dietary quality but also on the form and combinations of diets. Across all tested zooplankton groups, the combined diet of live *Scenedesmus* sp. and baker's yeast consistently resulted in superior zooplankton productivity compared to other single-source diets. These responses show that, besides nutritional adequacy, feeding accessibility and energy availability are also essential for achieving successful zooplankton culture. The variation in sensitivity among different zooplankton taxa suggests the need for species-specific feeding strategies. From a practical perspective, the inclusion of baker's yeast with live microalgae offers a cost-effective,

optimized, and efficient zooplankton culture strategy without compromising biological productivity.

Acknowledgment

We are grateful to the Bangladesh Academy of Sciences (BAS) - United States Department of Agriculture (USDA) for their financial support through the project (5th Phase BAS-USDA BAU FI-03) granted to Saleha Khan. We are also thankful to the Bangladesh Agricultural University Research System (BAURES) authority for their help in the smooth operation of this research project.

Authors contribution

Md. Milon Sarker: Investigation, Methodology, Formal analysis, Validation, Visualization, Writing-original draft, review & editing. Sadia Momota Hena: Methodology, Formal analysis, Writing- original draft, review & editing. Md. Al-Amin: Investigation, Methodology. Mohammad Ariful Islam Sumon: Investigation, Methodology. Md. Shahjahan: Validation, Writing- review & editing. Md. Mahfuzul Haque: Conceptualization, Writing- review & editing. Saleha Khan: Conceptualization, Funding acquisition, Project administration, Supervision, Resources, Writing- review & editing.

Conflict of interest

The authors declare no conflict of interest.

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