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(Research Article)

Joint production of Rotifers, Copepods and Cladocerans from the excrement of animals raised in Daloa, Midwest Côte d'Ivoire

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Abstract

Rotifers, Copepods, and Cladocerans are essential and irreplaceable food sources for successful fish larviculture. However, little is known about the production of these zooplankton organisms in fish farms in Daloa. This study aimed to provide information on zooplankton production in Daloa. Zooplankton organisms were cultivated in 12 plastic tanks for 40 days. Production was carried out in four environments, each with three replicates: an environment fertilized with dry broiler chicken manure mixed with rice husks, an environment with dry cattle manure, an environment fertilized with a mixture of these two fertilizers, and an unamended environment used as a control. All of these environments were seeded with phytoplankton and then zooplankton (296 ind./L). Physicochemical parameters were measured and zooplankton samples were taken daily. The results indicate that the highest zooplankton densities were obtained in the control environment (212,062 ind./L) and those fertilized with dry cow manure (197,515 ind./L). The environments fertilized with dry broiler chicken manure mixed with rice husks and those fertilized with a mixture of the two fertilizers, with densities of 67,478 ind./L and 44,716 ind./L, respectively, were the least productive. The structure of the zooplankton communities indicates a high abundance of Rotifers compared to Copepods and Cladocerans in all culture environments. The daily production of these organisms was not only abundant but also more consistent in environments fertilized with dry cow manure. Thus, cow manure proves to be a good fertilizer for the joint production of Rotifers, Copepods, and Cladocerans.

Keywords: Animal excrement; Production of Rotifers, Copepods and Cladocerans; Plastic Containers; Daloa

1. Introduction

The gradual depletion of natural aquaculture resources is now prompting populations to resort to domestication and controlled production of biological organisms in order to meet growing demand for animal protein. In this context, fish farming is emerging as a strategic and lucrative activity in many African countries [1]. However, the success of this sector depends largely on the availability of high-quality fry, which is closely linked to the use of live feed, particularly zooplankton, which is essential for the initial feeding of small-egg species [2], [3]. These species have a small yolk sac that is quickly absorbed [4], making the exogenous supply of zooplankton prey crucial to ensuring their survival and optimizing their growth [5], [6], [7], [8]. This contribution of zooplankton to the profitability of fish farming has increased interest in its cultivation. Zooplankton cultivation has thus spread to several Asian countries [9], European countries [10], [11] and American countries [12]. In these countries, zooplankton production is generally based on the use of brewer's yeast. In Africa, zooplankton organisms are generally produced from poultry manure, cow dung, or pig slurry [13], [14]. In Côte d'Ivoire, despite the importance of the fish farming sector and the presence of numerous

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hatcheries and aquaculture farms, very little research has been devoted to mastering simple, low-cost techniques for zooplankton production [15]. This scientific gap is an obstacle to the development of sustainable and competitive fish farming. The present study is part of this perspective and aims to test the effectiveness of two types of organic fertilizers: poultry manure and cow dung, applied alone or in combination, to stimulate the production of zooplankton communities under natural conditions in Daloa. The objective is to propose an accessible approach, adapted to local realities, and likely to increase the availability of live feed for fish farmers in Côte d'Ivoire.

2. Materials and methods

2.1. Experimental materials

The study was conducted in 12 plastic containers with a capacity of 45 L each, placed outdoors. Each container held a mixture of 30 L of well water and 10 L of pond water. Two types of locally available organic fertilizers were used, namely dried cow manure and dried broiler chicken manure mixed with rice husks. Before use, these fertilizers were sanitized by heat treatment to reduce the microbial load. In addition, phytoplankton and zooplankton, collected from a pond in Daloa with very green water, were used to seed the environments (tanks).

2.2. Experimental setup

Four treatments were tested, each in three replicates, for a total of 12 tanks

- Dry broiler chicken droppings mixed with rice husks: 600 g/m^3;
- Dried cow manure: 25 g/m^3;
- Mixture of the two fertilizers: 300 g/m^3 (600 g/m^3 of manure + 25 g/m^3 of dung);
- Control: unfertilized trays.

2.3. Plankton cultivation

Phytoplankton: On the fourth day after fertilization, the tanks were seeded with phytoplankton harvested from a pond with very green water. This plant plankton was obtained by filtering 20 L of water from this pond, first using a plankton net with a 50 µm mesh size, then another with a 20 µm mesh size. The net retentate was concentrated to 200 mL in a pill bottle, then distributed in 15 mL volumes to each of the 12 tanks.

Zooplankton: Three days later, zooplankton was harvested from the same pond by filtering 20 L of water from this environment using the 50 µm plankton net. The net retentate was concentrated to 200 mL. Each of the 12 tanks was seeded with 15 mL of this concentrate, then another 15 mL subsample was fixed in alcohol for counting under a photonic microscope. Each tank was thus seeded with average densities of 76 ind./L of Rotifers, 68 ind./L of Copepods, and 152 ind./L of Cladocerans, for a total density of 296 ind./L of zooplankton organisms per tank.

2.4. Physicochemical characterization of the tanks

Physicochemical parameters such as temperature, pH, conductivity, and turbidity were measured from the day the tanks were seeded with zooplankton. These parameters were then measured daily in situ between 10 a.m. and 12 p.m. Temperature and pH were measured using a pH meter, and conductivity and turbidity were measured using a digital conductivity meter (waterproof EC/TDS tester).

2.5. Zooplankton harvest

Zooplankton organisms were harvested daily from the 7th day of culture [16] for a period of 33 days. Each day, 10 L of water was sampled from each of the culture tanks, which had been thoroughly homogenized beforehand. The water taken was first filtered through a 250 µm mesh sieve to remove the substrate, then through a 50 µm mesh plankton net to retain the zooplankton organisms. The permeates and substrates are returned to the culture tanks after filtration. However, in order to maintain the culture in the long term, a volume of 10 L of water from the culture tanks was replaced by its equivalent in borehole water every five days [17]. For each tank, the net retentate was concentrated to 100 mL in a pill bottle and fixed by adding a 70% ethyl alcohol solution.

2.6. Evaluation of the density of zooplankton organisms produced

The sediment from each 10 mL subsample of each concentrate was observed, little by little, under a photonic microscope, and the zooplankton organisms were systematically counted. The population density was determined based on these counts [16].

2.7. Statistical processing

The data were processed using STATISTICA 7.2 statistical software and the densities using Excel software (Microsoft Office 2013). Kruskal-Walli's comparison tests and Mann-Whitney tests were applied at a significance level of 5% between values.

3. Results

3.1. Physicochemical characteristics of the tanks

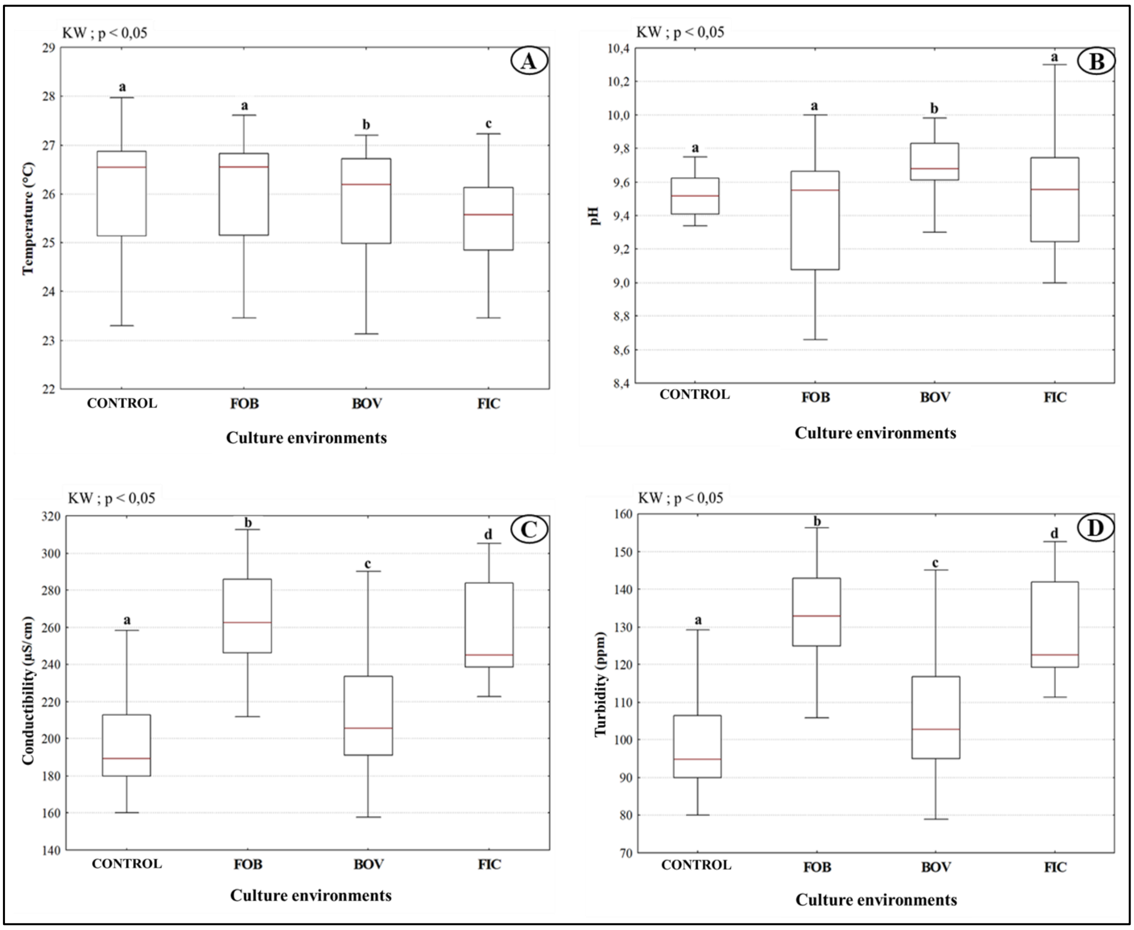

Figure 1 Variation in temperature (A), pH (B), conductivity (C), and turbidity (D) in zooplankton culture environments

CONTROL = unfertilized environment; BOV = environment fertilized with cow manure; FIC = environment fertilized with broiler chicken manure mixed with rice husks; FOB = environment fertilized with broiler chicken manure mixed with rice husks and cow manure.

The temperature ranged from 23.3 to 28°C in the CONTROL environment, from 23.5 to 27.7°C in the FOB environment, from 23.1°C to 27.2°C in the BOV environment, and from 23.5 to 27.2°C in the FIC environment. A significant difference was recorded between the temperature variations of the culture media (Kruskal-Wallis test, $p < 0.05$). Analysis of temperature variation in the different culture environment revealed a higher temperature value in the CONTROL environment (median = 26.6°C) and a lower value in the FIC environment (median = 25.6°C). However, no significant difference was noted between the CONTROL and FOB environment (Mann-Whitney test, $p > 0.05$).

The pH values ranged from 9.34 to 9.76 in the CONTROL environment, from 8.64 to 10 in the FOB environment, from 9.3 to 9.98 in the BOV environment, and from 9 to 10.3 in the FIC environment. A significant difference was recorded between the pH variations of the culture environment (Kruskal-Walli's test, $p < 0.05$). However, no significant difference between the CONTROL, FOB, and FIC environment was observed (Mann-Whitney test, $p > 0.05$). The variation in pH indicates that the water in BOV environment (median = 9.66) is relatively more basic than that in other culture environment.

Conductivity values ranged from 212 to 314 µS/cm in FOB environment and from 223 to 306 µS/cm in FIC environment. In the CONTROL and BOV environment, the values ranged from 160 to 258 µS/cm and from 158 to 290 µS/cm, respectively. The variations in conductivity showed a significant difference from one culture environment to another (Kruskal-Wallis test, $p < 0.05$).

Turbidity values ranged from 91 to 157 ppm in FOB environment and from 112 to 154 ppm in FIC environment. In the CONTROL and BOV environment, turbidity ranged from 80 to 129 ppm and 78 to 145 ppm, respectively. Turbidity variations were significantly different from one culture environment to another (Kruskal-Wallis's test, $p < 0.05$) (Figure 1).

3.2. Density of zooplankton organisms produced

The highest densities of zooplankton produced were observed in the CONTROL (212,062 ind./L) and BOV (197,515 ind./L) environments. The FIC and FOB environments, with densities of 67,478 ind./L and 44,716 ind./L respectively, were the least productive. In all culture environments, Rotifers were the most abundant. In the CONTROL and BOV environments, these Rotifers were followed by Cladocerans and then Copepods in terms of density. In contrast, in the FIC and FOB environments, Copepods were the second most abundant species after Rotifers. In the CONTROL environments, the density of Rotifers (113,166 ind./L) was almost double that of Cladocerans, while the density of Copepods was 43,858 ind./L. In BOV environments, the density of Cladocerans (63,267 ind./L) was three-quarters that of Rotifers. Copepods density was 49,172 ind./L. In FIC environments, Rotifers density was 26,943 ind./L, compared to 24,439 ind./L and 18,268 ind./L for Copepods and Cladocerans, respectively. In FOB environments, the densities of the three groups of zooplankton organisms were almost identical, with values around 16,000 ind./L (Figure 2).

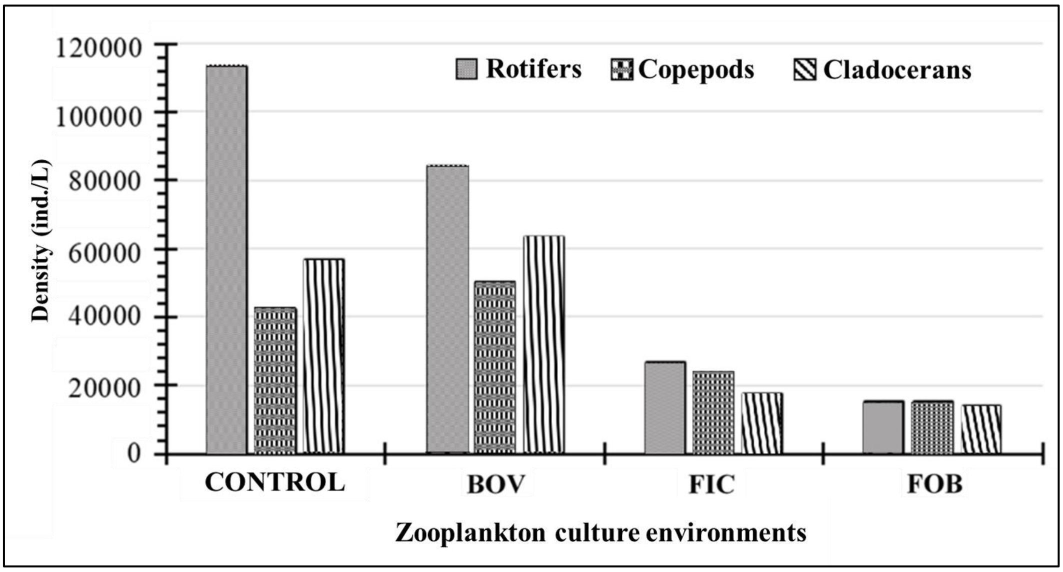

Figure 2 Densities of different zooplankton groups in culture environments

CONTROL = unfertilized environment; BOV = environment fertilized with cow manure; FIC = environment fertilized with broiler chicken manure mixed with rice husks; FOB = environment fertilized with broiler chicken manure mixed with rice husks and cow manure.

3.3. Daily changes in the densities of different groups of zooplankton organisms in the culture environment

3.3.1. Control environment

The density of Rotifers increased rapidly, reaching 6,760 ind./L on the 7th day of harvesting. This was followed by fluctuations in the density of these organisms until the 23rd harvest, when it reached 4,720 ind./L. However, after this harvest, the density of this zooplankton group gradually decreased, reaching 720 ind./L at the end of the experiment. The density of Copepods, meanwhile, rose from 68 ind./L on the day of loading to around 1,400 ind./L at the end of the experiment. The density of Cladocerans remained very low, below 152 ind./L, from the first harvest to the 16th harvest. From the 17th harvest onwards, the density of these crustaceans increased (Figure 3).

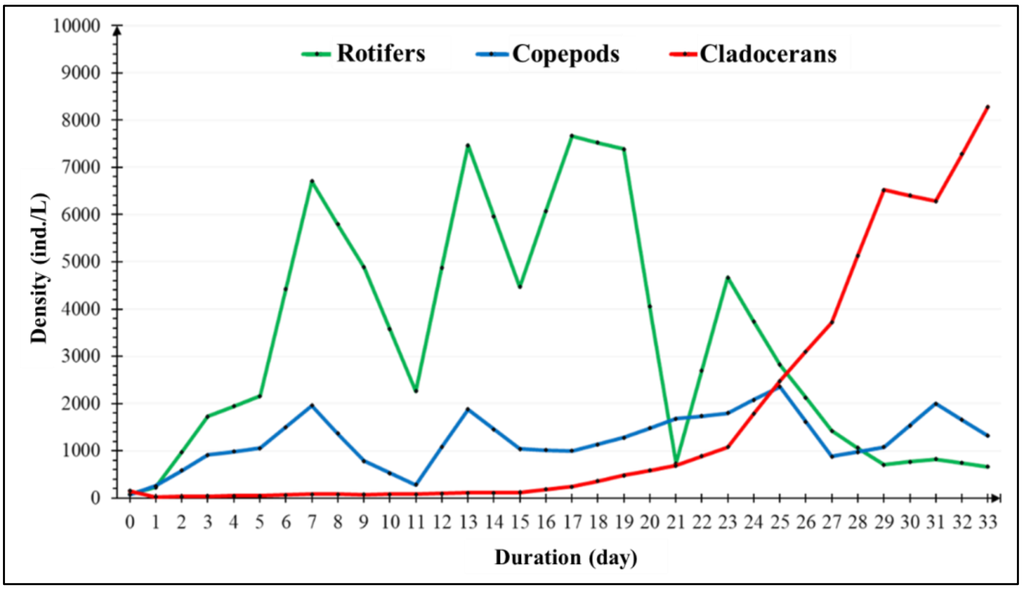

Figure 3 Changes in the densities of different zooplankton organisms in unfertilized environments

0 = day zooplankton was added; 0 to 1 (one week) = zooplankton proliferation time; 1 to 33 = zooplankton harvest days

3.3.2. BOV environment

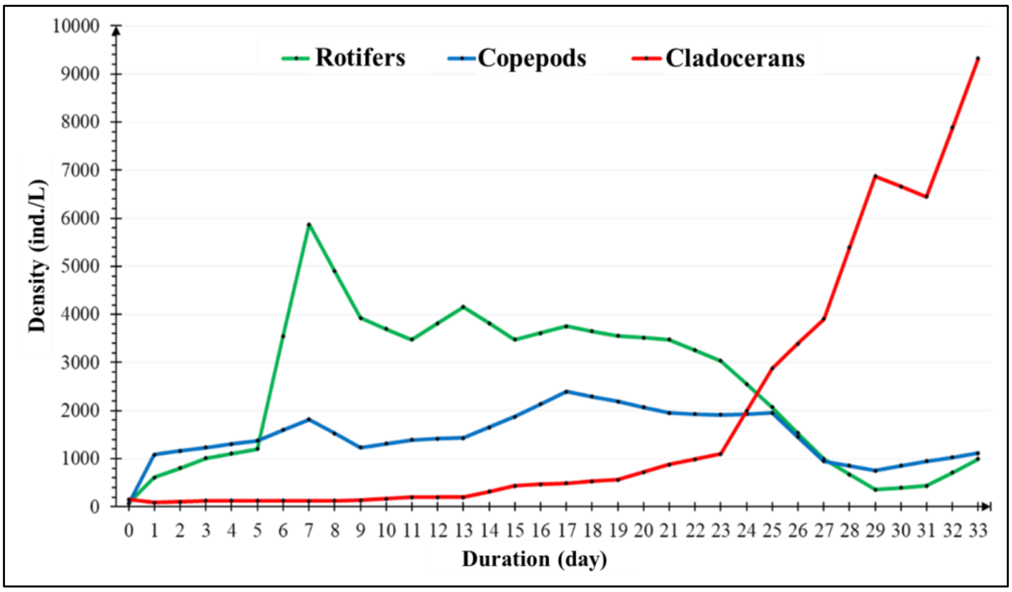

Figure 4 Changes in the densities of different zooplankton organisms in environments fertilized with cow manure

0 = day zooplankton was added; 0 to 1 (one week) = zooplankton proliferation time; 1 to 33 = zooplankton harvest days

The density of Rotifers increased rapidly during the first seven harvests, rising from 76 ind./L to 5,875 ind./L. This density then fell gradually to 400 ind./L by the 29th harvest, before increasing slightly to reach 1,000 ind./L at the end of the experiment. Copepod density increased gradually until the 25th harvest, rising from 68 ind./L to 2,000 ind./L. After the 25th harvest, the density of these organisms gradually fell to around 1,000 ind./L at the end of the experiment. The density of Cladocerans remained virtually constant at around 152 ind./L until the 9th harvest. However, from the 10th harvest onwards, the density of these organisms gradually increased to reach more than 9,300 ind./L at the end of the experiment (Figure 4).

3.3.3. FIC environment

The density of Rotifers increased gradually, reaching 1,200 ind./L at the seventh harvest. After this harvest, the density of these animals fluctuated irregularly until the 17th harvest, when it reached 1,680 ind./L. This density then gradually fell to 320 ind./L at the end of the experiment. Similar to the evolution of Rotifer density, Copepod density gradually increased to reach its maximum (1,440 ind./L) at the 11th harvest, before evolving irregularly until the 21st harvest. After this harvest, the Copepod yield in the FIC tanks fell to 640 ind./L by the end of the experiment. The density of Cladocerans remained below the loading density (152 ind./L) and almost constant until the 12th harvest. From the 13th harvest onwards, the density of these microcrustaceans gradually increased, reaching 2,120 ind./L at the end of the experiment (Figure 5).

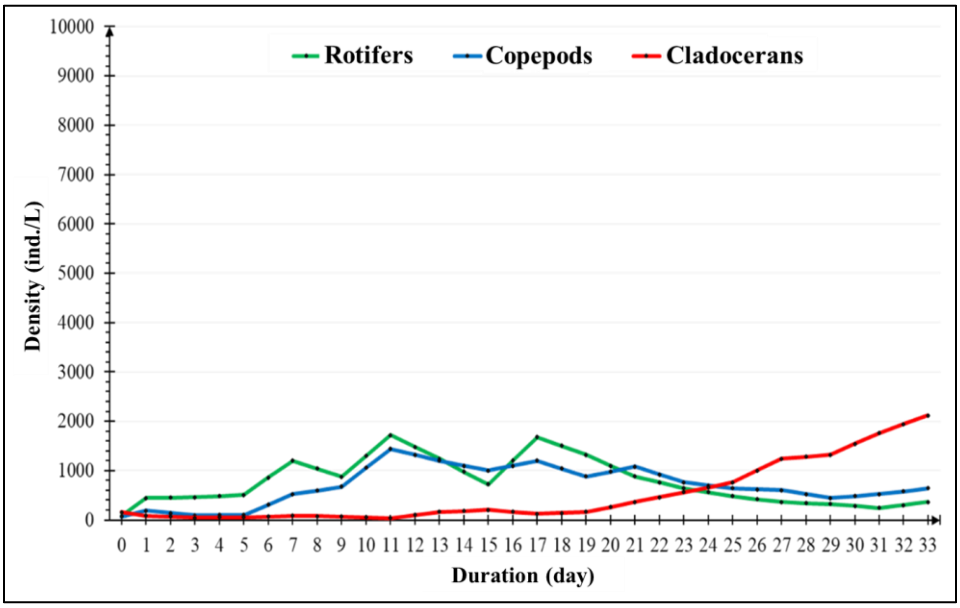

Figure 5 Changes in the densities of different zooplankton organisms in environments fertilized with broiler chicken manure

0 = day zooplankton was added; 0 to 1 (one week) = zooplankton proliferation time; 1 to 33 = zooplankton harvest days

3.3.4. FOB environment

The density of Rotifers fluctuated irregularly until the 13th harvest, when it reached 880 ind./L. This density decreased steadily to 440 ind./L at the end of the experiment. The Copepod density fluctuated irregularly throughout the culture, with peaks of 538 ind./L, 567 ind./L and 641 ind./L observed at the 5th, 17th, and 21st harvests, respectively. The density of Cladocerans, which remained low compared to the initial density (152 ind./L), remained constant at around 100 ind./L until the 19th harvest. It was only from the 20th harvest onwards that a gradual increase was observed, reaching 1,880 ind./L at the end of the experiment (Figure 6).

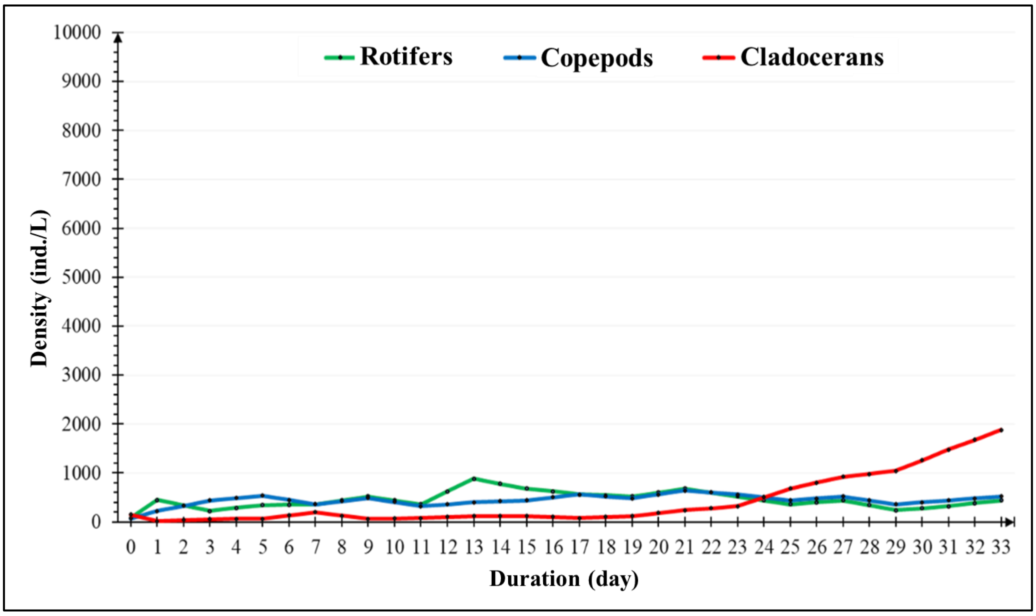

Figure 6 Changes in the densities of different zooplankton organisms in environments fertilized with a mixture of cow manure and broiler chicken manure

0 = day zooplankton was added; 0 to 1 (one week) = zooplankton proliferation time; 1 to 33 = zooplankton harvest days

4. Discussion

The joint cultivation of Rotifers, Copepods and Cladocerans in different environments showed that unfertilized environments (CONTROL environments) and those fertilized with cow manure (BOV environments) performed well in the production of these zooplankton organisms. Environments fertilized with dry broiler chicken manure mixed with rice husks (FIC environments) and those fertilized with a mixture of dry broiler chicken manure mixed with rice husks and cow manure (FOB environments) were the least productive. The zooplankton production performance in the CONTROL and BOV environments was linked to the physical and chemical state of the production environment. The water in these environments had lower turbidity than in the FIC and FOB environments, allowing better penetration of sunlight into the water column. This increased transparency stimulated the proliferation of phytoplankton, which, in addition to being an essential food source for zooplankton organisms, contributed to enriching the environment with dissolved oxygen, thereby improving overall production conditions. In addition, the FIC and FOB environments contain rice husks, which release silicic acid when they dissolve in water. This acid makes the water somewhat opaque, preventing sunlight from penetrating sufficiently into the water column [18]. These results, relating to the high production of the CONTROL and BOV environments, differ from those of [13], who found the highest densities of zooplankton organisms in environment fertilized with poultry manure. The same is true for [1], who obtained the highest densities of zooplankton organisms in environments fertilized with pig manure than in unfertilized environments. These differences are thought to be related to the physical environment and chemistry of the culture environment. In the present experiment, the water in the FIC and FOB environments was dark in appearance. This physical state of the water, probably caused by the presence of rice husks in the water, may have prevented optimal zooplankton production [19]. Indeed, the reproduction of zooplankton organisms is strongly influenced by light intensity. These organisms require well-lit water to reproduce more effectively [19]. The opacity or turbidity of the water in these FIC and FOB environments would have prevented it from warming up, making the water too cold and unsuitable for optimal zooplankton reproduction. However, according to [20], zooplankton organisms only reproduce significantly in warm water environments.

In the various culture environment, the zooplankton organisms produced were dominated by rotifers. This dominance of Rotifers is thought to be linked to their diet. Rotifers feed on bacteria, phytoplankton, and particulate organic matter present in the water, and these food sources actively promote their proliferation. The results of this study regarding the dominance of Rotifers over Copepods and Cladocerans are consistent with those of [21], [22] and [23] whose work has shown that rotifers account for more than 60% of the total abundance of zooplankton in the environments studied.

The density of Rotifers did not remain consistently higher than that of other zooplankton organisms in this experiment. In each culture medium, the density of Rotifers fell dramatically after four weeks of culture. This drop in density coincided with a sharp increase in Cladoceran density, which for three weeks had been almost negligible compared to Rotifer density and lower than Copepod density. This situation is thought to be due to the availability of nutrients. These results differ from those of [1], who, having seeded their environments with Rotifers, Copepods and Cladocerans at densities of 13 ind./L, 28 ind./L and 11 ind./L, respectively, noted a greater decline in Cladocerans than in Rotifers and Copepods towards the end of their experiment. This difference in results could be summarized as the availability of nutritional resources and predation. In addition, the simultaneous presence of Copepods and Cladocerans could accentuate this decline through food competition and predation, as certain juvenile stages of Copepods are known to actively consume Rotifers [8]. Copepods, which are essentially predators, attack prey according to the size and nutritional value of the food available in the environment [24]. According to [25], Cladocerans are prized by Copepods as a food rich in protein and fatty acids. At the time of zooplankton seeding, Cladocerans were the most numerous (152 ind./L of Cladocerans compared to 76 ind./L of Rotifers and 52 ind./L of Copepods). The decline in Cladocerans density after seeding is therefore likely due to predation pressure from Copepods. This targeted predation of Cladocerans by Copepods reduces trophic competition between Cladocerans and Rotifers, both of which are filter feeders, suspensivores, feeding mainly on algae [26]. This phenomenon then becomes a boon for Rotifers, which, now finding themselves with a more than sufficient supply, reproduce actively. The density of Rotifers had become too high in culture environment, suggesting that they were not being ingested by Copepods. In reality, Copepods, for the most part, continuously consume Rotifers and young crustaceans, in this case Cladocerans, captured in their habitat [27]. However, this ample supply cannot guarantee 100% survival of these organisms beyond four weeks in culture media. Finally, the short biological cycle of Rotifers, characterized by rapid generational renewal and natural decline after a peak in proliferation, also contributes to this dynamic. Indeed, Rotifers have a lifespan of between three and six weeks [28]. With the density of Rotifers having fallen sharply following the death of many of them, Cladocerans now become the masters of nutrient resources. These organisms therefore easily consume phytoplankton and reproduce actively in the environment. Copepods, no longer able to control the Cladocerans, which had become too numerous, attacked the surviving Rotifers, leading to a decline in the density of these tiny animals towards the end of the experiment. All of these factors explain the rapid decline in Rotifer populations after three weeks of culture, a phenomenon already described in similar experiments in West Africa [16], [1].

However, before the end of this experiment, the densities of Rotifers and Copepods remained relatively high and almost constant in the different culture environment for a long time (for nearly three weeks after seeding). The same was true for Cladocerans, whose density remained constant, albeit very low, for just over three weeks of culture. These results are thought to be related to the method used to harvest the zooplankton. Harvesting was carried out daily, while 10 L of water from the culture environment was replaced with an equivalent amount of fresh water every four or five days. According to [29], this harvesting technique allows the densities of organisms to be kept at maximum levels in the environment for several days. These results are similar to the work of [30] and [8], who noted a maximum and stable density of zooplankton organisms for more than 30 days despite daily harvesting periods.

5. Conclusion

The yield of culture media in Rotifers, Copepods and Cladocerans can vary depending on the ecological requirements of these zooplankton organisms. In this study, unfertilized environment (CONTROL environment) and environment fertilized with cow manure (BOV environment) produced high densities of zooplankton. environment fertilized with dry broiler chicken manure mixed with rice husks (FIC environment) and those fertilized with a mixture of FIC environment substrate and cow manure (FOB environment) were less conducive to the development of zooplankton organisms. In all culture environment, rotifer density was highest. However, zooplankton densities were more stable in BOV environment.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

Statement of ethical approval

This article does not contain any studies involving human or animal subjects.

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