Effects of Dactylogyrus spp. Co-infection on Mortality in Two Oreochromis niloticus Strains and Evaluation of Potassium Permanganate Treatment Efficacy for Sustainable Aquaculture Development

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Abstract. This study examined the impact of co-infection with *Dactylogyrus spp.* on the mortality of two strains of Nile tilapia (*Oreochromis niloticus*), the gray and red strains, under controlled aquaculture conditions. Over a seven-month period, 65 juveniles of each strain were monitored for growth, survival, and parasite infection levels. The results showed that the red strain significantly outperformed the gray strain in terms of growth (83.8 g vs. 51.3 g final weight) and survival (97% vs. 70%), mainly due to its greater resistance to *Dactylogyrus spp.* infections and environmental stressors. To ensure the survival of these individuals, we used potassium permanganate ($KMnO_4$) treatment; this demonstrated a rapid reduction in parasite load, thus improving fish health. This research highlights the importance of strain selection and effective parasite management to improve the productivity and sustainability of tilapia aquaculture, thereby contributing to sustainable energy and environmental protection.

1 Introduction

Tilapia (Oreochromis niloticus) is the leading species in African commercial fish farming, thanks to its economic and ecological significance in African water bodies and aquaculture systems [1]. This species is highly valued not just for its ability to adapt to various environmental conditions but also for its role in supporting sustainable aquaculture. As one of the most widely farmed fish species, tilapia plays a key role in the global aquaculture industry, with increasing demand from both farmers and consumers. Of the different tilapia species, Oreochromis niloticus is the most studied and widely cultivated. Its popularity is due

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to its strong market demand, ease of reproduction, fast growth, and resilience in various farming conditions. The species is often referred to as the "precious stone" of African fish farming, highlighting its widespread use and its crucial role in food security and economic development [2].

Nile tilapia stands out for its remarkable adaptability to various environmental conditions. It thrives in both freshwater and brackish water and can withstand a wide range of temperatures and salinity levels [3]. Additionally, Oreochromis niloticus is capable of enduring the stress associated with handling and intensive farming, making it an excellent choice for aquaculture. The species is also highly productive in terms of reproduction, capable of breeding prolifically in captivity, which further contributes to its widespread use in fish farming [4].

Despite these advantages, tilapia farming faces several challenges, particularly from diseases that impact farmed populations worldwide. Pathogens that have a significant effect on tilapia include bacterial diseases like Streptococcus agalactiae, S. iniae, Flavobacterium columnare, and Francisella spp., as well as viral diseases, especially iridovirus, and parasitic infestations caused by both monogeneans such as Dactylogyrus spp. and external protozoa like Trichodina spp. and Chilodonella spp. These pathogens are prevalent in tilapia farming regions, including North Africa, and contribute to high rates of disease and mortality in tilapia populations. Parasitic infections like Dactylogyrus are particularly damaging, negatively affecting fish health, growth, and survival . Tackling these challenges is essential for ensuring the sustainability and productivity of tilapia farming, as the species continues to be a cornerstone of global aquaculture [5].

Given these issues, ongoing research is vital to better understand the complex interactions between tilapia and its pathogens, especially in regions like North Africa, where diseases pose a serious threat to aquaculture. By improving disease management practices, breeding disease-resistant strains, and gaining a deeper understanding of pathogen dynamics, we can improve the health and productivity of tilapia farms around the world.

This article compares the growth and survival rates of two strains of Nile tilapia (Oreochromis niloticus), the gray and red strains, under controlled aquaculture conditions. The research examines the differences in resistance between these strains, focusing on parasitic infections caused by Dactylogyrus spp., which contribute significantly to the higher mortality observed in the gray strain. The study aims to understand how the varietal differences affect the growth and survival of these tilapia strains, while also considering the ecological factors and parasitic infections that could influence fish health."

2 Materials and methods

The research was carried out between October 2023 and April 2024, aiming to assess the impact of Dactylogyrus spp. co-infection on the mortality rates of two strains of Nile tilapia (Oreochromis niloticus). The study was conducted in a controlled environment to ensure consistency in the conditions for both strains, with particular attention given to water quality and parasite identification.

2.1 Water Quality Evaluation

The study relied on a comprehensive water quality evaluation to ensure optimal rearing conditions for the Nile tilapia. This evaluation was essential to maintain the health and growth of the fish, as various water parameters influence both fish performance and pathogen dynamics.

Water quality analysis was performed by the laboratory of the National Drinking Water Office, which provided detailed and reliable data on the following parameters

Table. 1: Physicochemical water quality parameters for tilapia farming compared to recommended standards.

Parametres	**Results**	**Water quality required for breeding Tilapia [5]**
Temperature (°C)	27	26 – 29
pH	7.20	6.5 – 7.3
Dissolved oxygen (mg/l)	4	3 –10
Electical condictivity (uS/cm^2)	1335	1455
TH (meq/l)	8.96	50 – 250
alkalimetric title (meq/l)	0	<175
Chloride (mg /l)	250.3	0-400
Nitrat (NO_3^-)(mg /l)	13.8	5-18
Nitrit (NO^-_2) (mg /l)	1.5	< 2,1
Salinity	6	1 – 8
Phosphate (PO_4) (mg/l)	0.1	0.2

2.2 Biological species

The study focused on two strains of Nile tilapia (Oreochromis niloticus), specifically the "gray" and "red" strains, which were raised at the breeding station of the Aquaculture Laboratory at the Higher Institute of Maritime Fisheries in Agadir. The study began with 65 juvenile.

A total of 65 juvenile fish tilapia weighing between 10 to 20 grams of two strains (gray and red), were used in this study to assess the impact of Dactylogyrus spp. co-infection on the mortality and growth rates of Nile tilapia. The fish were reared in two separate, well-controlled 0.5 m³ tanks, which served as experimental basins. Each tank was designed to mimic the conditions of a typical aquaculture system, with continuous monitoring of water parameters to ensure consistency and optimal conditions for the fish.

The tanks were set up in a closed-loop system to prevent contamination and ensure a stable environment for the fish. This closed system included appropriate filtration and water circulation mechanisms to maintain water quality throughout the study period.

2.3 The identification of parasitic

The identification of parasitic infestations, particularly Dactylogyrus spp., was crucial to understanding its role in the mortality rates of the tilapia strains. Parasite identification was carried out at the Physiology and Oceanography Laboratory at the Higher Institute of Maritime Fisheries in Agadir.

Sampling Method: Fish were regularly sampled from the tanks twice a month. A total of 20 fish from each strain were randomly selected for inspection. These fish were euthanized using 0.02% phenoxyethanol, and their gills and external body parts were carefully examined for signs of parasitic infection. Samples from infected fish were prepared for microscopic examination.

Microscopic Analysis: The external parasites were identified using standard parasitological methods, including wet mount preparations and staining techniques. The presence of Dactylogyrus spp. was confirmed by its characteristic morphology, including its anterior attachment organs (haptor) and egg-bearing structures [6].

2.4 Experimental device

The experiment was conducted in two 0.5 m^3 rearing tanks, each supplied with water that met the necessary conditions for tilapia cultivation. Growth performance was primarily measured in terms of the specific growth rate (%/day), focusing more on the weight change over the duration of the breeding cycle than on the absolute difference between the initial and final weights. Feeding was done manually twice daily once in the morning between 9:00 and 10:00 a.m. and again in the afternoon between 3:00 and 4:00 p.m. The daily feed amount was set at 5% of the estimated fish biomass, calculated from monthly sampling that included all size classes.

2.5 Determination of growth parameters

Each month, a sample of 20 fish was randomly selected from each tank using a net for measurement. The fish were anesthetized with 0.02% phenoxyethanol prior to being weighed individually using an electronic balance with 1 g precision, and their length was measured to the nearest millimeter using an ichthyometer. The offspring's number and weight were excluded from the calculations.

Growth parameters including average weight gain (GPM), daily weight gain (GPJ), specific growth rate (TCS), and survival rate (TS) were calculated based on the following equations:

The main parameter for the curve is the average weight as a function of time (days or months). Since growth is expressed by a specific growth rate (SGR), the weight at any time t can be approximated by an exponential growth function, because the SGR is generally calculated as follows:

$$W_t = W_0 \times e^{(r \times t)} \quad (1)$$

Where:

- W_t: weight at time t (in days)
- W_0: initial weight (10 g)
- r: specific daily growth rate in decimal form (e.g., 4.38% = 0.0438)
- t: time in days (from 0 to 210)

2.6 Treatment protocol

2.6.1 Potassium Permanganate ($KMnO_4$)

The chemical protocol used in this study involved potassium permanganate ($KMnO_4$), a potent oxidizing agent recognized for its efficacy in targeting and disrupting the cells of Dactylogyrus spp. Infected tilapia were subjected to a prolonged bath with a concentration of 2 mg/L of $KMnO_4$ for a duration of 4 to 6 hours. This treatment works by breaking down the cellular structure of the parasite, leading to a significant reduction in infection levels. However, the potential toxicity or stress effects of potassium permanganate on the fish were not discussed. Including a brief review or discussion of the known side effects, such as oxidative stress or damage to non-target organisms, as well as the safety thresholds for the use of $KMnO_4$ in aquaculture, would offer a more comprehensive and balanced perspective on the efficacy and safety of this treatment method.Sea Salt (NaCl) [7].

For the natural treatment protocol, sea salt (NaCl) was tested against Dactylogyrus spp.. Tilapia were subjected to a salt bath at a concentration of 20 to 30 g/L for 10 to 30 minutes. The use of sea salt works by causing dehydration in the parasites, effectively leading to their elimination from the fish's body. This treatment is less toxic to the fish compared to chemical agents and offers a gentler alternative for parasite management.

3 Results and discussions

Table 1 presents the measured physicochemical parameters generally indicate favorable conditions for the farming of Oreochromis niloticus, in accordance with the recommendations of [5] The temperature (27 °C) is optimal (26–29 °C) for metabolism and growth . The pH (7.20), neutral to slightly alkaline, promotes enzymatic stability and ionic availability Dissolved oxygen (4 mg/L) exceeds the minimum required threshold (>3 mg/L) but remains close to the lower limit, necessitating monitoring. Electrical conductivity (1335 µS/cm²) is close to ideal values, ensuring good osmotic balance.

Total hardness (8.96 meq/L) is below the recommended range (50–250 meq/L), suggesting a low supply of calcium and magnesium, which may affect osmotic regulation.The absence of alkalinity indicates a low buffering capacity, increasing vulnerability to pH fluctuations . Concentrations of chlorides (250.3 mg/L), nitrates (13.8 mg/L), and nitrites (1.5 mg/L) remain within non-toxic limits Salinity (6 ppt) is compatible with the euryhaline tolerance of tilapia. Finally, the low phosphate concentration (0.1 mg/L) reduces the risk of eutrophication [8].

Table 2 presents the average weights of the fish at the beginning and end of the experiment, along with the growth performance of the two strains of *Oreochromis niloticus*, including average weight gain, daily weight gain, specific growth rate, and survival rate.

Table. 2. Comparative Analysis of Growth Performance Parameters between Gray and Red Tilapia Strains

Parameter	Gray Strain	Red Strain	Scientific Interpretation
Average Initial Weight (g)	10 ± 0.6	10 ± 0.6	Similar initial weight, ensuring a fair comparison between strains.
Average Final Weight (g)	51.3 ± 0.2	83.8 ± 0.2	Significantly higher final weight in Red strain, indicating better growth performance.
Variation Coefficient (%)	23.45 ± 0.5	25.49 ± 0.5	Slightly higher variability in Red strain, possibly reflecting greater intra-group diversity.
Biomass (kg)	2.271 ± 0.15	3.45 ± 0.14	Total biomass is higher in Red strain, a key indicator of production efficiency.
Feed Conversion Rate (FCR %)	4.38 ± 0.5	5.24 ± 0.5	Gray strain converts feed slightly more efficiently, but statistical analysis needed to confirm significance.
Conversion Index	2.43	1.12	Red strain has a lower conversion index, meaning it requires less feed per unit of weight gain, indicating better feed efficiency overall.
Density (kg/m³)	3.025 ± 0.01	3.89 ± 0.01	Red strain supports a higher biomass density, showing good adaptation to intensive farming conditions.

Survival Rate (SR %)	70 ± 1.5	97 ± 1.7	Much higher survival in Red strain, suggesting greater resistance to stress and disease.

"ANOVA is used to analyze these results."

- ✧ Final weight: Perform a t-test to compare the final weight means between gray and red strains. Given that the red strain has a higher final weight (83.8 ± 0.2) than the gray strain (51.3 ± 0.2), we can hypothesize that a significant difference exists.
- ✧ Specific Growth Rate (TCS%): Perform a t-test to compare the TCS values (4.38% for gray and 5.24% for red). This will tell us if there is a statistically significant difference in growth rates between the strains.
- ✧ ·Conversion Index: The red strain has a much lower conversion index (1.12) compared to the gray strain (2.43). A t-test can confirm if this difference is statistically significant, meaning the red strain is more efficient at converting feed into biomass.
- ✧ Survival Rate (TS%): The red strain has a higher survival rate (97 ± 1.7%) compared to the gray strain (70 ± 1.5%). The t-test will indicate if this difference in survival is statistically significant

❖ **Proposed equations to model growth:**

- **Gray Strain (blue curve):** Growth can be modeled with a second-degree polynomial function (quadratic), since the growth shows a nonlinear trend with a temporary plateau:

$$W_j(t) = a_j t^2 + b_j t + c_j \quad (2)$$

t is the time in months since the starting date (23/11/2023).

- **Red Strain (red curve):**
Growth is faster and seems to follow an exponential growth with a plateau towards the end, so it can be modeled by a logistic or adjusted exponential function. Here, an exponential model moderated by a saturation term fits well:

$$W_a(t) = \frac{L}{1+e^{-k(t-t_0)}} \quad (3)$$

where:

- ◆ L is the maximum asymptotic value,
- ◆ K is the growth rate, and
- ◆ T_0 is the inflection point.

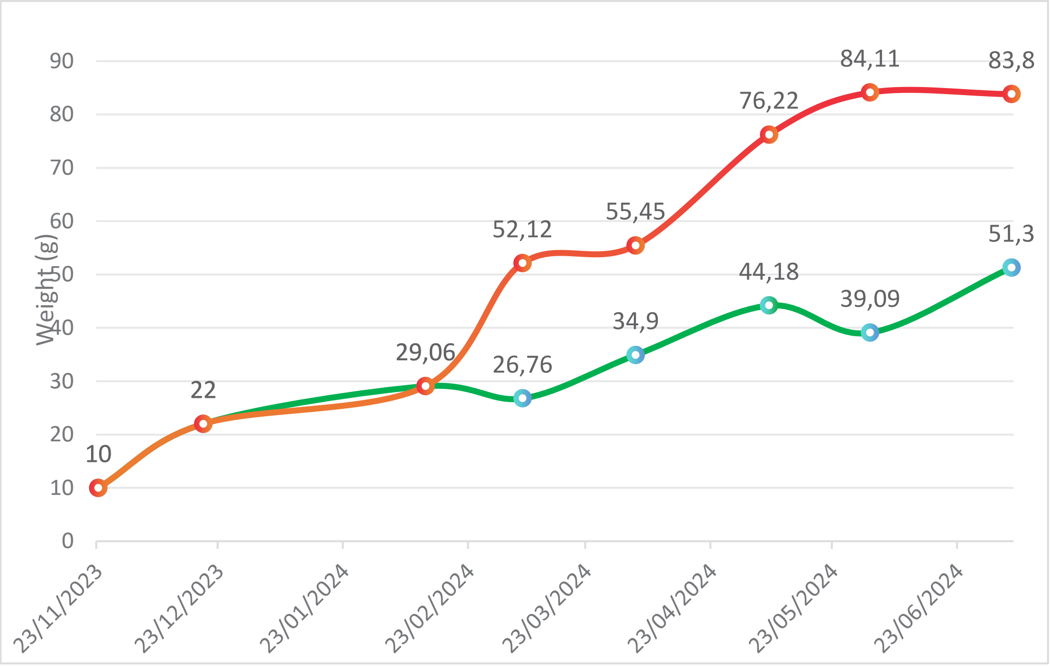

Fig. 1. Average weight growth of gray and red juveniles during the experimentation period.

The results of this study demonstrate significant differences in the growth and survival rates of two strains of Nile tilapia, specifically the red and gray strains, over a seven-month rearing period. The pronounced growth observed in both strains, especially in the red tilapia, highlights the critical role of strain selection in aquaculture for optimizing production outcomes [9;10]. (Fig1) show the growth of two varieties of tilapias. After seven months, the red tilapia achieved an average weight of 83.8 g, whereas the gray tilapia reached 51.3 g. This marked disparity reflects inherent genetic differences in growth potential and adaptability to intensive culture conditions. Tilapia exhibited marked growth progression beginning in November, consistent with growth patterns reported in similar tropical aquaculture environments [9]. Feed conversion efficiency, a key performance indicator in aquaculture, was evaluated using the feed conversion index (CI), which exceeded 1 for both strains. The red strain's CI of 1.12 indicates superior feed utilization compared to 2.43 for the gray strain, suggesting more efficient biomass production likely due to better metabolic efficiency and digestive capacity [10]. These results align with previously reported CI values for *Oreochromis niloticus*, such as 1.45 reported by [11].

Survival rates also differed substantially between strains, with the red strain showing a high survival rate of 95.8% ± 1.1%, contrasting with 70.4% ± 1.5% in the gray strain. This difference is primarily attributed to the gray strain's lower resistance to parasitic infections, notably *Dactylogyrus* spp., and its reduced capacity to cope with environmental stressors such as water quality fluctuations and feed variability [12]. *Dactylogyrus* spp. is a monogenean ectoparasite attaching to gill tissues, causing physical damage, inflammation, and secondary infections that increase mortality risk [9, 10]. The parasite impairs respiration, weakens fish, and reduces appetite, leading to pallor, excessive mucus secretion, and weight loss, as observed in infected gray tilapia [13].

The gray tilapia's reduced resistance is likely linked to a compromised immune response aggravated by ecological stressors [12], whereas the red strain displays a more robust immune defense, enabling better tolerance of parasitic and environmental challenges [14]

Chemical treatment using potassium permanganate ($KMnO_4$) has been recognized as an effective approach to control ectoparasitic infestations including *Dactylogyrus* spp. [12]. This study confirms the efficacy of $KMnO_4$ baths in rapidly reducing parasite loads, with recovery observed as early as the third day post-treatment. The strong oxidative properties of $KMnO_4$ disrupt parasite cell structures, thereby significantly diminishing infection levels and preventing further tissue damage [14]. Such results reinforce the historical success and widespread use of potassium permanganate in managing monogenean infestations in aquaculture.

4 Conclusion

This study shows that the red strain of tilapia (Oreochromis niloticus) outperforms the gray strain in terms of growth and survival rates, primarily due to its better resistance to Dactylogyrus spp. infections. The results also highlight the importance of feed conversion efficiency, with the red strain being more efficient. Potassium permanganate and sea salt treatments were effective in controlling parasitic infections, although potassium permanganate provided quicker results. This research underscores the importance of selecting resilient strains and effectively managing parasites to ensure the sustainable productivity of aquaculture.

Author Contributions:

Khadija O*uaissa* / developed the concept and aims of the study; Jamila B*ouchgl* /prepared and compared the literature; M'Hamed H*mamou* /prepared and compared the literature; Youssef E*nnaciri* / reviewed and checked the structure of the manuscript; Mustapha H*asnaoui*/ reviewed and checked the structure of the manuscript. All authors contributed to the final manuscript.

All authors have read and approved the manuscript.

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