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Feeding regimes influence growth, survival, morphometric indicators, and water quality correlations in *Betta splendens* (Super Red Plakat strain) fry

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Abstract. *Pramudia Z, Ismail A, Risqiana MA, Maimunah Y, Bahri AS, Setiawan AF, Kurniawan A, Irawandani TD. 2026. Feeding regimes influence growth, survival, morphometric indicators, and water quality correlations in* Betta splendens *(Super Red Plakat strain) fry. Biodiversitas 27 (1): d270114. https://doi.org/10.13057/biodiv/d270114.* The early larval stage is crucial for growth and survival in ornamental fish culture, yet feeding strategies for *Betta splendens* (Super Red Plakat strain) remain underexplored. This study evaluated the effects of five feeding regimes, comprising live prey and formulated diets on the morphometric growth and survival of *B. splendens* fry during a 28-day post-infusoria rearing period. Five dietary treatments: *Artemia* nauplii, *Alona* sp., *Moina* sp., *Daphnia magna*, and artificial pellets, with infusoria provided in all treatments during the first week. Survival rate (SR), total length (TL), and standard length (SL) were measured at the end of the experiment. Fry fed with *Artemia* nauplii and *Moina* sp. exhibited the highest survival (88-89%) and growth performance (TL up to 15.6 mm), while *D. magna* resulted in the lowest values. Statistical analysis confirmed significant differences among treatments. Water quality remained within optimal thresholds, ensuring reliable interpretation. Pearson correlation analysis showed strong positive associations among SR, TL, and SL, confirming that survival is closely linked to growth. Moderate correlations between DO and biological metrics suggest oxygen availability may indirectly influence performance. These findings highlight the importance of feed type and particle size compatibility with larval open-mouth for enhancing productivity in *B. splendens* hatchery practices. The use of *Artemia* or *Moina* during the post-infusoria stage can enhance hatchery yield by approximately 10-20%, providing practical guidance for sustainable *B. splendens* aquaculture and supporting SDG 14 (Life Below Water) through improved fry survival and responsible freshwater biodiversity management.

Keywords: *Betta splendens*, live feed, morphometric growth, survival rate, ornamental aquaculture

INTRODUCTION

The commercial *Betta* belongs to the anabantoid group (suborder Anabantoidei), which is predominantly found in freshwater habitats across Africa and Southeast Asia (Murray et al. 2024). The popularity was transformed from being bred only for aggression in Thailand, and therefore referred to as ‘fighting fish’. Modern strains are now primarily selected for ornamental traits such as vivid coloration and elaborate fins (Kwon et al. 2022; Watson et al. 2024).

In Indonesia, *Betta* sp. reached 211 tons in ornamental fish production, driven by the rising demand and global interest in Indonesia’s native ornamental fish in international markets, particularly for the endemic exotic fish, such as Asian arowana fish and wild *Betta* fish. These markets extended beyond Asia, reaching into American and European regions (Ministry of Marine Affairs and Fisheries 2024). Among the existing strains, the Plakat strain is particularly notable for its short and rounded tail type (Pebianti et al. 2023). Originating from Indonesia, the Super Red strain developed through selective breeding. It yielded intensified red pigmentation across entire body, enhancing its appeal in the ornamental fish market. What is in wild type is typically limited to pelvic, anal and caudal fins, positioned above a layer of black color (melanophores) (Kusumah et al. 2012).

The early larval stage is a critical period in fish development. The success in production of fingerling fish is heavily dependent on the availability of suitable live prey such as marine rotifer (*Brachionus rotundiformis* and *Brachionus plicatilis*) and *Artemia* nauplii (Lim et al. 2003; Ottersen et al. 2014; Tadeo and Veracruz 2018), open mouth of fish (Cahu and Infante 2001), which efficiently digests and provides the required nutrients to support good growth and health (Giri et al. 2002). However, reliance on live prey becomes impractical when its cultivation is challenging to sustain, requiring considerable space and expense, while formulated artificial diets are easier to maintain and typically involve lower production costs (Melaku et al. 2024). Numerous attempts have been made to partially or completely replace live prey with formulated diets in larval and post-larval shrimp. However, other studies also showed that total replacement of live diets has generally resulted in lower survival and growth (Brito et al. 2001). Especially, when fighter fish larvae are usually very small, extremely fragile and generally not physiologically fully developed (Srikrishnan et al. 2017).

Despite the commercial importance of *Betta splendens*, especially the Super Red Plakat strain, limited studies have compared the effectiveness of live prey versus formulated diets in *B. splendens* larvae, particularly in the Super Red Plakat strain, highlighting the need for further investigation into optimal feeding strategies for this commercially valuable variant. Besides the feed regimes, environmental factors such as water quality were closely related to survival rate and growth of the species commodity (Pramudia et al. 2022a; Serihollo et al. 2024).

Traditional morphometrics is one of the most widely used and fundamental approaches to assess biodiversity parameters and phenotypic variation, describing the phenotype among the population (Dwivedi and De 2024). Even recently developed methods like geometric morphometrics, which identify biological landmarks, enable the analysis of changes in fish size and shape over time, such as growth patterns observed across different developmental stages throughout the years (Kelly et al. 2024). Thus, morphometric parameters, for instance, total length and standard length, can serve as indicators to evaluate fish growth through changes in body size.

This study aims to investigate the effects of feeding *B. splendens* after the post-infusoria stage using different types of live prey and formulated diets, adjusted according to the fish's mouth gape, on their morphometric growth and survival rate. The findings are expected to provide insights into optimal feeding practices that enhance growth performance and survival in ornamental fish aquaculture, particularly for the commercially valuable Super Red Plakat strain of *B. splendens*. It is hypothesized that live feeds with particle sizes compatible with the larval mouth gape, such as *Artemia* nauplii and *Moina* sp., will result in higher survival and better growth compared to larger prey (*Daphnia magna*) or formulated pellets, while maintaining water quality within optimal rearing conditions.

MATERIALS AND METHODS

Culture and feeding regime

The larvae used in this experiment were obtained from a healthy broodstock pair of *B. splendens* (Super Red Plakat strain), consisting of one male and one female. The broodfish were selected based on their vigor, coloration, and reproductive maturity, and were maintained under standardized conditioning in a separate spawning tank (volume 10 L) for one week prior to fertilization. The spawning process was allowed to occur naturally, with the male constructing a bubble nest under controlled conditions (28°C, pH 6.8-7.0, DO >4 mg/L). Fertilized eggs were collected and incubated in the same tank, and newly hatched larvae were transferred into experimental rearing containers on day 3 post-hatch (Day of Culture (DOC) 3).

The rearing experiment was conducted for 28 days using five dietary treatments, each with 3 replicates (n=3). Larvae were stocked into 1-L transparent containers (n=10 larvae per container), filled with aged, dechlorinated water, and subjected to static water conditions with daily 80% water exchange. Aeration was not provided to avoid excessive current that could stress the larvae. In total, 150 larvae were used in the experiment.

Following regime, feeding treatments were applied using different live prey, including *Artemia* nauplii (T1), *Alona* sp. (T2), *Moina* sp. (T3), *D. magna* (T4), as well as artificial pellets under the brand MeM Prime (T5), imported from Belgium (Bernaqua MeM Prime, https://www.bernaqua.com/memprime/). The pellets were provided in two pellet sizes: 200-300 µm and 300-500 µm, and the treatments are detailed in Table 1. The experiment was designed with five treatments and three replications for each treatment.

Infusoria were supplied ad libitum from DOC 3 to DOC 7, after which second feeds were gradually introduced based on treatment-specific regimens. Feeding was performed three times daily (08:00, 13:00, and 17:00), and uneaten feed was siphoned out prior to each water exchange. Representative images of the male and female broodstock (Super Red Plakat strain) used in this study are presented in Figure 1 to illustrate the morphological traits and pigmentation of the parental fish.

Figure 1. A. Male, and B. Female broodstock (Super Red Plakat strain)

Table 1. Feeding treatment for *Betta splendens* fry

DOC	Live prey				Artificial pellet
	T1	T2	T3	T4	T5
4-7	Infusoria	Infusoria	Infusoria	Infusoria	Infusoria
8-14	*Artemia* nauplii	*Alona* sp.	*Moina* sp.	*Daphnia magna*	MeM prime 200-300µm
15-28	*Artemia* nauplii	*Alona* sp.	*Moina* sp.	*Daphnia magna*	MeM prime 300-500µm

Morphometric growth and survival rate parameters

Morphometric growth measurement and survival rate of *B. splendens* were conducted on DOC 28, which marked the final day of the experiment. Morphometric growth was represented by two parameters: total length (TL) and standard length (SL). According to Howe (2002), total length (TL) is measured from the snout to the end of the longest caudal fin ray. Meanwhile, standard length (SL) is the straight-line distance from the tip of snout to the end of the scale cover at the base of the caudal fin or hypural plate.

Survival rates were estimated on DOC 28 by calculating the number of fish that remained alive from the initial stocking quantity. The survival rate was calculated using the following formula:

$$SR = \frac{Nt}{No} \times 100\%$$

Where: SR refers to abbreviation for survival rate, Nt represents the number of fish at the end of culture period, and N0 denotes the number of fish at the initial stocking.

Percentage increase in growth and survival was calculated by relative change using the following formula (Vickers 2001):

$$Relative\ change = \frac{new\ value - baseline}{baseline}\ x\ 100\%$$

Relative change is the ratio of the difference between the baseline and the new value compared to the baseline.

Water quality parameters

Water quality parameters were represented by three key parameters: temperature, potential of Hydrogen (pH) and dissolved oxygen (DO). These parameters were measured regularly on a weekly basis. Temperature and DO were measured using Lutron 5509 (Lutron Electronic Enterprise Co., Ltd.). pH was measured using pH meter P-2Z-B1900126 (Mediatech Travel Gadget).

Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics Version 26.0 (https://www.ibm.com/id-id/products/spss). Prior to hypothesis testing, the data were assessed for normality using the Shapiro-Wilk test and for homogeneity of variances using Levene's test. When the assumptions of normality and homogeneity were met, a one-way analysis of variance (ANOVA) was used to determine significant differences among treatments based on feed type. If significant effects were detected ($p<0.05$), Tukey's Honestly Significant Difference (HSD) test was applied as a post hoc analysis to identify pairwise differences. For datasets that did not meet the assumptions of normality or equal variances, a non-parametric Kruskal-Wallis test was used to assess treatment effects. In such cases, Dunn's test with Bonferroni correction was employed for post hoc multiple comparisons. All results were considered statistically significant at $p<0.05$.

RESULTS AND DISCUSSION

Survival rate analysis

This study demonstrated that different types of feed significantly influenced the survival rate (SR) of *B. splendens* larvae over a 28-day rearing period (Figure 2). At DOC 28, the highest mean SR was recorded in Treatment 3 (*Moina* sp.) at 89.00±2.00%, followed by Treatment 1 (*Artemia* nauplii) at 88.00±1.00%, and Treatment 2 (*Alona* sp.) at 86.67±0.58%. Conversely, the lowest SR was observed in Treatment 4 (*D. magna*), which yielded 72.00±1.00%, followed by Treatment 5 (artificial pellets) at 80.67±1.53%. Statistical analyses supported these observations. Most SR data were normally distributed, with the exception of T2 (*Alona* sp.), and Levene's test indicated homogeneity of variance across treatments ($p>0.05$). One-way ANOVA revealed a highly significant difference in SR among treatments ($F = 86.77$; $p<0.001$), which was further confirmed by the Kruskal-Wallis test ($H=12.34$; $P=0.015$), indicating that feed type had a statistically significant impact on larval survival.

Trend analysis showed that all treatments experienced a gradual decrease in survival rate over time, though the rate of decline differed among treatments. Based on relative change analysis from the initial survival baseline, the order of decline was T3 (11.0%) < T1 (12.0%) < T2 (13.3%) < T5 (19.3%) < T4 (28.0%). The sharpest decline occurred in T4, likely due to the relatively large size of *D. magna*, which may have exceeded the mouth gape capacity of *Betta* larvae, particularly during the early developmental stage.

Infusoria generally range from 100-150 µm, *Artemia* nauplii from 200-400 µm, *Alona* sp. around 300-350 µm, *Moina* sp. from 500-1,000 µm, and *D. magna* from 1,000-2,000 µm. The artificial pellets used in this study measured approximately 200-500 µm. Considering the relatively small mouth size of *Betta* larvae, especially from DOC 4 to DOC 10, feeds such as *D. magna* likely surpassed the larval ingestion threshold, resulting in ineffective feeding and consequently lower survival. Similar result also described by Srikhrisnan et al. (2017) and Thongprajukaew et al. (2018), even though the survival rate of *B. splendens* larvae were not significant different with treatments using different live prey, but higher in Bread worm, following by *Artemia* and *Moina*, indicated fish larvae are able to consume prey having same size of their mouth but small prey is more preferable. Supported by Nunn et al. (2012), for a fish predator, the energetic content of a given prey type increases with prey size, but there is also an associated increase in handling time.

In addition, Treatments T3, T1 and T2 from live prey exhibited the smallest reduction compared with T5, even though artificial feed has a smaller size than *Moina* sp. (T3), likewise a relatively similar size range with *Artemia* nauplii (T1) and *Alona* sp. (T2). This condition may be correlated with suitability of the live prey to *Betta* larvae. According to Conceição et al. (2010), independently of their nutritional value, live feeds are easily detected and captured, due to their swimming movements in the water column.

Therefore, the size and type of feed were critical determinants of successful larval rearing in commercial ornamental fish. Live feeds such as *Moina* sp. and *Artemia* nauplii offer advantages in terms of particle size suitability, nutritional content, and active motility factors that align well with the physiological and behavioral capabilities of early-stage larvae in *B. splendens*. In contrast, larger organisms like *D. magna* and inert artificial pellets may be less effective or even detrimental due to physical or behavioral incompatibility with *B. splendens*. These findings underscore the importance of selecting feed size and types that align with the larval developmental stage in ornamental fish to maximize survival and hatchery productivity.

Growth performance (total and standard length)

The growth performance of *B. splendens* larvae reared under five different feeding treatments exhibited a significant increase in body length throughout the 28-day rearing period. Both total length (TL) and standard length (SL) parameters showed consistent increases from day 4 (DOC 4) to day 28 (DOC 28) across all treatments, although the growth rates varied among them.

Total length (TL)

At the end of the rearing period (DOC 28) in Figure 3, the highest mean TL was recorded in Treatment 1 (*Artemia* nauplii) at 15.60±0.46 mm, followed by Treatment 3 (*Moina* sp.) at 14.40±0.16 mm, and Treatment 5 (artificial pellets) at 13.70±0.34 mm. The lowest mean TL was observed in Treatment 4 (*D. magna*), which only reached 11.70±0.46 mm. Compared with T4 and T5, treatments T1 and T3 exhibited approximately 16-17% and 7-8% greater relative increase in TL values, respectively. A similar trend was observed in the SL values, where the highest SL was also in T1 (13.70±0.07 mm) and the lowest in T4 (10.30±0.22 mm).

Statistical analysis showed that TL data were normally distributed with homogeneous variances, allowing for one-way ANOVA to be applied, which revealed a highly significant difference among treatments ($F=149.68$; $p<0.001$). In contrast, SL data exhibited non-normal distributions in some treatments (notably T1 and T4), so the ANOVA results were confirmed using the non-parametric Kruskal-Wallis test, which also indicated significant differences ($H=13.30$; $P=0.010$). These results confirm that the type of feed had a significant effect on larval growth.

Feed particle size plays a crucial role in the feeding efficiency of fish larvae, especially during early developmental stages when mouth gape is limited. It showed that the superior TL values observed in T1 and T3 are likely attributed to the compatibility of feed particle size, when *Artemia* nauplii and *Moina* sp. fall within the optimal size range for *Betta* larval mouth gape, approximately 200-400 µm and 500-1,000 µm, respectively. Beyond that, ingested feed also plays a crucial part in optimal nutrient uptake and tissue synthesis. Thus, the nutritional composition and digestibility become other key factors driving growth and body development. Feed that is highly digestible and rich in nutrients is more efficiently absorbed and utilized for tissue synthesis and biomass accumulation. As emphasized by Dwivedi et al. (2025), in the early stages of ornamental fish, fry should be fed highly digestible and nutrient-rich foods to support rapid growth and body development.

Interestingly, the larvae in Treatment 5 (pellet feed, 200-500 µm) exhibited moderately high TL values, although still lower than those in live feeds. This indicates that formulated feeds can support growth through their nutrient content when appropriately sized and timed. However, their efficacy remains inferior to that of live feeds, likely due to lower palatability and digestibility during the early larval phase in *B. splendens*. Saekhowa et al. (2022) described that *Betta* fish are naturally carnivorous, and they prefer a live diet as prey over an artificial diet. One of the most critical technical challenges in designing artificial diets is the rapid leaching of water-soluble nutrients, such as free amino acids and vitamins, when microparticles are hydrated in the rearing water, although encapsulation techniques can improve nutrient retention, they may also be reduced due to polymerization during the process (Hamre et al. 2013). In addition, larval feeding success is influenced by behavioral and morphological factors, including mode of feeding, mouth size and the size of the available food particles (Dabrowski 1984). Therefore, Medium-sized live feeds such as *Moina* sp. and *Artemia* proved more effective in promoting body length growth compared to oversized feed organisms like *D. magna* or prematurely introduced pellet diets. Nevertheless, studies have shown that fish larvae process digestive enzymes early on, suggesting that well adapted artificial diets, especially when combined with live feeds through co-feeding may offer a viable alternative under certain conditions (Cahu and Infante 2001; Murwantoko et al. 2018; Souza et al. 2020). Overall, these findings highlight that larval growth in *B. splendens* is not only influenced by mouth opening and particle size suitability, but also by the palatability, digestibility and nutritional value of the feed.

Standard length (SL)

The standard length (SL) of *Betta* larvae also demonstrated consistent upward trend across all treatments, although with significant differences among them (Figure 4). On DOC 28, larvae from Treatment 1 showed the highest SL (13.70±0.07 mm), followed by Treatment 3 (*Moina* sp.) at 12.30±0.11 mm, and Treatment 5 (pellets) at 12.00±0.22 mm. The lowest SL was observed in Treatment 4 (*D. magna*), at 10.30±0.22 mm, a pattern that remained consistent throughout the rearing period.

The Kruskal-Wallis test confirmed a significant difference in SL among treatments ($H=13.30$; $P=0.010$), validating the influence of feed type on axial body development in larval *Betta*. Although ANOVA also showed significant results ($F=356.5$; $p<0.001$), the use of the non-parametric approach was more appropriate due to violations of normality in some treatments.

Higher SL values in Treatments 1 and 3 suggest that *Artemia* and *Moina* sp. were able to provide sufficient energy and protein to support axial body development, including the head, trunk, and caudal peduncle, independent of fin growth. In contrast, feed organisms like *D. magna*, with excessive body size, likely resulted in restricted consumption during early stages, contributing to slower linear growth. The other study related to the locomotor and feeding behavior in *B. splendens* studied by Souza et al. (2020) found that larvae fed exclusively with live feed had higher swimming speed and larvae fed with artificial feed displayed low velocity.

Furthermore, SL is considered a more reliable indicator of functional body structure, reflecting aspects such as respiratory surface area, locomotion efficiency, and feeding ability (Da Silva et al. 2016; Samat et al. 2020). While TL offers a general measure of body growth, SL provides a more accurate estimate of the larva's structural development and physiological readiness, particularly during the critical early life stages. Interestingly, although not perfectly identical, the results for standard length (SL) were consistent with those for total length (TL), which both reflect the growth performance of *B. splendens*.

Water quality parameters

Water quality plays a critical role in the survival, growth, and overall physiological performance of fish larvae during early developmental stages. In this study, key environmental variables, including dissolved oxygen (DO), water temperature, and pH were continuously monitored to ensure that all treatments were conducted under stable and non-limiting conditions. Assessing these parameters not only ensures the reliability of the experimental results but also helps to rule out environmental confounders that might otherwise influence larval performance (Hasanah et al. 2020; Putri et al. 2025). The following sections describe the dynamics of each parameter and evaluate its potential influence on the observed biological responses.

Dissolved oxygen (DO)

Over the 28-day rearing period, the dissolved oxygen (DO) levels across all five treatments exhibited minor fluctuations but consistently remained within the acceptable range for tropical freshwater fish larvae (Figure 5). The highest DO values were recorded on day 7 (DOC 7), ranging from 4.15 to 4.26 mg/L, while the lowest values occurred on day 28 (DOC 28), particularly in Treatment 4 (3.51±0.10 mg/L). On average, DO values ranged between 3.51 and 4.26 mg/L. Although there was a gradual decline in DO as larval biomass increased, all recorded values stayed above the critical minimum threshold of 3.00 mg/L, which is sufficient to support respiration and metabolic processes in larval *B. splendens*.

The analysis of DO data suggests no occurrence of extreme deviations that could compromise larval physiology. The observed decline in DO towards the later stages was likely associated with increased biomass and organic matter from uneaten feed, but it did not substantially degrade water quality (Kari et al. 2023; Pramudia et al. 2024). Given that all DO levels remained within optimal limits, oxygen availability was not a determining factor in the observed differences in survival or growth across treatments (Melaku et al. 2024). Therefore, DO can be considered a stable and unbiased environmental parameter, reinforcing the conclusion that feed type was the primary driver of larval performance in this study.

Temperature

Water temperature throughout the experiment remained highly stable, with average values ranging from 28.40 to 29.99°C (Figure 6). The highest temperatures were recorded on DOC 7, while the lowest occurred on DOC 28. All treatments exhibited narrow fluctuations, with inter-treatment variation of approximately ±0.5°C. These values fall within the optimal thermal range for *B. splendens* larvae (25-30°C), supporting essential physiological functions such as enzymatic activity, digestion, and nutrient assimilation.

Temperature data analysis indicated that no treatment experienced thermal stress—neither from excessive cooling nor overheating. The consistent temperature conditions across treatments suggest that variation in larval performance was primarily influenced by the feed types rather than external thermal factors (Norazmi-Lokman et al. 2020; Pramudia et al. 2022b). This thermal stability is particularly significant for larval development, a stage known to be highly sensitive to environmental fluctuations (Kurniawan et al. 2025). As a result, the thermal constancy observed in this experiment strengthens the validity of feed-related conclusions and suggests high reliability of the experimental conditions for similar aquaculture settings.

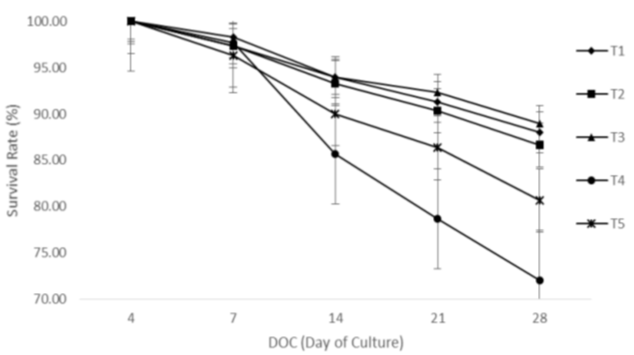

Figure 2. Survival rate (%) of *Betta splendens* larvae over a 28-day rearing period under different feeding treatments

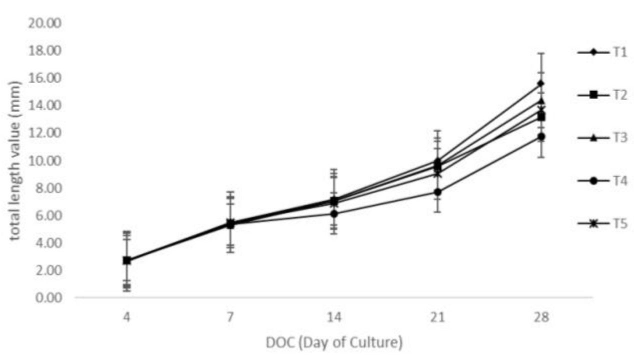

Figure 1. Growth performance of *Betta splendens* fish larvae (Total Length, TL) under different feeding treatments over a 28-day culture period

pH

pH levels during the rearing period also remained stable, ranging between 6.67 and 7.13 (Figure 7). The highest pH was observed on DOC 14, while the lowest was recorded during the early phase (DOC 4-7). All treatments maintained pH values within a neutral to slightly alkaline range, which is generally considered suitable for the physiological needs of *B. splendens* larvae. No extreme acidic or alkaline shifts were observed that could have caused environmental stress.

From an analytical perspective, the stable pH values reflect efficient management of organic waste decomposition, including uneaten feed and larval excretion (Krishnakumar et al. 2020; Mulyati et al. 2022). The absence of pH spikes supports the interpretation that feed treatment, rather than water chemistry, was the dominant factor influencing larval survival and growth patterns. Moreover, the neutral pH values suggest that microbial activity in the water remained stable, promoting effective nutrient cycling and contributing to overall environmental balance (Kurniawan et al. 2021).

Correlation analysis between biological and environmental factors

To better understand the interrelationships between biological performance (survival and growth) and environmental conditions during the rearing period, a Pearson correlation analysis was performed using the average values of Survival Rate (SR), Total Length (TL), Standard Length (SL), and water quality parameters (dissolved oxygen, temperature, and pH) on day 28 (DOC 28). The results are visually presented in a heatmap (Figure 8) and numerically in a correlation matrix (Table 2), illustrating the strength and direction of pairwise associations among the parameters.

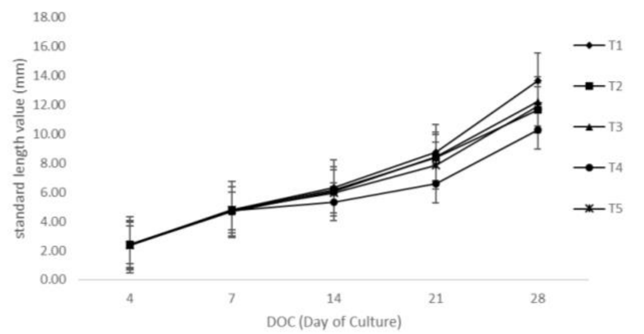

Figure 4. Standard Length (SL) progression of *Betta splendens* fish larvae subjected to five different feeding treatments during a 28-day rearing period

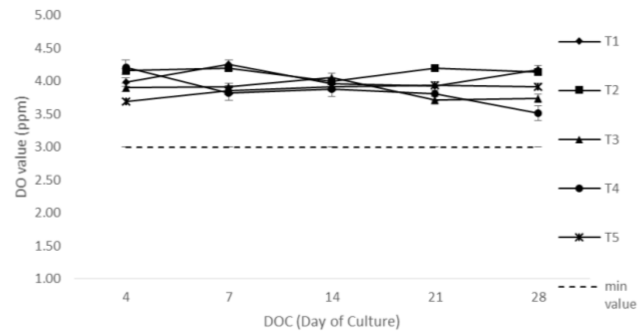

Figure 5. Dissolved oxygen (DO) levels (mg/L) were measured across different feeding treatments during the 28-day rearing period of *Betta splendens* fish larvae

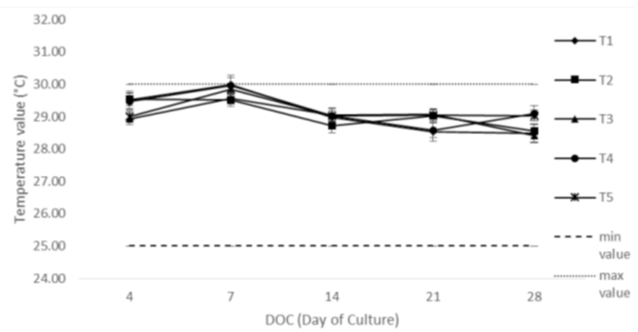

Figure 6. Water temperature (°C) observed throughout the 28-day experimental period under five feeding treatments

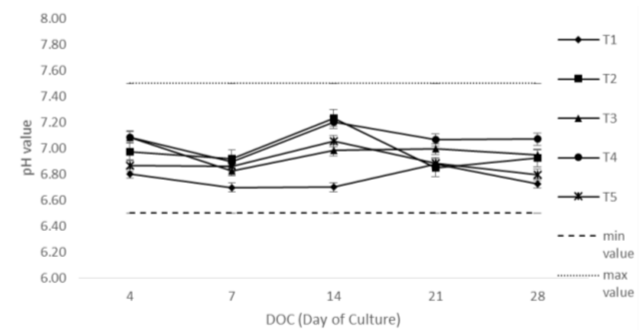

Figure 7. pH values recorded under each feeding treatment during the larval culture period of *Betta splendens* fish

Table 2. Pearson correlation matrix between survival rate (SR), growth parameters (total length and standard length), and water quality parameters (dissolved oxygen, temperature, and pH) of *Betta splendens* larvae on day 28 (DOC 28)

Parameters	SR	TL	SL	DO	Temperature	pH
SR	1	0.84	0.81	0.70	0.65	0.62
TL	0.84	1	0.99	0.69	0.49	0.18
SL	0.81	0.99	1	0.75	0.53	0.11
DO	0.70	0.69	0.75	1	0.92	0.21
Temperature	0.65	0.49	0.53	0.91	1	0.48
pH	0.61	0.18	0.11	0.21	0.48	1

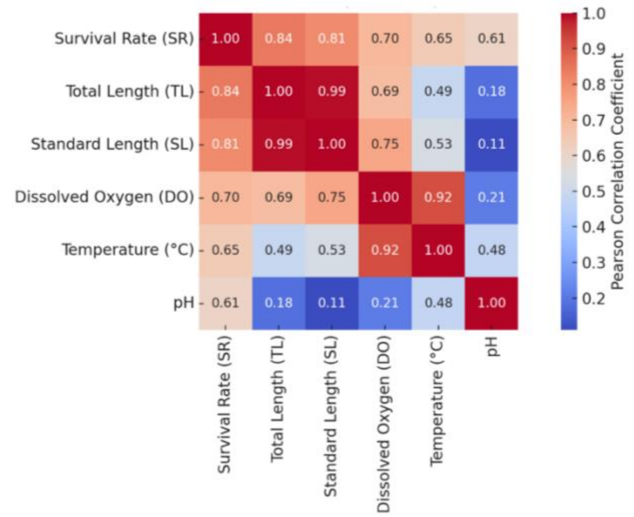

Figure 8. Heatmap of Pearson correlation coefficients between biological performance parameters (Survival Rate, Total Length, Standard Length) and water quality variables (Dissolved Oxygen, Temperature, pH) at day 28 of rearing

The analysis revealed a very strong positive correlation between TL and SL (r=0.99), indicating that larval growth occurred proportionally in both total and standard body lengths. Additionally, strong correlations were observed between SR and TL (r=0.84), and between SR and SL (r=0.81), suggesting that treatments enhancing survival also promoted linear growth. This implies that feed quality and size compatibility not only improved larval survival but also supported efficient growth.

From an environmental standpoint, dissolved oxygen (DO) showed moderate positive correlations with SR (r=0.70), TL (r=0.69), and SL (r=0.75). Although DO values remained within the optimal range, minor declines particularly in Treatments 4 and 5 may have influenced metabolic efficiency and feed utilization, contributing to lower growth and survival in those groups. Temperature displayed weak to moderate correlations with SR (r=0.65), TL (r=0.49), and SL (r=0.53), suggesting that despite being within the optimal range (28.3-29.9°C), small fluctuations did not substantially influence biological outcomes. Meanwhile, pH exhibited the weakest correlations with all biological parameters (r<0.30), indicating that the neutral and stable pH conditions during the trial were not a limiting factor for larval performance.

Based on the correlation results, it can be concluded that feed type and larval biological traits particularly mouth size and digestive capacity are the primary determinants of rearing success (Couto et al. 2018; Utama et al. 2020). High SR was directly associated with increased growth, indicating that larvae that survived were also those capable of effectively capturing and assimilating feed. While DO serve as a supportive factor, especially during critical metabolic phases, temperature and pH acted more as baseline environmental stabilizers rather than as active drivers of performance variation (Usman et al. 2024). Similar result was reported in juvenile bighead carp Zhou et al. (2024), where higher DO levels enhanced growth performance through regulation of HIF-related genes. Under hypoxic conditions, stabilization of HIF-α triggers physiological adjustments that prioritize survival over growth, thereby reducing metabolic efficiency and feed utilization. Therefore, DO is not merely a passive environmental variable, but also influences molecular regulation that determines whether energy is allocated to growth or to survival.

These findings underscore the importance of selecting feed types that match larval morphology and development, as well as maintaining stable but non-limiting water quality conditions. For aquaculture practitioners, ensuring the right feed size and type is paramount to achieving both high survival and optimal growth in early life stages of *B. splendens*.

In conclusion, this study demonstrates that feed particle size, palatability, digestibility and nutritional value of feed significantly affect the survival rate and morphometric growth (total and standard length) of *B. splendens* (Super Red Plakat strain) larvae during the early rearing period. Larvae fed with *Artemia* nauplii and *Moina* sp. exhibited the highest survival rates and superior growth performance, primarily due to the compatibility between prey size and larval mouth gape, as well as their high palatability and digestibility. Conversely, *D. magna* and formulated pellets yielded lower performance due to mismatched prey size and reduced palatability. Environmental parameters, such as dissolved oxygen, temperature, and pH remained within optimal ranges, confirming that biological outcomes were primarily feed-driven. Pearson correlation analysis further confirmed a strong positive association between survival and growth parameters, indicating that larvae that survived also achieved better linear growth. Moderate correlations with dissolved oxygen suggest its supportive role in larval metabolism, while temperature and pH appeared as stable background variables.

This study was limited to a 28-day culture without aeration and tested only one artificial diet. Biochemical and enzymatic analyses were not conducted, and growth was evaluated solely by length parameters. Further studies should assess longer rearing periods, co-feeding or weaning strategies, and digestive enzyme activity to optimize formulated feed use and enhance sustainable *B. splendens* hatchery practices. Those findings underscore the critical role of feed selection both in type and size during the post-infusoria larval stage, offering practical guidance for improving survival and growth in ornamental aquaculture systems, especially for high-value strains such as the Super Red Plakat *B. splendens*.

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