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Effects of weaning age on survival and growth factors of *Heterotis niloticus* (Cuvier, 1829) larvae

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ABSTRACT

Heterotis niloticus is an important fishery resource because of its individual large size and high commercial value. There is population decline due to habitat degradation and high fishing effort. The rearing of *H. niloticus* larvae, particularly the weaning phase, is one of the major problems for the successful farming of this species. This research aimed at investigating the age at weaning of *H. niloticus* larvae and its effects on survival and growth rates. Two independent series of weaning experiments were conducted under natural conditions. The first experiment (early weaning stage) included four treatments, namely: T1 (control) = larvae fed only *Artemia* nauplii, and T2, T3, T4 corresponding to three weaning ages of 11, 13, and 15 days after hatch (DAH), respectively. The second experiment (late weaning) included three treatments: T1 (control) = larvae fed only *Artemia* nauplii, and T2, T3 corresponding to two weaning ages, 24 and 26 DAH, respectively. For the early weaning experiment, eight days (9 DAH -16 DAH) of larval rearing resulted in low survival (14.7%, 10.0%, and 14.1%) and low SGR (6.56%.d^{-1}, 6.55%.d^{-1}, and 7.68 %.d^{-1}) for the 11 DAH, 13 DAH, and 15 DAH larvae, respectively. The survival (65.29%) and SGR (12.55%.d^{-1}) from *Artemia* fed larvae were the highest and significantly different ($p<0.05$) from those of weaned larvae. On the contrary, the late weaning (larvae weaned at 24 and 26 DAH) exhibited some positive responses to the shift to artificial diet. After twelve days of rearing, the survivals (45% and 50.83% for 24 DAH and 26 DAH, respectively) and SGR (8.90%.d^{-1} and 9.95% d^{-1} for 24 DAH and 26 DAH, respectively) were improved, suggesting that the weaning of *H. niloticus* larvae should begin approximately from 24-26 DAH. With respect to the rearing conditions and food types, additional research should seek to determine the appropriate age of switch from live food to an artificial diet to improve survival and growth rates of *H. niloticus* larvae.

Keywords: Aquaculture, artificial diet, *Heterotis niloticus*, larvae, survival, weaning age.

INTRODUCTION

The success of a fish species in aquaculture depends on the production and the availability of its fingerlings to supply fish culture centers (Micha, 1973; Balarin and Hatton, 1979; Leveque and Quensiere, 1988; FAO, 1991; Edna and Boyd, 1997; Rønnestad et al., 2001; Adite et al., 2005, 2006; Monentcham, 2009). However, the rearing of fish larvae has been reported as the major concern for many aquaculture processes (El-Dakar et al., 2001). Particularly for some species, high larval mortality occurs during the weaning phase because of poor food digestion resulting from a less-developed and rudimentary larval digestive tract (Watanabe and Kiron 1994; Breine and al., 1995; Rønnestad et al., 2001). Like many fish species, *Heterotis niloticus* larvae exhibit a very high mortality rate ranging between 80% and 100% (Moreau, 1982). Indeed, in fishponds, at 50 DAH and 90 DAH, De Kimpe (1967) and Rakotomanampisson (1966) reported some mortality rates of about 82% and 96% respectively. According to Reizer (1964, 1968) and Vincke (1971) a mortality rate of 100% usually occurs between 5 DAH and 7 DAH and the whole school of

Heterotis larvae could disappear in a short time (Daget and Aubenton, 1956; Rakotomanampisson, 1966). Based on fishpond observations, several hypotheses have been formulated to explain the low larval survival. Daget (1957) hypothesized that the massive mortality occurs after the weaning phase because of the food change. According to Rakotomanampisson (1966), once the larvae weaned, only bigger individual continue to swim to search for food whereas weaker individuals swim less, fall in the bottom before dying. Monentcham (2009) indicated that protein contents of the artificial food may affect the survival and growth performance of *H. niloticus* larvae and juvenile. In addition to the high food requirement for rapid growth, Micha (1973) reported that high larval density reduces rapid food consumption of individual larvae. Moreau (1982) suggested that the combined effects of these causes could act to increase the mortality of *Heterotis niloticus* larvae. There is dearth of information on the controlled or semi-controlled rearing of *Heterotis niloticus* larvae and particularly on its weaning age. Information from this study is useful for rapid expansion of *Heterotis niloticus* farming and for fish culture diversification.

MATERIALS AND METHODS

The two series of experiments, "early weaning experiment" and the "late weaning experiment" were independently conducted.

Early weaning experimental procedure

Larvae of *H. niloticus* were collected from a nest (diameter = 1.45 m; opening = 0.47 m) at the spawning ground in Lake Hlan (South-Benin) six days after hatching (DAH). Water depth, temperature, pH and dissolved oxygen in the nest were 0.62 m, 30.5 °C, 5.71, and 1.34 $mg.l^{-1}$ (22% of saturation), respectively. Larvae age was determined using *Heterotis* larvae's growth phases composed of 10 larvae stages as developed by Moreau (1982). The 6 DAH larvae collected measured about 13 mm. Their anal and pectoral fins were barely initiated. There were no ventral and dorsal fins and the yolk was almost resorted and less visible. Once collected, larvae were immediately shipped to the aquaculture research center of the Department of Zoology and Genetics of the Faculty of Sciences (University of Abomey-Calavi, Benin) and put into a 0.4-m^3 rectangular concrete tank (1.22 x 1.06 x 0.66 m) under atmospheric conditions. Before the beginning of the experiment, larvae were fed only on live food for two days, mainly zooplankton (freshwater rotifers: *Brachionus spp*) collected in a pond with planktonic net (model KIEL), and *Artemia* nauplii. At 9 DAH, larvae were then randomly distributed among 8 tanks (170 larvae/tank) according to four treatments and two replicates: T1 (control) = larvae fed only with *Artemia* nauplii; T2, T3, and T4 corresponding to complete weaning to dry food at 11 DAH, 13 DAH, and 15 DAH, respectively. The Kurios-*Artemia* 90% Grade A contains about 54% of protein and 12% of fat with $10mg.g^{-1}$ polyunsaturated fatty acids. *Artemia* nauplii were obtained 24 hours after incubation of *Artemia* cysts in a 1.5-liter cylindrical plastic vessel containing 30‰ salt water at 25 °C. The salt water was continuously oxygenated with a motorized air-pump to enhance *Artemia* nauplii hatching. The dry food contained 40% of protein with 2249 kcal and was a mixture of dry fish (10%), maize (25%), residue from processed groundnuts (25%), residue from processed soya bean (15%), dry cassava (2%), residue from processed wheat (10%), residue from processed cereals (10%), oyster shell (2%), and salt (1%). This diet was mixed and ground to very fine particles.

The food substitution was progressive and was 25%, 50%, and 100% of artificial food for the first, second and the third day respectively according to the feeding plan reported in Table 1.

During the rearing period, temperature, dissolved oxygen and pH were recorded with an Oxy-thermometer (W.T.W oxi 197) and a pH meter (W.T.W). The experiment was conducted for eight (8) days and larvae were fed daily to satiation every two hours (7 am, 9 am, 11 am, 1 pm, 3 pm, 5 pm, 7 pm). Day length was about 12 hours (7 am- 7 pm). Dead fish were removed and counted twice a day (7 am and 7 pm) to monitor survival. The removed dead fish were examined by binocular microscope to assess signs of cannibalism and malformation. Water temperature, pH and dissolved oxygen were recorded three times a day (7 am, 2 pm, 7 pm)

Table 1: Feeding plan of *Heterotis niloticus* larvae in the early weaning experiment.

LARVAE AGE	TREATMENTS			
	T1	**T2**	**T3**	**T4**
DAH6-DAH8 (Pre-experiment)	A + zooplankton	A + zooplankton	A + zooplankton	A + zooplankton
DAH9 (Beginning of the experiment)	A	25% AF + 75% A	A	A
DAH10	A	50% AF + 50% A	A	A
DAH11*	A	100% AF	25% AF + 75% A	A
DAH12	A	100% AF	50% AF + 50% A	A
DAH13*	A	100% AF	100% AF	25% AF + 75% A
DAH14	A	100% AF	100% AF	50% AF + 50% A
DAH15*	A	100% AF	100% AF	100% AF
DAH16	A	100% AF	100% AF	100% AF

A: *Artemia* nauplii; AF: Artificial food; DAH: Days after hatch.
***** Weaning ages

and tank water was renewed every two days. At the beginning of the experiment, 30 larvae were measured and weighed. At the end of the experiment, ten larvae per tank were transferred to 10 liters of 30‰ salt water for 15 minutes at investigating their resistance to osmotic stress, and 15 larvae per tank were measured and weighed for growth evaluation. Larvae total length (LT) was measured to 1 mm increments with a graduated ruler and body weight was measured to 0.1 mg with an electronic balance (SCALTEC SBA 32).

Late weaning experimental procedure

Seven (7) DAH *Heterotis niloticus* larvae were collected from a nest (diameter = 1.28 m ; opening = 0.30 m) at the spawning ground in Lake Hlan (South-Benin). Water depth, temperature, pH and dissolved oxygen predetermined at the collecting site (nursery ground) were 0.80 m, 27.7 °C, 5.0, and 1.2 $mg.l^{-1}$ (20% of saturation) respectively. Larvae age was determined using *Heterotis* larvae's growth phases composed of 10 larvae stages as developed by Moreau (1982). The 7 DAH larvae collected measured about 13.5 mm. Their ventral and dorsal fins begin to appear and the yolk was completely resorted. Once collected, larvae were immediately shipped to the Aquaculture Research Center of the Department of Zoology and Genetics of the Faculty of Sciences (University of Abomey-Calavi, Benin) and put into a 0.4-m^3 rectangular concrete tank (1.22 x 1.06 x 0.66 m) under atmospheric conditions. Before starting the weaning experiment, larvae were reared for two weeks (up to 21 DAH) and fed with live food, mainly freshwater rotifers (*Brachionus spp*) and *Artemia* nauplius. Experimental procedures were the same as the early weaning experiment. However, because of the limited number of larvae, only three treatments (T1 = Larvae fed only *Artemia* nauplii; T2 = Larvae weaned at 24 DAH; T3 =Larvae weaned at 26 DAH) were considered with 120 larvae per treatment. The food substitution was progressive and was 25%, 50%, and 100% of artificial food the first, second and the third day respectively according to the feeding plan reported in Table 2. After the weaning at 26 DAH, larvae were fed only on dry diet until 33 DAH corresponding to a total of twelve (12) days of rearing.

For both experiments, the following survival and growth parameters were computed:

$S\ (\%) = Nf \times 100/Ni$

$SGR\ (\%.\Delta T^{-1}) = [LN\ (FBW)-LN\ (IBW)] \times 100 / \Delta T$

$SOR\ (\%) = Ns \times 100/Nt$

$MDG = (FBW - IBW) / \Delta T$

Where S (%) = Survival ; SGR = Specific growth rate; SOR = Survival from osmotic resistance; MDG = mean daily growth; Ni, Nf = initial and final number of larvae; ΔT = duration of the experiment; IBW, FBW = initial and final body weight (mg);

Table 2: Feeding plan of *Heterotis niloticus* larvae during the late weaning experiment.

Larvae age	Treatments		
	T1	**T2**	**T3**
DAH7-DAH21 (Pre-experiment)	A + zooplankton	A + zooplankton	A + zooplankton
DAH22 (Beginning of the experiment)	A	25% AF + 75% A	A
DAH23	A	50% AF + 50% A	A
DAH24*	A	100% AF	25% AF + 75% A
DAH25	A	100% AF	50% AF + 50% A
DAH26*	A	100% AF	100% AF
DAH27	A	100% AF	100% AF
DAH28	A	100% AF	100% AF
DAH29	A	100% AF	100% AF
DAH30	A	100% AF	100% AF
DAH31	A	100% AF	100% AF
DAH32	A	100% AF	100% AF
DAH33	A	100% AF	100% AF

A: *Artemia* nauplii; AF: Artificial food; DAH: Days after hatch.
***** Weaning ages

Ns, Nt = initial and final number of larvae for the osmotic experiment.

One way-ANOVA analysis of variance and Student's t-test were performed with SPSS computer program (Morgan et al., 2001) to search for data variation and to compare the mean values of the treatments, respectively.

RESULTS

Early weaning experiment

Mean values (± SD) of zootechnical parameters of *Heterotis niloticus* larvae reared from 9 DAH (IBL=13.03mm; IBW=16.22mg) are shown in Table 3. In general, significant differences were recorded among the five treatments for survival ($p<0.01$), SGR ($p<0.01$), MDG ($p<0.01$) and body weight ($p<0.01$). Overall, larvae fed *Artemia* nauplii exhibited the best zootechnical performances: pairwise comparisons with the three remaining treatments (larvae weaned at 11 DAH; 13 DAH; 15 DAH) showed significant differences for survival ($p<0.05$), SGR ($p<0.05$), MDG ($P<0.01$), body weight ($p<0.01$) and body length ($p<0.05$). Larvae weaned at 11 DAH, 13 DAH and 15 DAH with the artificial diet, exhibited very low performance: high larval mortality (85.3%; 90%; 85.9% respectively) associated with low specific growth rates and low daily growth were recorded. Daily mortalities were high during the experiment causing a rapid drop in survival (Figure 1). These three latter weaning ages failed to show any significant differences for survival ($p=0.86$), SGR ($p=0.36$), MDG ($P=0.36$) suggesting that at these three ages, performance of the weaning groups were similar. Also, there were some positive correlations between survival and SGR ($r^2=0.88$; $P<0.01$), survival and FBW ($r^2=0.87$; $p<0.01$) and final body length (FBL) ($r^2=0.87$; $p<0.01$) suggesting that survival increases with the increase of SGR, FBW and FBL. During the experimental period, binocular observations of dead and live larvae coupled with direct observation in tank did not show any cannibalism and malformation signs. Survival from the osmotic stress test ranged from 80% to 100% indicating that *Heterotis niloticus* larvae is resistant to a short salt water exposure, even though its major habitat is a freshwater environment.

Late weaning experiment

Table 5 shows the mean values (± SD) of zootechnical parameters of *Heterotis niloticus* larvae reared from 22 DAH (IBL=20.7 mm; IBW=36.7 mg) to 33 DAH. Like the early weaning experiment, significant differences were recorded among the three treatments for survival ($p<0.05$), SGR

($p<0.01$), MDG ($p<0.01$), body weight ($p<0.01$) and body length ($p<0.01$). Similar to the early weaning experiments, *Artemia*-fed larvae exhibited the highest zootechnical performances. Pairwise comparisons with the two remaining treatments showed significant differences for survival ($p<0.05$), SGR ($p<0.05$), MDG ($P<0.05$), body weight ($p<0.05$) and body length ($p<0.05$). However, there were no significant differences between weaning at 24 DAH and at 26 DAH for survival ($p=0.57$), SGR ($p=0.44$), MDG ($p=0.44$), FBW ($P=0.44$) and FBL ($p=0.25$).

Unlike the early weaning experiment, daily mortalities in the late weaning experiment were considerably reduced from the fourth day of rearing and the survival was relatively stable the following days (Figure 2). Like in the early weaning experiment, no cannibalism and malformation was recorded. In general when comparing the weaned larvae of the two experiments, significant differences were recorded for survival ($p<0.01$) and SGR ($p<0.05$) suggesting that the weaning at 24-26 DAH is relatively efficient in improving *Heterotis niloticus* larvae survival and growth factors.

DISCUSSION

In fish culture, the weaning phase is the critical period of larviculture. During this phase of diet shift, the larvae must ingest and progressively digest a formulated dry diet and absorb the essential nutrients to support rapid growth. This task requires a well developed digestive system. In our early weaning experiment (larvae weaned at 11 DAH, 13 DAH, 15 DAH), *Heterotis niloticus* larvae weaned with dry diet and reared from 9 DAH to 16 DAH exhibited very low survival and growth rate presumably due to the less developed digestive tract. Similar results were reported by Kestemont (1995) for the common perch (*Perca fluviatilis*) weaned at 13 and 15 DAH and exhibiting low survival and SGR as a consequence of low dietary protein utilization. While some fish larvae with incompletely resorbed yolk start to ingest and successively digest exogenous food as defined by Kamler (1992), many other larvae feed on live food (essentially zooplankton) up to an age called weaning age. At this age, larvae shift progressively from an exclusively intestinal digestion to a stomachal digestion period at which they can consume and digest a formulated dry diet (Dabrowsky, 1992; Kestemont et al., 1995). According to Rønnestad (2001), the digestive system of fish larvae is the foremost cause for low survival and low growth rate and plays a central role in nutrient acquisition after the resorption of the yolk. Also, Monentcham (2009) reported that dietary protein levels may greatly affect the survival and the growth performance of *Heterotis niloticus* larvae and juveniles. As a result, feeding is the most important factor that may affect performance from the early weaning of *Heterotis niloticus* larvae and the hypothesis of poor dry food digestion from an insufficiently developed digestive system causing high mortality and low growth, is the most relevant.

Physico-chemical conditions of water satisfied the general requirement recommended for larval rearing (Melard and Philipart, 1980; Schlumberger, 1993; Melard, 1999; Imorou Toko, 2002) (Table 4). Also, tank water did not show any significant differences in temperature ($p=0.75$), pH ($p=0.83$) or dissolved oxygen ($p=0.15$), suggesting that water quality between tanks was similar and could not be the driving factors of the low trends observed in zootechnical performances. However, the significant ($p<0.05$) daily variation of the water features recorded within a single tank for the two series of experiment (Tables 4, 6) may have affected, to some degree, the growth rates and survival, but the observed effects were in the same range because of the lack of differences between tank water qualities.

Observations of larvae behavior during feeding showed that *Heterotis niloticus* larvae greatly preferred *Artemia* nauplii. Once *Artemia* nauplii were released in the tank, the larvae previously in a school, scattered to chase their prey and come again together after eating. Likewise, the larvae ingested the dry food by swimming perpendicularly to the water surface and picking it up at the surface. Binocular observations of larvae stomachs revealed that *Artemia* nauplii and dry food were well ingested by the larvae. Visually, *Artemia* nauplii fed larvae were more vigorous than dry food fed larvae suggesting that at this age, *Artemia* nauplii (live food) was more efficient in providing essential

Table 3: Survival rates and growth factors (for early weaning) of *Heterotis niloticus* larvae weaned at different DAH and reared for a period of 8 days.

Parameters	*Artemia* (control)	Weaning ages		
		11 DAH	13 DAH	15 DAH
Initial number	340	340	340	340
Final number	222	50	34	48
IBL (mm)	13.03±0.71	13.03±0.71	13.03±0.71	13.03±0.71
FBL (mm)	17.96±1.27 [a]	15.13±0.86 [b]	14.96±1.50 [b]	15.86±0.86 [b]
IBW (mg)	16.22±1.98	16.22±1.98	16.22±1.98	16.22±1.98
FBW (mg)	44.25±6.86 [a]	27.41±4.81 [b]	28.11±5.05 [b]	30.27±3.09 [b]
Initial biomass(mg)	5514.8	5514.8	5514.8	5514.8
Final biomass (mg)	9823.5	1370.5	955.74	1452.9
Survival (%)	65.29±1.66 [a]	14.70±5.82 [b]	10.00±3.33 [b]	14.10±14.14 [b]
SGR (%.d^{-1})	12.55±0.23 [a]	6.56±0.47 [b]	6.85±0.70 [b]	7.68±0.79 [b]
MDG (mg.d^{-1})	3.50±0.10 [a]	1.40±0.12 [b]	1.49±0.20 [b]	1.76±0.24 [b]
SOR (%)	80	95	95	100

DAH: Days after hatch; **SD**: Standard deviation; **d^{-1}** : Per day; **IBL**: Initial body length; **FBL**: Final body length; **IBW**: Initial body weight; **FBW** = Final body weight; **SGR**: Specific growth rate; **MDG** = Mean daily growth; **SOR**: Survival from osmotic resistance. Values followed by (± SD) are means.
No significant differences (p>0.05) were found with means in rows and lettered with the same superscript.

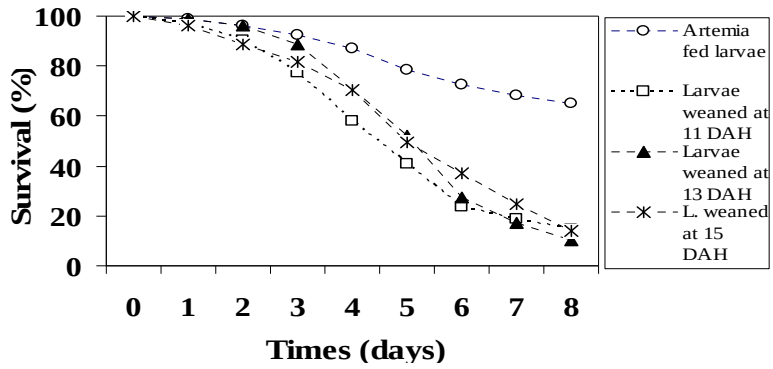

Figure 1: Daily survival trends of *Heterotis niloticus* larvae during the early weaning experiment. On X-axis, weaning occurred at time = 2 days, time = 4 days and time = 6 days of rearing for 11 DAH, 13 DAH and 15 DAH larvae respectively. DAH: Days after hatch.

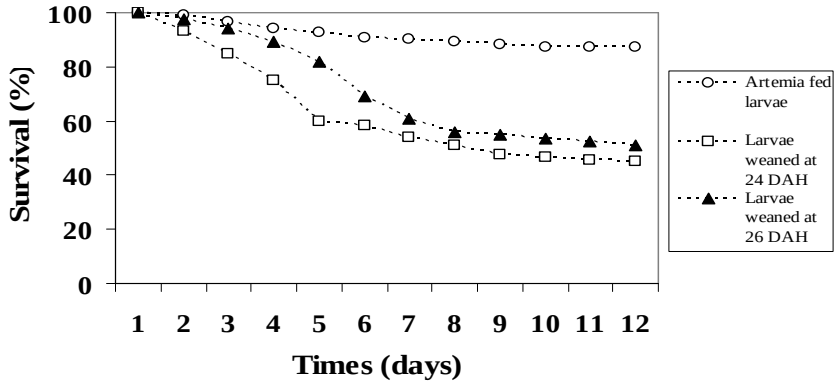

Figure 2: Daily survival trends of *Heterotis niloticus* larvae during the late weaning experiment. On X-axis, weaning occurred at time = 3 days and time = 5 days of rearing for 24 DAH and 26 DAH larvae respectively. DAH: Days after hatch.

Table 4: Mean values (n=20) of water quality parameters recorded during the early weaning experiment.

Treatment	Temperature (°C)**	pH**	Dissolved oxygen ($mg.l^{-1}$)**
T1A	28.3±1.3	6.6±1.5	10.2±2.7
T1B	28.4±1.2	6.7±1.6	10.8±2.6
T2A	28.4±1.2	6.7±1.6	10.2±2.7
T2B	28.4±1.1	6.6±1.5	9.9±2.5
T3A	28.3±1.3	6.7±1.5	10.0±2.8
T3B	28.7±1.1	6.5±1.5	10.1±2.6
T4A	28.5±1.3	6.7±1.5	9.8±2.4
T4B	28.7±1.2	6.5±1.5	9. 9±2.6

** No significant differences (p>0.05) were found. Values followed by (± SD) are means.
SD : Standard deviation.

Table 5: Survival rates and growth factors (for late weaning) of *Heterotis niloticus* larvae weaned at different DAH and reared for a period of 12 days.

Parameters	*Artemia* (control)	Weaning ages	
		24 DAH	26 DAH
Initial number	120	120	120
Final number	105	54	61
IBL (mm)	20.7±3.34	20.7±3.34	20.7±3.34
FBL (mm)	36.7±3.79 [a]	29.5±2.83 [b]	30.5±2.92 [b]
IBW (mg)	64.2±33.62	64.2±33.62	64.2±33.62
FBW (mg)	391.8±103.8 [a]	186.8± 58.67 [b]	211.9±63.22 [b]
Initial biomass (mg)	7,224	7,224	7,224
Final biomass (mg)	41,133.3	10,086.1	12,928.5
Survival (%)	87.5±0.06 [a]	45.0±0.12 [b]	50.83±0.035 [b]
SGR ($\%.d^{-1}$)	15.07±0.06 [a]	8.90±0.56 [b]	9.95±1.39 [b]
MDG ($mg.d^{-1}$)	27.2±0.24 [a]	10.2±1.05 [b]	12.3±2.93 [b]

DAH: Days after hatch; **SD**: Standard deviation**;** $\mathbf{d^{-1}}$: Per day; **IBL**: Initial body length; **FBL**: Final body length; **IBW**: Initial body weight; **FBW** = Final body weight; **SGR**: Specific growth rate; **MDG** = Mean daily growth; Values followed by (± SD) are means. SD : Standard deviation.
No significant differences (p>0.05) were found with means in rows and lettered with the same superscript.

Table 6: Mean values (n=28) of water quality parameters recorded during the late weaning experiment.

Treatment	Temperature (°C)**	pH**	Dissolved oxygen ($mg.l^{-1}$)**
T1A	29.1±1.9	6.8±1.6	8.9±2.8
T1B	28.9±1.7	6.7±1.5	9.1±2.6
T2A	28.9±1.8	6.7±1.6	8.2±3.2
T2B	28.9±1.8	6.5±1.6	7.8±2.8
T3A	28.9±1.8	6.8±1.6	8.5±2.8
T3B	28.7±2.0	6.7±1.6	8.6±2.7

** No significant differences (p>0.05) were found. Values followed by (± SD) are means.
SD : Standard deviation.

nutrients to larvae than artificial dry diet. Though the possible leaching of essential nutriments reported by Grabner et al. (1981) and Fiogbe et al. (1995) could partially affect the growth of larvae fed dry food, in this experiment, the leaching factor was reduced because fish larvae were fed ad libitum, thus compensating for the eventual loss of essential nutrients.

The significant positive correlations between survival and SGR, FBW, and FBL indicates that there was an association between survival and the growth factors (SGR, FBW, FBL) which mostly depend on food digestion and nutrient assimilation.

Unlike the first experiment, survival and growth factors were significantly improved in the late weaning experiment. This result is probably due to a more developed digestive system enabling the larvae to process, to a greater degree, the dry diet.

Similar trends were obtained for other fish larvae. Bengtson et al. (2000) reported that the summer flounder (*Paralichthys dentatus*) weaned beginning 35 DAH survived to the end of the experiment in a relatively large percentage whereas the weaning between 14 to 21 DAH resulted in complete mortality. Similarly, the bullseye puffer (*Sphoeroides annulatus*) when weaned at 29-34 DAH with micro particulate diets, had relatively high final survival (49.3%) (Garcia-Ortega et al., 2003). Studying the weaning age of the Senegalese sole (*Solea senegalensis*), Dinis et al. (2000) suggested that only 31 DAH larvae had a morphologically complete digestive tract enabling them to absorb complex nutrients. In the late weaning experiment of the current study, final survival for 24 DAH and 26 DAH were 45% and 50.83%, respectively, indicating that digestive enzyme secretion has been initiated. This was shown by the increase in SGR of the late weaning compared to the larvae weaned at 11 DAH, 13 DAH and 15 DAH in the first experiment (Tables 3 and 5).

Conclusion

These two experiments give insight on the rearing of *Heterotis niloticus* larvae in semi-controlled environments. The results showed that the weaning of *Heterotis niloticus* larvae with artificial dry diet is possible, but at an older age (at least 26 DAH). Future research to reduce the weaning age and to improve survival and growth factors should consider (1) the rearing in a totally controlled environment, (2) the food supply and food type, (3) the refinement of nutrient requirements, (4) the analysis of digestive enzymes, and (5) the use of product to early initiate the metamorphosis of the digestive tract.

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