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Growth performance of three tilapia fish species raised at varied pond sizes and water depths

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An on-farm study was conducted in Chingale area in Zomba, Southern Malawi to assess the growth of three tilapia fish species in earthen ponds of different sizes and water depths. The experiment was laid out in a factorial design of 200 and 400 m^2 pond sizes, 0.8 and 1.2 m pond water depths, and fish species: *Oreochromis karongae*, *Oreochromis shiranus* and *Tilapia rendalli*, replicated thrice among randomly selected farmers. Ponds were fertilized monthly with fresh chicken manure at an application rate of 1 ton/ha and fish were fed on maize bran as a supplement at 5% body weight. Fish were sampled and weighed every four weeks over 6 months. *O. karongae* attained the highest weight gain (65.75 g) in smaller ponds (200 m^2) translating into an overall higher gross yield of 2.91 tons/ha/year ($P<0.05$). Overall mean weight gain for *O. shiranus* (49.70 g) and *O. karongae* (43.87 g) was not significantly different in 400 m^2 ($P>0.05$). Fish in deeper ponds had a significantly higher overall mean final weight (52.26 g) ($P<0.05$). *T. rendalli* exhibited the lowest average daily weight gain (0.27) especially in 200 m^2 ponds, but had the highest specific growth rate (1.65%) while overall, *O. karongae* was the most advanced of the three tilapia species in terms of growth. Findings from this study suggest that for small-commercial fish farmers, smaller but deeper ponds produce better fish production results, hence should be adopted.

Key words: Tilapia, pond water depth, pond size, weight gain.

INTRODUCTION

One of the areas where culture of tilapia has flourished in recent years is Chingale in Zomba district of Southern Malawi. The area has the potential for developing fish farming due to its perennial water supply from Zomba

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Mountain and availability of locally produced fish feed ingredients. This has motivated the Malawi Department of Fisheries (DoF) and organizations such as World Vision International, Worldfish and the Japanese International Cooperation Agency (JICA) in supporting fish farming in the area. These initiatives have resulted into mushrooming of fishponds with more than 1000 farmers organized into vibrant working groups known as Fish Farmers' Clubs. However, despite all the efforts and resources invested, production of fish has remained low due to, among many factors, poor performing indigenous species.

Tilapia is the commonest cultured fish species in Malawi and there are mainly three species that are commonly cultured which include; *Oreochromis karongae* (Lake Malawi Tilapia), *Tilapia rendalli* (Red breasted Tilapia) and *Oreochromis shiranus* (Shire River Tilapia strain). These species are also raised by small scale farmers in Chingale. *O. karongae* is the most sought after species and exhibits better growth characteristics, and it is preferred by consumers for taste and flavor. The main challenge to raising this species by farmers in ponds has been its difficulty to reproduce in captivity (Sakala and Musuka, 2014). *T. rendalli* is also preferred for being more herbivorous and hence less reliant on supplemented diet (Koekemoer and Steyn, 2014). *O. shiranus* on the other hand, is the most prolific breeder of the three tilapias but the slowest grower (Sakala and Musuka, 2014).

Earlier pilot studies by JICA (ADiM, 2005), demonstrated that some challenges with production of tilapia such as breeding and growth can be eliminated through manipulation of the pond environment. This study was therefore designed and carried out to determine tilapia species that grows best (out of the three), and pond design (size and water depth) combination that would produce better fish production with locally available inputs amongst small-commercial fish farmers in Chingale area.

MATERIALS AND METHODS

Area of study

The on-farm research was conducted in Chingale area in Zomba district of Southern Malawi involving 48 farmers over a period of 180 days (6 months).

Experimental design and activities

Three species of tilapia namely: *O. karongae*, *O. shiranus* and *T. rendalli* were raised in earthen ponds of two different sizes (200 and 400 m^2) and pond water depths (0.8 and 1.2 m). The experiment was laid out in a 2×2×3 factorial design involving the two pond sizes, pond water depths and three tilapia fish species. The earthen ponds were fertilized monthly with chicken manure which was locally sourced at an application rate of 1 ton/ha. Fish were fed on maize bran as a supplement at 5% body weight.

Fish sampling and data collection

Fish were sampled and weighed monthly for over 6 months throughout the experimental period. This was a small scale farmer managed study, with local, easy and non-costly water quality control methods, such as using the hand to assess turbidity and water fertility, rather than the conventional laboratory methods. Pegs with predetermined water level marks were put into every pond to help farmers check and maintain water depths.

Cost (buying price) of the fingerlings, feed (maize bran) and chicken manure including the prevailing selling price of the fish per kg as well as the total harvest (kg) at the end of the trial were computed to determine gross margins for the three tilapia species.

Data analysis

Data were analyzed using Statistical Package for Social Sciences (SPPS) statistical software for Windows version 16. Univariate analysis showed that data were normally distributed. Therefore, the data were subjected to analysis of variance (ANOVA) using the general linear model. The Tukey's-b was used to carry out multiple comparisons of means for interactions. Weight gain was determined by subtracting initial (stocking) weight (W_o) of the fingerlings from the final weight (W_t). Specific growth rate (SGR) was determined using the formula: $SGR=100\times(lnW_t-lnWt_0)/t$; and average daily weight gain as; ADG (gd^{-1})=Weight gain(g)/t; where W_0 is initial weight, W_t is final weight at time t, t is the number of days (180 days) over which the fish were raised. Gross margins were calculated by subtracting total variable costs (TC) from the total revenue (TR). Variable costs included fingerlings (US$0.07/piece), feed (US$0.13 kg^{-1}) and manure (US$0.02 kg^{-1}). Total revenue was the product of total harvest (kg) and prevailing tilapia wholesale price in the country (US$4 kg^{-1}).

RESULTS

Weight gain of fish species versus pond size and depth

Results (Figure 1) showed that *O. karongae* attained the highest mean weight gain of 65.75 g in 200 m^2 ponds while weight gain for *T. rendalli* and *O. shiranus* were not significantly different (p=0.037). Means of weight gain for *O. shiranus* (49.70 g) and *O. karongae* (43.87 g) in 400 m^2 ponds were significantly higher (p=0.037) than these of *T. rendalli*. Results furthermore showed that pond depth had an effect on the final mean weight of the fish, regardless of species. Higher pond water depth (1.2 m) resulted in higher final fish weight gain (52.26 g) than shallow (0.8 m) deep ponds (p=0.043).

Specific growth rate (SGR) of fish species by pond size and pond depth

There were no significant differences in SGR between pond size, pond depth and fish species (p=0.601) (Table 1). Differences in SGR were however, observed between pond size and fish species, where *T. rendalli* had the highest SGR (1.653%) than *O. karongae* (1.367%) and *O. shiranus* (0.900%), respectively (p=0.001). The effect

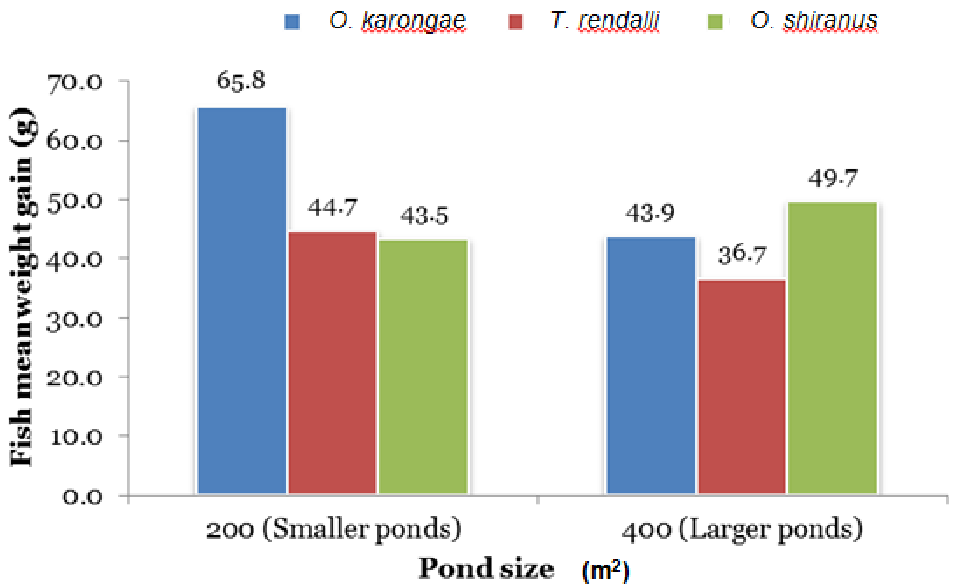

Figure 1. Mean weight gain (g) of fish species raised in 200m^2 and 400m^2 ponds for 6 months.

Table 1. Specific growth rate (SGR) of fish species by pond size and pond depth for 6 months.

Parameter	Fish Species	Pond size (m^2)(p=0.001)		Pond depth (m) (p=0.043)	
		200	400	0.8	1.2
SGR (%)	*O. karongae*	1.367±0.077^b	1.050±0.077^c	1.183±0.077^a	1.233±0.077^a
	T. rendalli	1.653±0.092^a	1.227±0.080^d	1.210±0.063^b	1.671±0.111^b
	O. shiranus	0.900±0.077^b	1.167±0.077^c	0.983±0.077^a	1.083±0.077^a

Values with different superscripts in the same column under the same factor are significantly different (P<0.05).

of pond depth on SGR of fish species had a similar pattern as that of pond size on fish species but was lower (p=0.043).

Average daily weight gain (ADG) of fish species by pond sizes and pond depths

Average daily weight gain (ADG) was significantly influenced by pond size and fish species raised (Table 2). Average daily weight gain for *T. rendalli* was 0.274 g dy-1 being lower (p=0.028) than for *O. karongae* (0.383 g dy-1) and *O. shiranus* (0.267 g dy-1), respectively, whose ADG were not significantly different in 200 m^2. The trend was similar for the 400 m^2 pond except for *O. shiranus* whose ADG (0.267 g dy-1) was higher (p=0.028) than that of *O. karongae* (0.233 g dy-1) and *T. rendalli* (0.221 g dy-1), and the latter two were not significantly different since weight gain had a similar trend as observed in 200 m^2 pond. There were no significant differences in ADG between pond depth and fish species (p=0.067), and neither did pond depth have independent effect on ADG of the fish.

Gross yields and extrapolated gross margins analysis

Mean gross yield of the fish (Table 3) was only affected by pond size (p=0.021) but not pond water depth (p=0.867) and fish species (p=0.101) with highest mean fish yields (2.91 tons/ha/year) reported in smaller ponds (200m^2) which agrees with the weight gain results. Results also showed that these factors did not significantly affect the extrapolated gross margins (Table 4).

DISCUSSION

Higher mean weight gain for *O. shiranus* and *O. karongae* than *T. rendalli* in 400 m^2 could be due to the fact that farmers found it easier to manage the 200 m^2 ponds (smaller ponds), despite attempts to standardize

Table 2. Average daily weight gain (ADG) of fish species by pond size and pond depth for 6 months.

Parameter	Fish Species	Pond size (m^2) (p=0.001)		Pond depth (m) (p=0.043)	
		200	400	0.8	1.2
ADG	*O. karongae*	0.383 ± 0.027^a	0.233 ± 0.027^c	0.317 ± 0.027^a	0.300 ± 0.027^a
	T. rendalli	0.274 ± 0.030^b	0.221 ± 0.028^c	0.186 ± 0.022^a	0.309 ± 0.038^a
	O. shiranus	0.267 ± 0.027^b	0.267 ± 0.027^b	0.233 ± 0.027^a	0.300 ± 0.027^a

Table 3. Gross margins of fish in 200 and 400 m^2 ponds at 0.8 and 1.2 m water depth raised for 6 months.

Pond size (m^2)	Pond water depth (m)	Fish species	Mean gross margin (US$)
200	0.8	*O. karongae*	73.997 ± 34.738^a
		T. rendalli	$89.830\pm30.084^*$
		O. shiranus	70.663 ± 34.738^a
	1.2	*O. karongae*	33.330 ± 42.545^a
		T. rendalli	$41.330\pm60.167^*$
		O. shiranus	103.997 ± 34.738^a
400	0.8	*O. karongae*	74.670 ± 42.545^a
		T. rendalli	$56.670\pm42.545^*$
		O. shiranus	88.670 ± 34.738^a
	1.2	*O. karongae*	82.670 ± 60.167^a
		T. rendalli	$90.670\pm42.545^*$
		O. shiranus	130.003 ± 34.738^a

Values with different superscripts in the same column under the same factor are significantly different (P<0.05).

key management parameters during the on-farm study. Pond management is usually a challenge among small scale fish farmers in integrated farming systems and it is often variable (Nsonga and Mwiya, 2014). For *O. shiranus*, the effect of overcrowding due to prolific breeding was higher hence poor performance in the smaller pond. Lower mean weight gain for *T. rendalli* in bigger ponds can also be attributed to the generally poor and irregular management practices that affect pond fertility (primary production) was compromised also observed during farmer pond assessment tours. Fish therefore depended more on the supplementary feed (maize bran) hence a nutrition challenge. *T. rendalli* is predominantly herbivorous feeding on macrophytes, algae and also insects, crustaceans, aquatic invertebrates and small fish (Skelton, 2001). Better performance of *O. karongae* could be due to its ability to respond better to supplementary feed than *O. shiranus* (Malcom and Brendan, 2000).

Better growth of all fish species in deeper ponds suggests that pond water depth is a management parameter which farmers can adopt to improve fish production irrespective of species. Unpublished results by the JICA Project in the area of study showed that *O. karongae* and *T. rendalli* (species that have breeding problems in ponds) exhibited higher breeding performance in ponds that were more than a metre deep. Deeper ponds entail more water volume, that is, lower volumetric stocking density which provides more space and relatively more natural food for the fish. Implicitly, there was more available oxygen and low water deterioration rate from fish wastes. When surface water becomes warmer due to high temperatures, fish seek refuge at the deeper end to avoid stress (Walberg, 2011).

Overall lowest average daily weight gain (ADG) for *T. rendalli* may be due to the fact that the average daily gain was general throughout the culture periods. As mentioned earlier, adequate fertilization necessary for higher aquatic plants in the ponds which is a major requirement for *T. rendalli* (Hlophe and Moyo, 2013), was not achieved due to irregular manure application by the farmers. The highest specific growth rate (SGR) nevertheless, could be due to the cumulative growth advantage which the species had owing to the smallest initial stocking weight. Experience at the Malawi National Aquaculture Center shows that Tilapia fingerlings stocked at smaller sizes exhibit high SGR as they easily adapt to the new environment and have relatively high metabolic

Table 4. Mean fish gross yield by experimental factor.

Factor	Level/type	Mean fish yield (tons/ha/year)
Pond size (p=0.021)	200 m^2	2.91±1.375[a]
	400 m^2	2.05±0.912[b]
Pond water depth (p=0.867)	0.8 m	2.54±1.279[a]
	1.2 m	2.46±1.227[a]
Fish species (p=0.101)	*O. karongae*	2.03±1.007[a]
	T. rendalli	2.40±1.489[*]
	O. shiranus	3.09±1.016[a]

Values with different superscripts in the same column under the same factor are significantly different (P<0.05).

rate. This finding agrees with earlier research work of M'balaka et al. (2012).

SGR and ADG values attained in this on-farm research are comparable with some earlier researched works but with lower values than other researchers reported previously some but lower than others earlier reports. Khosa (2008), who conducted an on-station study and used a mixture of organic and in-organic fertilizer, supplemented with feed, reported SGR for *O. shiranus* ranging from 1.08 to 1.24%, as well as ADG between 0.35 and 0.49 g dy^{-1}. Kang'ombe et al. (2006) reported between 0.13 and 0.77 g day^{-1}) for *T. rendalli* raised in fish ponds fertilized with cattle, pig and chicken manure.

Although results seem to suggest that *O. shiranus* gave higher yields and gross margins than *O. karongae* which could be attributed to prolific breeding (Valeta et al., 2012) and not necessarily good growth performance (weight gain) the data are highly dispersed and skewed, this may likely be due to unreported harvesting practices, which distorted the final harvest biomass data.

CONCLUSIONS AND RECOMMENDATIONS

The study has demonstrated the possibility of attaining high mean fish weight gain in small ponds (200 m^2) which are manageable at small scale on-farm level using basic rates of affordable and locally available maize bran as a supplementary feed and chicken manure as pond fertilizer. The study has also demonstrated to farmers that maintaining high pond water depth (more than a metre) results in higher fish growth performance and yields. The potential for commercial fish farming at small scale fish farming level exists especially for *O. karongae* in deeper ponds but be carefully supported with supplementary feed and organic fertilizers in small ponds.

It is recommended, that small scale fish farmers should adopt raising of *O. karongae* in deeper (more than a metre water depth) and small ponds and adopt using manure and supplementary feed as the first step towards commercial fish farming. With improved management practices, bigger ponds should be used to obtain higher fish biomass at harvest. This on-farm researches and results should be replicated for validation, and out-scaled to other areas where fish farming is failing to develop owing to poor technology and management.

Conflict of interests

The authors have not declared any conflict of interests

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