Adaptation and growth performance of Nile tilapia (O. niloticus) in integrated fish farming on North Western Amhara Region

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Abstract

Improper management has led to over fishing of most inland waters. Therefore, more attention has to be given to fish farming (aquaculture) in Ethiopia. Currently aquaculture contributes over 30% of the fish consumed throughout the world. An investigation was carried out to evaluate the adaptation and growth performance of tilapia fish in aquaculture ponds established within agricultural lands. The study was conducted in three different administrative zones of the Amhara Regional State; East Gojjam, West Gojjam and Awi Zones. A total of 15 fish farmers from different agro-ecologies had been selected. Each farmer has a fish pond size of 100 m^2 with 1.5 m average depth. A total of 4,000 tilapia fish (Oreochromis niloticus) fingerlings, 3-5g in size, have been collected from the wild and stocked. Fish sample was collected every two months and the growth and maturity of fish was recorded. The pond water was supervised and managed at its optimum quality required for fish growth in grow out ponds. More than 97% of the experimental fish adapted pond culture and the maximum mortality record was during the first 5 days after stocking. Fish have shown different growth performances depending on the agro-ecology they were stocked. Those in the warmer areas grew faster and attained 231g within 9 months of time, whereas those in the colder took a year and more to attain the required size. Stocking tilapia in farmers pond constructed within agricultural land is a promising technology to be scaled-up/out, but the size of fish fingerlings going to be stocked should be compromised with the agro-ecology where the ponds are going to be established.

Key words: Aquaculture, fingerling, fish pond, scale-up, tilapia.

Introduction

Backyard ponds can be designed and built to serve multiple purposes including fish farming with advanced planning. Pond fish culture is the most popular method of growing tilapia. The advantage of pond fish farming is that the fish are able to utilize natural foods (Rakocy *et al*, 2005) and farmers can receive higher net returns from fish farming integrated with agricultural practices. Even small ponds can contribute to farm income or reduce family spending as fish are sold, bartered or eaten.

The various types of aquaculture form a critical component within agricultural and farming systems development that can contribute to reduce malnutrition through the provision of food of high nutritional value, decreased risk of production, sustainable resource management and increased farm sustainability (Little and Edwards, 2003). Aquaculture, especially integrated one, is sustainable because it makes use of locally available materials. Integration with other forms of agriculture diversifies farm productivity; provide opportunities for intensified production with more efficient allocation of land, water, equipment and other limited capital than practices which run independently. Fish culture integrated with garden irrigation, livestock watering and various domestic uses are all possible.

Fish being cheap source of high quality protein is used as an alternative way to fulfill the protein requirement of the farm family. Production cost of fish, if the ponds are constructed once, is lower when compared with poultry, beef and sheep. Pond fish convert food in to flesh efficiently as they are essentially weightless in water, and thus expend little energy for locomotion or maintain a normal upright position. They are cold blooded animals and do not expend energy to maintain a relatively high body temperature as other warm blooded ones. Thus, the amount of energy required to produce one kg of fish is much less than the amount required producing an equal weight of terrestrial animal.

Tilapia are extremely tough fish that can thrive in poor quality water, on low-cost feeds (Bronson, 2005), fast-maturing fish, easy to keep, popular with consumers and nutritious with white meat (CTA, 2007) and proven to grow on kitchen scraps and other low-cost inputs (WFC, 2007; Economist, 2007). They exhibit maximum growth rates at temperatures between 25 and 30°C (Bocek, 2003), making them more likely to become established and invasive in tropical climates. Nile tilapia (*Oreochromis niloticus*) is the most predominant species of tilapia in aquaculture (Gupta and Acosta, 2004); and well adapted to artificial culture environments, gain weight quickly at optimum conditions and reproduce on the farm without special management or infrastructure. Nile tilapias (*O. niloticus*) reach sexual maturity at about 5 to 6 months (Gupta *et al*., 2004).

If the natural productivity of a pond is increased through fertilization or manuring significant production of tilapia can be obtained without supplemental feeds. To maximize fish production, manure from livestock should be added daily to the pond in amounts that do not reduce dissolved oxygen (DO) to harmful levels as it decays. A pond should be fertilized at a rate of 10kg for cattle, equine and sheep/goat manure and 6-8 kg for pig and chicken in a 100m² ponds every week. The maximum rate depends on the quality of the manure, the oxygen supply in the pond and water temperature. The rate of manuring should be increased gradually as the fish grow (Rakocy *et al*., 2005). Liming (at a rate of 1000 to 2000 kg/ha) promoted phytoplankton growth and increase fish production.

The farmers do have water running and by-passing via their backyard or stored at and their farm land. In some areas small streams residing around the backyard are barraged to irrigate tree nurseries and vegetable seedbeds. Mostly, a family does have cattle or small ruminants or chicken or both who potentially can produce manure every day that will be used to fertilize water stored in a pond. Fertilized water can provide live food for fish since multiplication and growth of important plankton species is enhanced. Today, aquaculture becomes responsible for an ever-increasing share of global aquatic food production, which has increased from 3.9% in 1970 to 31.9% in 2003 (Carballo *et al*., 2008). Despite of these opportunities, the farming family is suffered from malnutrition and scarcity of protein food. The gap between supply and demand for fish is widening, natural fish stocks in the region as elsewhere in the country been declined yet human populations and hence demand, continue to increase. Backyard fish farming research has been demonstrated in three zones (East Gojjam, Awi and West Gojjam) of the Northwestern Amhara for the last three years since 2008. The demonstration has been undertaken to check whether it is possible to integrate fish farming in farmers' back yard.

Material and methods

Backyard demonstration ponds were prepared at *eight Woredas* of the North Western Amhara Region; fife in East Gojjam, two in west Gojjam and one in Awi Zone. The ponds were located at different altitude ranges (1791 to 2314 meters above sea level). All backyard fish ponds were earthen but the one at Dangila and the other at Bahir Dar Zuria were lined and plastered with hard plastic sheet (geo-membrane) cover as the area which percolates pond water.

Ponds were located on land with a gentle slope. They are rectangular or square-shaped, having dikes and devoid from the entrance of run-off water from the surrounding watershed. Side slopes varied from 2:1 or 3:1 (each meter of height needed 2 or 3 meter of horizontal distance) for easy access to the pond and minimized risks of erosion. Most of the ponds drained water partly when the fish were harvested. Ponds receiving water from surface sources did have an inlet pipe (PVC) or ditch or canal that let water in and an outflow to remove water out. Every pond did have plot of land around, most of them down to the pond, so as to perform different agricultural activities. One pond built with chicken shade over it and chickens were reared on over the pond so that the litter dropped in to the pond water, which is used as a fertilizer of the pond water.

Water: The source of water for the backyard ponds varied according to the resource found in the area. Majority of the ponds in East Gojjam were ground sources where by water has been recharged and filled naturally by pumping it up. A farmer from Bahir Dar district pumped water from Lake Tana to refill and refresh the pond. Most of the farmers used irrigation water which had been running over the backyard farm land before the adoption of fish farm technologies.

Cultivable land: All participant framers integrated fish production with different vegetable production, tree seedling and chicken rearing. Each farmer had plot of land aside from his fish pond. The size varied from 300 to 500 m^2. The vegetables which were cultivated most include Cabbage (*Brassica oleracea*), Carrot (*Daucus carota*), Tomato (*Lycopersicon esculentum*), Beetroot (*Beta vulgaris*) and Pepper (*Capsicum annum*). Tree seedling species which were grown by farmers was Eucalyptus tree (*Eucalyptus globulus*). The breed of chickens reared by farmers along with his fish pond was Rhode Island Red.

Equipment and inputs used: Global Positioning System (GPS) were used to navigate the location of each pond. Tape meter used to delineate the pond area and to construct the pond. Big plastic jar, filled with water and equipped with oxygen supplier (aerator), were used to transfer fish fingerlings from the hatchery/natural water body to the farmers' ponds (grow out ponds). Seine net and/or gillnets of 6 and 8 cm mesh size, cast net, sensitive balance, measuring board and different scoops have been used to collect and measure pond fish during sampling. Water quality parameter measuring field equipments like Oxygen meter, pH meter and secchi disc were used. Lime was applied at a rate of 100 grams/pond to make the pond bottom comfortable for fish and adjust the soil pH prior to filling the pond with water and stocking fish. Tilapia fish fingerlings (mixed sex) were used to stock each pond. Animal manure (mostly cow dung) was used to fertilize the pond water.

Methodology

A total of 15 farmers (14 male and 1 female households) having a pond or two with an area of 100 m^2 and more were selected. Ponds were prepared at a depth of 1.25 m on the inlet and 1.75 m on the outlet side (Average 1.5 m). Once the ponds were dug, lime was spread on the sides and its bottom at a rate of 10 kg per 100 m^2. After the application of lime and filled with water, manure was added at a rate of 15 kg in a week to fertilize the pond (FAO, 1994). Once the pond is fertilized and food availability in the pond is realized, fish fingerlings were collected from hatcheries or natural water body and stocked at a density of 2 fishes per m^2.

The fish used for this demonstration was mixed sex Tilapia fingerlings having a size of 3-5 grams. For ponds which were established within the basin area of Lake Tana, artificially reared Nile Tilapia (*Oreochromis niloticus*) fingerlings were stocked to avoid contamination of the Lake with other Tilapia strains. Fish fingerlings died during the first three days after stocking has been recorded. Fish adaptation and growth were checked every two months using seine net and gillnets with different mesh sizes (6, 8, and/or 10 cm). Once the fish attained the recommended table size (150 grams and more), they were collected from the pond and taken to home for food or market for sale. During fish collection 50% of the pond water is lowered first. The fertilized pond water siphoned out from pond regularly and irrigated the cultivable plot of land. All the fish were collected once they reached the intended table size. To track the fish produced, consumed and/or sold as well as the costs expended, records were made using data recording sheet given to individual farmers.

Results and discussion

Fish adaptation and growth

The average pH of all the pond water was between 4 and 9 and that of temperature was in between 14 and 26.8 ^{O}C depending of the altitude where the ponds are situated. In rare cases the temperature has been dropped to the minimum limit for tilapia. The average Dissolved Oxygen level was in between 1.74 and 10.93 mg/lit. The lower temperature was recorded during rainy season on ponds where the runoff water enters. The adaptation of fish stocked in the ponds reached 97.05%. The remaining 3% lost due to temperature shock happened while refreshing the pond water from the river during cold season in areas where the altitude is higher.

Productions from the integration

Fish: The selected farmers adapted the technology of fish farming in integration with the existing and new farming practices. Fish growth has been increased by 2 fold after 2 months of stocking in warmer sites. Fish has been grown at a maximum weight of 231 grams, 85% of the fish fall between 190 and 231 grams and 75% of the fish had a length of more than 23 cm. A farmer enabled to produce 17 kg of fish/cycle. Growth performance varied depending on the time that the fish spent and the altitude. The fish needed 9 to 14 months to reach table size at an altitude range of between 1791–2320 m.

All the 15 demonstration household farmers prepared 16 fish ponds covering an area of 1660 m^2. The total fish produced from these ponds reached to 2.89 quintals. According to Rakocy *et al* (2005) approximately 22 kg of fish per year can be produced in an acre of pond with local management, but the result in this integration exceeded by manifolds.

Farmers living at the lower elevated areas enabled to produce more fish than the others living in higher altitudes using the same size of backyard fish pond. The time taken to produce table size fish (150 gm and more) varied with elevation, the higher the elevation the longer it took. The time required to produce 13.9 kg of fish was 14 months at an altitude of 2320 m. But a farmer used to live at an altitude of 1791 m required only 9 months of

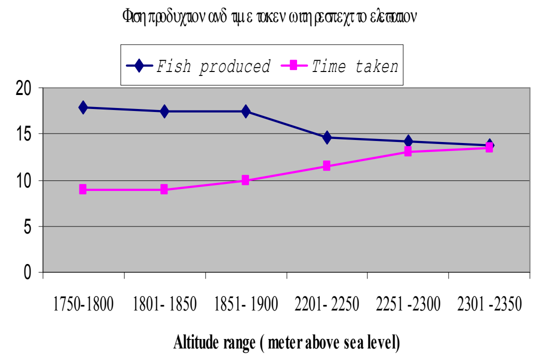

Figure 1. Fish produced (kg/pond) and time required (month) with altitude.

Vegetables

The farmers integrated vegetable production with fish were14 in number. Demonstration farmers produced, including those never did before, 168 to 2500 kg of vegetables using the fertilized pond water where fish were growing. Those farmers prepared bigger plot (500 m^2) of land and having previous experience in cultivation of vegetables has got more production than the others started during the demonstration (Table 2). Totally 153 quintals of different vegetables produced in a year (i.e. one fish production cycle). Most of the vegetables (more than 93%) produced in the farmers' plot of land sold to the local market and about 6% (nearly 10 quintal) of the produce used at home. Aside from their vegetables, two farmers produced 40 fruit and 15,000 tree seedlings for market.

Table 2. Vegetable produced and sold by category of farmers.

Category	Number of participants	Vegetable produced (kg)	Vegetable sold (kg)	Vegetable consumed (kg)
Experienced farmers	8	12,904	12,078	826
Non experienced (Starters)	7	2,428	2,258	170
Total	15	15,332	14,336	996

Chicken

A farmer at Bahir Dar zuria woreda constructed chicken house and reared Rhode Island Red breeds in one season (Figure 2). Chicken manure was directly added to the pond water and the farmer planted some green feeds for the chicken using pond water. The water has been fertilized frequently and the multiplication and growth of planktons were fast. Apart from the scarcity of chickens, it has been possible to rear more than one time in one fish production cycle as the fish in his pond stayed for about 9 months to reach table size. He brought a month old 36 chicken from multiplication center and keep for 3 months of time. He grew all the chicken successfully and sold all of them at a time.

Figure 2. Integrated farming experience of a farmer at the vicinity of Bahir Dar city.

Market value of the products

In areas where fish has never been produced or hardly known, it was possible to produce and use it. Currently children and women are taking fish out of their pond when meat is needed at home. Furthermore the farmers realized the possibility of producing fish to the local market and made money. More than 50% of the demonstration farmers (Table 2) have been producing vegetables since the last 4 to 5 years, but not in integration with fish. During this demonstration, farmers enabled to produce a new product and got additional yield and income with low cost using the pond water. A farmer has got net income of more than 8,000 birr from integrated farming system (Table 3). Those started to produce fish fingerlings by supplementing feed has got better income than those waiting for the grow-out fishes only. The gross income of this integration reached more than 57,000 ETB and fish farming contribution varied from 5% to 40%. The overall gross income contribution of vegetable production, chicken rearing and fish production in the integration system was 84%, 3% and 12%, respectively.

Table 3. Income (birr) generated from integrated farming.

Farmer code	Cost of production			Gross income			Net Income
	Fish	Agriculture	Total	Fish	Agriculture	Total	
01	187	230	417	254	3,360	3614	3197
02	187	230	417	280	3,200	3480	3063
03	122	340	462	338	4,500	4838	4376
04	127	230	357	184	600	784	427
05	110	360	470	1046	7,500	8546	8076
06	100	340	440	426	4,500	4926	4486
07	100	340	440	328	6,000	6328	5888
08	319	230	549	1080	1,600	2680	2131
09	228	230	458	418	5,000	5418	4960
10	162	230	392	302	2,000	2302	1910
11	160	230	390	236	3,000	3236	2846
12	198	340	538	300	1,620	1920	1382
13	161	230	391	284	450	734	343
14	150	230	380	470	3,200	3670	3290
15	178	980	1158	755	3,844	4599	3441

Conclusions and recommendations

Tilapia fish can adapt and grow up to an altitude of 2300 m (pond water average T° of ≥ 18 ^{O}C) with appropriate management practice and allow to stay extra growing time. Using fingerlings having a size of ≥30 grams and mono-sex fish shown best performance. The demonstration indicated that integrating pond fish farming at the farmers' backyard can at least improve the nutritional status of the farm family and fetch an income. In this demonstration, it is proved that the technology can potentially sustain the livelihood of a family. This system helped the farmers to adapt new technology and acquire knowledge so that they could able to be benefited more. For the success of this technology the species to be selected for integration should fit to the site. In higher altitude areas aquaculture ponds need to be protected from the cold wind and cold river water during cold seasons of the year. Due consideration should be given to promote the technology through awareness creation and participatory demonstration. As the produce of the integrated technology are mostly perishable; appropriate handling, processing and marketing system should be arranged. Further research has to be undertaken on the implementation of the technology, especially on mono-sex fish fingerling production system for different species to be integrated and pond depth and management practices to be applied in highland areas.

References

ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA). 2007. Making a living with fish farming. CTA practical guide series, No.9. ISSN 1873-8192.

Bocek, R. 2003. Water harvesting and aquaculture for rural development. International centre for aquaculture and aquatic environments. Swing hall, Auburn University, Alabama. USA.

Bronson H. 2005. Aquaculture Plan Florida Aquaculture Plan 2005-2006. Florida department of Agriculture and consumer services, Division of aquaculture. Florida, USA).

Carballo E., van Eer A., van Schie T. and Hilbrands A. 2008. Small-scale freshwater fish farming. Agrodok 15. ISBN Agromisa: 978-90-8573-077-4

Food and Agriculture Organization (FAO). 1994. Hand book on Small-Scale freshwater fish farming. FAO Training series. Food and Agriculture Organization of the United Nations. Rome,1994.

Gupta M. and Acosta B. 2004. A review of global tilapia farming practices. Aquaculture Asia Magazine IX (1).

Little D. and Edwards P. 2003. Integrated livestock-fish farming systems. Inland water resources and aquaculture service. Animal production service Food and Agriculture Organization of the United Nations, Rome.

Rakocy and McGinty. 2005. Pond culture of Tilapia. Published by Southern Regional Agricultural Center and the Texas Aquaculture Extension Service. USA.

The Economist. 2007. Fish versus AIDS. August 30, 2007. https://www.economist.com/world/africa/ Accessed July 28, 2010.

World Fish Centre (WFC). 2007. Innovative Fish Farming Project for HIV-affected Families in Malawi Doubles Incomes and Boosts Household Nutrition. http:// www.worldfishcentre.org/ resource centre/WorldFish Press Release. Final. pdf. Accessed July 28, 2010.