ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

THE EFFECT OF STOCKING DENSITY AND SUPPLEMENTARY FEEDING ON GROWTH PERFORMANCE AND YIELD OF NILE TILAPIA [*OREOCHROMIS NILOTICUS* (L, 1758)] IN CAGE CULTURE IN WONJI RESERVOIR, ETHIOPIA

BY

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JUNE, 2010

The effect of stocking density and supplementary feeding on growth performance and yield of Nile tilapia [*Oreochromis niloticus* (L, 1758)] in cage culture in Wonji Reservoir, Ethiopia

A THESIS PRESENTED TO
ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF
THE REQUREMENT FOR THE DEGREE OF MASTER OF SCIENCE
IN BIOLOGY

By
Abdilahi Dill

June, 2010

Acknowledgements

I would like to express my gratitude and respect to my research advisors, Dr. Abebe Getahun and Prof. Krishen Rana, for their committed guidance and unreserved support. The encouragement and assistance I received from them is priceless and has contributed a great deal to the success of this study.

I also gratefully acknowledge the financial support I recieved from Development Partnerships in Higher Education (DelPHE) through my research advisor Dr. Abebe Getahun.

I would like to express my appreciation to all of those who gave me the possibility to complete this thesis. I want to be very thankful to my colleagues in the FASS stream for all their help, support, interest and valuable hints. Especially I am indebted to Ashagrie Gibtan, Akewak Geremew and Asfaw Alemayehu for all their assistance in the field.

My gratitude goes to Wonji Sugar State which provided a study site and protection to cages and materials in their reservoir. My special thanks go to Ato Awol Abegaz and Ato Bahiru Burka who took the responsibility of taking care of the cages day and night for five months.

My special thanks also extend to my family for their consistent support in various ways. The Department of Biology, AAU, is greatly appreciated for giving me the opportunity to study my MSc at the Department and also assisting me with materials and financial resources during my thesis work.

I also thank the laboratory assistant Neway Andarge for his help in the preparation of feed.

Finally I wish to thank all those who helped me in one way or another. Above all, I praise Allah for giving me the strength to withstand all ups and downs.

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Abstract

This research was conducted to investigate the effect of stocking density and supplementary feeding on growth performance and yield of Oreochromis niloticus in cage culture in Wonji Reservoir. The treatments had stocking densities of 25 (25F), 50 (50F), 75 (75F) with supplementary feed and 25 (25N), 50 (50N), 75 (75N) fish per m^3 cage without supplementary feed. The treatments with supplementary feed were in duplicates and the controls were single. Juveniles with average weight of 43.70 ± 0.19, 43.12 ± 0.5, 43.38 ± 1.14, 43.97 ± 0.36, 43.51 ± 0.33 and 43.98 ± 1.18 gm were stocked in 25F, 50F, 75F, 25N, 50N and 75N treatments, respectively. The fish were fed 3% of their body weight twice per day using feeding trays for 100 days. The results indicated that growth performance of O. niloticus was density dependent. The final mean weight of O. niloticus in 25F was 175.83±0.68 gm and the mean daily weight gain was 1.36 gm, whereas in treatments (50F, 75F) and controls (25N, 50N and 75N), final mean weight was 154.92±0.82, 146.70±0.15, 86.67±0.51, 73.64±0.26, 72.62±0.46 gm and mean daily weight gains were 1.06, 0.77, 0.55, 0.28 and 0.27 gm, respectively. Moreover, feed conversion and condition of fish were affected by stocking density and supplementary feeding. The apparent feed conversion ratio (1.45 – 4.45) was significantly affected by stocking density ($P<0.05$). Fulton condition factor was inversely affected by stocking density while it was directly affected by supplementary feeding. However, survival rate was not affected by stocking density and supplementary feeding ($P > 0.05$). In this experiment, it can be concluded that the most effective stocking densities for O. niloticus cultured were at 25 fish / m^3 cage for larger size fish demand in short period and 75 fish/m^3 for higher gross production with supplementary feed. Physical, chemical and biological parameters were the same among cages or between cages and the open water in the present experiment. Thus, all O. niloticus had similar culture environment and equal access to natural feeds.

Key words / phrases: *Cage culture, Growth performance, Wonji Reservoir, Nile tilapia, Stocking density, Supplementary feeding.*

1. Background

Aquaculture is the use of water resources for growing aquatic organisms under controlled conditions or selected environments for economic or social benefits. It makes use of all kinds of waters- seawater, brackish water and freshwater. Although it is akin to terrestrial agriculture, it can make a unique contribution to nutrition in many parts of the world by virtue of its extremely high productivity in many situations and its provision of primarily protein crops than starchy staple feeds (Bardach *et al*., 1972).

There are three types of aquaculture operations known to be exercised commonly: (1) pond culture, (2) enclosure cultures (raft or cage), and (3) rice or paddy field culture (Bell and Canterbery, 1976). The feeding system could be through direct feeding of high protein containing low price feed or through fertilization of the aquatic environment to raise level of natural feed production, depending on the species reared. In general the kind of culture, type of water used and the feeding system will depend on the relative economic costs and benefits under given environmental conditions (Bardach *et al*., 1972).

The world population pressure on natural resources is increasing on a continuous basis. Each year millions of people are dying of starvation and malnutrition, due to problems of incompatibility between feed supplies and demand. According to Meadows *et al*. (1972; cited in Bell and Canterbery, 1976), the resource exploitation together with the exponentially growing population result in a collapse of per capita feed production.

World fisheries production has a spectacular contribution to the global feed production. Though catches between 1950 and 1990 increased to some 100 million tons (Heckmann, 2005), they are now in slow decline, and as a result, prices have risen. As a panacea for increasing food production and to cope with wild stock scarcity and price increase, aquaculture is being exercised to ensure food security while improving natural resource management and the conservation of biodiversity.

In addition to the above reasons, Bardach *et al*. (1972) stated that favorable feed conversion rates and high productivity per hectar as compared with traditional agricultural methods and products could be reasons for rapid growth of aquaculture activities. Protein from feeds of animal origin is dangerously lacking in the everyday diet of much of the population of Africa. Others like carbohydrate and lipids are relatively found for a great deal of ill health and many deaths each year in almost all the countries of Africa.

Apart from producing large quantities of lower-cost protein-rich feed, aquaculture is used to enhance wild stocks, to propagate organisms of ornamental importance and to produce bait organisms. Aquaculture practices, in some cases, are characterized by the relative intensity of human effort applied to them and by their small size landholdings (Bardach *et al*., 1972; Bell and Canterbery, 1976).

Modern concept of aquaculture was introduced from Europe into African countries during the colonial periods (FAO, 2004a). In the 1950s, about 300,000 fish ponds were operating by mainly rearing tilapia in about 20 African countries. Now, despite the existence of aquaculture for the past 55 years in Africa, the total aquaculture output is still very low compared to production from the capture fisheries. In 2002, total fish production in Africa was 7.5 million metric tones which was 5.6 % of world production. Because of this, the input of aquaculture in Africa is fairly insignificant compared to the rest of the world.

African aquaculture contributed merely 1.2% (463 x 103 Metric tones) of total world aquaculture production. Only four countries, Egypt, Nigeria, Madagascar, and Ghana, represented 90% of the continental total aquaculture production (FAO, 2004b).This is due to a lack of regular planning and exercises for aquaculture development in most African countries.

Aquaculture in Africa is still a secondary and part-time activity in small farms with small freshwater ponds, and it is still an industry in its early developmental stage. Freshwater aquaculture in ponds is the most widespread type of aquaculture in Africa today, and it produces the greatest amount of fish equivalent to 80% of the total aquaculture harvests. Thus, freshwater aquaculture is the most promising avenue to increase aquaculture production in the short and medium term.

Ethiopia is endowed with sizable amount of lotic (running) and lentic (standing water) environments whose fishery potential has not yet been fully realized. The inland water body of the county is estimated at about 7,400 km^2 of lake area and about 7,000 km total length of rivers (Shibru Tedla, 1973). These water bodies harbor more than a hundred edible fish species, and the annual potential fish yield of the main lakes is roughly between 30,000 and 40,000 metric tons. However, current exploitation is about 20 % of the potential, and a few species contribute to the fishery. Therefore, though some stocks show signs of over fishing, the fishery could be expanded so that it can contribute to food security and the economy.

The major fishing activities in Ethiopia are capture fisheries and currently the fishery is at the verge of collapse in some of these water bodies. To mitigate this problem culture fishery should be considered as alternative. Aquaculture as the primary means of achieving increases in fish supply to overcome constraints that capture fisheries are confronted with. Therefore, a great effort is needed not only to maximize fish production but also to tackle the problem associated with poverty, since fish culture activities increase job opportunity for some people. Consequently, there is a need to look for less expensive technology which requires simple methodology and high yield and tolerant fish (Beveridge, 2004).

With regard to the situation of fisheries, Ethiopia has an estimated annual total exploitable potential of 60,000 tons from lakes and streams. The per capita fish production is less than 240g (FAO, 2003), but if population as a factor is taken the total annual fish demand will be more than 65,344 tons, approximately 1 kg/person (FAO, 2003). In view of this, the supply from the water bodies can no more meet the demand (ONAR, 2004). In addition, if other positive factors that trigger the demand such as low fish price, increased distribution networks and improved product quality are considered, the demand will be much higher. Contrary to the increasing demand, the supply from the currently exploited natural stocks has already shown signs of stock decline due to overfishing (Reyntjens and Tesfaye Wudneh, 1998).

Furthermore, the growing hydroelectric projects together with the irrigation projects will potentially aggravate the threat on the riverine stocks (Abebe Getahun and Stiassny, 1998). This, therefore, calls for an increasing attention to be given for aquaculture development in Ethiopia from the point of view that it can contribute to the conservation of biodiversity.

Many researchers have suggested small-scale commercial aquaculture, for Ethiopia faced with deficit in animal proteins, in particular to supply during fasting periods (Balarin, 1986). Aquaculture in Ethiopia is still non-existent in spite of the fact that the country's physical and socio-economic conditions favor its development. The high central Plateau above 2,500 m (11% of total area) could be appropriate for all year round farming of cold-water species. The surrounding and central highlands are believed to be present temperature characteristics favorable to the breeding of a large number of species, from cold water to warm water.

However, such developments require significant technical support in terms of provision of fingerlings, demonstration and extension services, which are lacking. Taking this into account, the Sebeta Fishery Research Center is attempting to develop aquaculture activity for culture-based stock enhancement operation into natural water bodies and man made reservoirs since 1973. Although the potential for aquaculture in Ethiopia has so far been assessed at a country level by Balarin (1982) and at a continental level for Africa by Kapetsky (1994), information as to what extent Ethiopia is appropriate for aquaculture is lacking.

Cage culture is one of the alternative aquaculture systems to other culture systems such as open ponds, raceways, and tanks. It utilizes existing water resources (lakes, large reservoirs, farm ponds, rivers, cooling water discharge canals, estuaries and coastal embayment) that cannot be drained or seined and would otherwise not be suitable for aquaculture but encloses the fish in a cage or basket which allow water to pass freely between the fish and the pond (Swann, 1992).

The origin of cage culture traces back almost two centuries to the Asian region, the use of cages for holding and transporting fish for short periods (Pillay and Kutty, 2005), and marine commercial cage culture was pioneered in Norway in the seventies with the rise and development of salmon farming (Beveridge, 2004).

The cage aquaculture sector has grown very rapidly during the past 20 years and is presently undergoing rapid changes in response to pressures from globalization and growing demand for aquatic products in both developing and developed countries, for instance, high fish consumption rate in developing countries, by 57% from 62.7 million metric tons in 1997 to 98.6 million in 2020 (Tacon and Halwart, 2007).

In addition, the move within aquaculture toward the development and use of intensive cage farming systems is driven by a combination of factors, including increasing competition faced by the sector for available resources (Tilman *et al.*, 2002). The need for economies of scale and the drive for increased productivity per unit area, particularly the need for suitable sites resulted in the aquaculture sector accessing and expanding into new untapped open water culture areas such as lakes, reservoirs, rivers, and coastal brackish and marine offshore waters.

Cage culture is advantageous, it is flexible and easy to manage, low cost of harvesting, close observation of fish feeding, response and health, ease and economical to treat parasites and diseases. Besides, it is of relatively low capital investment compared to ponds and raceways (McGinty and Rakocy, 1989). Furthermore, in cage culture it is possible to disrupt breeding cycle of tilapia, and therefore mixed-sex populations can be reared without the risk of reproduction when mesh is large enough to let eggs fall through (Paz, 2004).

The design of fish cages is determined by the behavior of the culture species (Rakocy and McGinty, 2005). For *O. niloticus,* which is less active and sometimes territorial in habitat, the shape of the cage does not affect its mobility. In this case, one has to design rectangular cages for easy assemblage and management (Fitzsimmons, 2004). Cage size depends on the size of the pond, the availability of aeration, and the method of harvest. So, cage size may vary from 1 to more than 1000 cubic meters. As cage size increases, costs per unit volume decrease but production per unit volume decreases, resulting from a reduction in the rate of water exchange.

Cages can be floating surface or standing surface cages (McGinty and Rakocy, 1989). Standing cages are tied to stakes driven into the bottom substrate, whereas floating cages require a flotation device to stay at the surface. Flotation can be provided by metal or plastic drums, sealed PVC pipe (pipe made of Polyvinyl chloride), or Styrofoam. Cages should be constructed from materials that are durable, lightweight and inexpensive, such as galvanized and plastic coated welded wire mesh, plastic netting and nylon netting (Fitzsimmons, 2004).

Mesh or netting materials that can be used include plastic coated welded wire, solid plastic mesh, and nylon netting (knotted or knotless). Mesh size should be no smaller than 12.5 mm to assure good water circulation through the cage while holding relatively small fingerlings (100 to 130 mm) at the start of the production cycle (Dikel *et al.*, 2005). A larger mesh size can be

used if large fingerlings are stocked. The mesh size for tilapia cages should be at least 12.5 mm, but 20 mm is preferred. These mesh sizes provide adequate open space for good water circulation through the cage to renew the oxygen supply and remove waste.

The use of large mesh size requires a larger fingerling size to prevent gill entanglement or escape. For example, a 20 mm plastic mesh will retain 9 gram tilapia fingerlings while a 25 mm mesh requires a fingerling weighing at least 25 grams with plastic netting and 50 to 70 grams with nylon netting (Silva *et al.*, 2000). These fish will grow too large to swim out of the cage, but they do not grow large enough to reach marketable size, thereby representing a waste of feed. Cages should be equipped with covers to prevent fish losses from jumping or bird predation. Covers are often eliminated on large nylon cages if the top edges of the cage walls are supported 30 to 60 cm above the water surface (McGinty, 1991). Larger mesh size facilitates the entry of wild fish into the cage.

The other most important factor that affects cage culture is the placement of the cage. It is very important that the wastes from the fish and excess fish feed fall through the cage and away from the immediate area of the cage. Therefore, the fish cage should be placed in an area where there is at least 60 cm of water between the bottom of the cage and the pond or lake bottom (Bardach *et al.*, 1972). It is undesirable for wastes to accumulate in or near the fish cage. Moreover, the fish cages should also be placed where the water can move freely through and around the cage.

Moreover, vascular aquatic plants (those with stems), wind-protected covers, and areas around excessive structures should be avoided (Coche, 1982). Since wind action is the primary contributor to water movement, the cage should be placed in open water where the prevailing winds can create water movement. Even the slightest breeze helps to flush water through and around the cage, remove waste products, and provide fresh, oxygenated water. However, disturbances near the cage, such as swimming, boating, and fishing activities are not desirable. Large bodies of water are better suited for cage culture than small ponds since the water quality is generally more stable and affected less by fish waste. It is possible to use small ponds for cage culture, but provisions for water exchange or emergency aeration may be required. Cages

should be placed usually to the windward side, where water currents are greatest. Calm, stagnant areas should be avoided (Konikoff, 1975).

Regardless of its obvious economic and technical success, cage farming sector has faced numerous issues and challenges during its development. In general, these issues and challenges have impacts not only on the system but also affect the surrounding aquatic environment and ecosystem.

The loss of large amount of nutrients from uneaten feed, and excreta from cage-reared fish has a potential impact (negative and/or positive) upon water quality and surrounding aquatic ecosystem health and the possibility of disease occurrence within cage reared fish and the potential risk of transfer of diseases to and from natural fish populations (Ferguson *et al*., 2007).

Other problem of cage culture includes its dependency upon the capture of wild caught seed where hatchery development is new or production is not currently sufficient to meet demand (Ottolenghi *et al*., 2004). Moreover, the risk of fish escapes from cages has potential impacts (negative and/or positive) on wild fish populations, including potential genetic, ecological and social impacts (Ferguson *et al.,* 2007; Hindar *et al*., 2006; Naylor *et al.,* 2005; Soto *et al.,* 2001).

The long-term ecological sustainability of rearing carnivorous fish species within cage-based farming systems depends upon the use of fishery resources as feed inputs (Tacon *et al.,* 2006) are additional basic issues related with cage cultures.

Supplementary feeds are needed in semi-intensive and intensive culture systems. The use of supplemental feeds improves aquaculture productivity economically (Brown *et al.,* 2000) and could result in higher survival rates (Wang and Zhang, 1995). Locally available supplementary feeds may consist of wheat bran, copra meal, wheat flour, oilseed cakes (for instance, rapeseed, peanuts and soybean), green fodder, maize bran, chicken waste, and/or kitchen waste (Suloma and Ogata, 2006).

Ethiopia has many kinds of agricultural by-products, such as wheat bran, oil seeds, and poultry droppings and by-products which are promising as supplementary feeds in fish culture. The

availability of these agricultural residues and industrial by-products for feed seems promising to support small-scale commercial aquaculture and commercial intensive aquaculture for export. However, the knowledge on different culture systems and how to use and how to processing agricultural by-products is deficient. Moreover, there is lack of experience and research on feeding level, feeding frequency and feeding time in different fish culture systems. Poor feeding practice is a common cause of cage culture problem (stress) (Masser, 1997).

Malfeeding practices are acute in cage since insignificant natural feeds are usually available to the caged fish and water quality deterioration from waste feed has a more direct effect on confined fish especially for cages that are placed in small shallow water bodies. Feeding problems common in cage culture include poor quality feed, incomplete feeding, inadequate feeding or under feeding, over feeding and feeding at the wrong time of the day. Many of these problems have no simple solutions and need thorough investigations.

So far, commercial cage culture has been mainly restricted to the culture of higher-value (in marketing terms) compound-feed-fed finfish species. In terms of diversity, 40 families of fish are cultured in cages, but only five families (*Salmonidae, Sparidae, Carangidae, Pangasiidae* and *Cichlidae*) make up 90 percent of the total production (Tacon and Halwart, 2007).

Tilapia is the generic name of a group of cichlids indigenous to Africa. The group consists of three aquaculturally important genera- *Oreochromis, Sarotherodon* and Tilapia. All Tilapia species are nest builders (fertilized eggs are guarded in the nest by a brood parent); while species of both *Sarotherodon* and *Oreochromis* are mouth brooders (eggs fertilized in nests are picked up immediately by the parent's mouth and held them through incubation for several days after hatching).

Almost 90% of all commercially farmed tilapia outside Africa are Nile tilapia (Popma and Masser, 1999). In all *Oreochromis* species the male excavates a nest in the bottom of a pond and sheds the milt on the eggs in such a way that the male will fertilize the spawned eggs in the nest. The eggs will then be held in the female buccal cavity till it gets hatched and finish absorption of the yolk sac at the fry stage. Under good growth conditions this same species will reach sexual maturity in farm ponds at an age of 5 to 6 months (150 to 200 grams).

There is no problem of obtaining spawn in tilapia culture, but it is indeed difficult to prevent them from spawning which will potentially cause overpopulation and subsequent stunting in the growth. The fact that it takes no skill whatever to spawn tilapia in ponds is one of the reasons they have been widely promoted as a fish for subsistence culture in many Asian and African countries (Bardach *et al*., 1972; Bell and Canterbery, 1976). Fish farming strategies that prevent overcrowding and stunting include: 1) cage farming; 2) polyculture with predatory fish; 3) culture of only males (monosex), which grow faster than females. The most acceptable and commonly used predatory fish to control tilapia population in Southeast Asia is the catfish of genus *Clarias* (Bardach *et al*., 1972).

Tilapia feeds on a wide variety of natural feeds, including plankton, some aquatic macrophytes, planktonic and benthic aquatic invertebrates, larval fish, detritus, and decomposing organic matter (Popma and Masser, 1999). Coche (1982) suggested that about 90 kg as being the maximum carrying capacity for 250 – 350 *O. niloticus* fed a complete diet and reared in $1m^3$ cages. *O .niloticus* is currently considered to be the most important and second cultured fish species around the world. They have earned the title “the aquatic chicken”. They are fast-growing, breed easily with no need for special hatchery technology, eat a wide range of feed types and are able to survive in poor water conditions. Moreover, it is suitable species for increasing protein production, profits and the quality of nutrition of poor fish farmers and consumers.

With heavy supplemental feeding, natural feed organisms typically account for 30 to 50% of tilapia growth. In general, tilapias are so efficient in using natural feed that crop of more than 3,000 kg/ha can be sustained in well fertilized ponds without supplemental feed. Fish can reach market size (80-120g) in 3-6 months, depending on the level of fertilization with inorganic N-P-K fertilizers and/or organic manures and on-farm feeds, made from materials such as rice bran, wheat middling and brewery wastes, mixed with little fish meal to supplement natural diet (Beveridge and Haylor, 1998). Basically, pond culture is the most popular method of growing tilapia because of the ability of the fish to utilize natural feeds (Rakocy and McGinty, 2005).

Tilapias are more tolerant than most commonly farmed freshwater fish to high salinity, high water temperature, low dissolved oxygen, and high ammonia concentration. Nile tilapia being the most saline tolerant among commercially important tilapia, it can grow well at salinities up to 15 ppt, performing better below 5 ppt (Popma and Masser, 1999).

Optimal water temperature for tilapia growth is from 20 to 30 °C and the lethal temperature levels are ≤12°C and ≥42°C (Popma and Masser, 1999). Although tilapia can survive acute low dissolved oxygen concentrations (<3 mg /L, considerably below the tolerance limit of most cultured species) for several hours, tilapia ponds should be managed to maintain DO concentrations above 1 mg/L. They can survive in pH ranging from 5 to 10 but do best in 6 to 9 ranges (Coche, 1982).

Tilapias are more resistant to viral, bacterial and parasitic diseases than other commonly cultured fish, especially at optimum temperatures for growth. Under good growth conditions, 1-gram fish are cultured in nursery ponds to 20 to 40 grams in 5 to 8 weeks and then restocked into grow out ponds. As a common practice grow out ponds are stocked at 6000 to 8000 males per acre with aeration or 20,000 to 28, 000 males per acre where 20% daily water exchange is economically practical. After 6 months of feeding with good quality feeds, such ponds can produce 5, 000 to 7,000 pounds per acre and 18,000 to 20,000 pounds per acre, respectively. Due to its presence in almost all the drainage basins of Ethiopia (Shibru Tedla, 1973) and its good cultural characteristics (Rakocy and McGinty, 2005; Popma and Masser, 1999), *O. niloticus* is highly preferred as a candidate species in Ethiopia.

The growth of tilapia (*O. niloticus*) depends upon the stocking density, feed quality, energy content of the diet, its physiological status, reproductive state, and environmental factors such as temperature, pH, etc. (Lovell, 1989).

In many cultivated fish species, growth is inversely related to stocking density and this is mainly attributed to social interactions (Holm *et al*., 1990; Haylor, 1991; Silva *et al*., 2000). Canario *et al.* (1998) studied the effect of stocking density (0.35, 1.3, and 3.2 kg/m3) on the growth of gilthead sea bream, *Sparus aurata*, and found that fish in the highest density group grew 25 % slower than fish in lower density. Silva *et al* (2000) also studied the effect of

stocking density (2, 3 and 4 kg / m^3) on the growth of tetra hybrid red tilapia, and found that final body weight gain was significantly higher at a density of 2 and 3 kg / m^3, while the biggest biomass and feed consumption were observed at a density of 4 kg/m^3. This has been observed in Chinook salmon (Martin and Wetheimer, 1989), Nile tilapia (Siddiqui *et al*., 1989), African catfish (Haylor, 1991) and Arctic charr (Jorgensen *et al*., 1993).

In tilapia, experiments on the effect of stocking density have been conducted on different fish sizes including fry and juveniles (El-Sayed, 2002), sub-adults (D'Silva and Maughan, 1995) and adults (Yi *et al*., 1996). Studies were also conducted using different culture systems such as tanks (Bailey *et al*., 2000), ponds (Diana *et al*., 2004) and net cages (Cruz and Ridha, 1991; Yi *et al*., 1996; Ouattara *et al*., 2003). The results of these studies generally demonstrated an inverse relationship between stocking density and growth rate.

There were efforts to assess the effects of stocking density on the growth performance of *O. niloticus* in fresh water ponds in Jimma, Ethiopia (Kebede Alemu, 2003). Studies were also carried out by Abebe Tadesse (2007) and Ashagrie Gibtan *et al (*2008) to evaluate the effects of stocking density and supplementary feeding on the growth performance, survival and production of *O. niloticus* reared in cages in Lakes Elen and Kuriftu, respectively. These studies confirmed effects of stocking density and supplementary feeding on the growth performance and yield of *O. niloticus* but have reported no effects on survival rate by stocking density and supplementary feeding.

There is also another recent study conducted by Belsti Fetene (2008) and Solomon Hailu (2008) to identify effects of local feed types on the growth performance of Nile tilapia cage culture in Lake Babogaya, Ethiopia. Best result of growth performance was achieved in mill sweeping chicken droppings diet and the best feed amount was 3% feeding rate.

It is evident, therefore, that further studies are required to investigate the effect of stocking density and feeding on the growth performance of different fish species under different water systems especially in countries like Ethiopia where aquaculture is not practiced.

2. Objectives of the study

2.1 General objective

The general objective of the study was to generate baseline study on cage culture fisheries in order to improve food security and reduce environmental impacts.

2.2 Specific objectives

- To assess the effect of different stocking densities on growth performances and yield;
- To compare the difference in growth performance and yield of *O. niloticus* fed on natural feed and supplementary feed in cage culture; and
- To examine the effect of cage culture practice on water quality.

3. Description of the Study Area

3.1. Wonji Reservoir

The study was carried out in the irrigation fields of Wonji sugarcane plantation (7000 ha), right downstream of the Koka Dam. The Wonji–Shoa Sugar Estate is located at 8°21' to 8°29' N 39°12' to 39°18' E (Ethiopian Mapping Agency, 1986) and is found in the Central Rift Valley of Ethiopia in the Awash River Basin, 110 km southeast of Addis Ababa and 10 km south of Nazareth (Fig. 1).

It is found at an altitude of approximately 1,500 meters above sea level (m.a.s.l.). It has a semi-arid climate and receives an average annual rainfall of 831.2 mm, peak daily evapotranspiration of 4.5 mm, and mean annual maximum and minimum temperatures of 27.6 ^{0}C and 15.2 ^{0}C, respectively (Source: NMSE).

The Wonji plain is an active agro-industry area with high population density and urbanization. It shows high nitrate concentration due to excessive application of fertilizers, high population density (septic tanks) and livestock breeding. Around 50,000 people live within the plantation alone.

The source of irrigation water for the scheme is the Awash River. The distribution is facilitated by the presence of seven on-channel reservoirs which have a total design storage capacity of 376,875m^3 and twelve small reservoirs scattered all over the plantation.

The Awash River Basin is the most important river basin in Ethiopia and covers a total land area of 110,000 km^2 and serves as home to 10.5 million inhabitants. The river rises on the high plateau near Ginchi town, west of Addis Ababa in Ethiopia and flows along the rift valley into the Afar triangle, and terminates in salty Lake Abbe on the border with Djibouti, being an endorheic basin. The total length of the main course is about 1200 km. Awash River Basin communities are predominantly farmers and pastoralists.

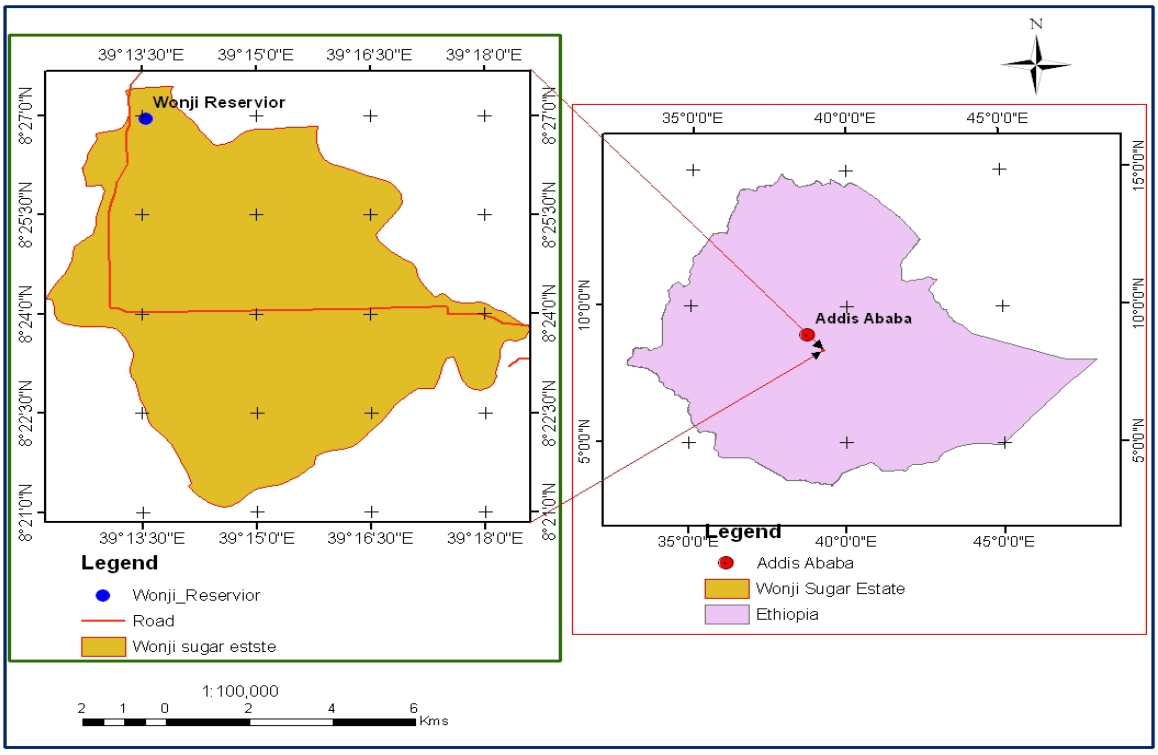

Figure 1. Map of the study area.

As with other parts of Ethiopia, the upper Awash Basin and its major tributaries have been subjected to major environmental stress. The demand for natural resources by the high and fast growing population remains a major challenge to effective agricultural and forestland management. The high pressure on forest resources, in particular, has led to the exploitation of fragile watersheds and ecosystems that have resulted in loss of vegetation and subsequent soil erosion in the lower part of the Awash River Basin.

The dominant vegetation in the basin include *Balanites aegypticus, Salix subserata, Flueggia virosa, Carissa edulis, Rumex nervosus, Tamarindus indica, Ulcea schimperi* and *Acacia spp.*

Awash drainage basin is dominated by fishes of the genera *Oreochromis, Labeobarbus, Barbus, Clarias, Garra,* and *Varcorhinus* (Abebe Getahun and Stiassny, 1998).

4. Materials and Methods

4.1 Site selection

Appropriate and secure experimental site for cage placement was selected in Wonji Reservior. Jetty was constructed by using eucalyptus poles (plate 1). Two sites, one in cage area (designated as Site 1) and the second on the center (designated as Site 2) (Plate 1) were chosen for physical parameters, phytoplankton and zooplankton sampling and assessment.

It was assumed that there would be good protection for equipment and cultured fish at this site. Moreover, there is a depth of >1.5 m below the cage that would enable sufficient water circulation for waste removal and enough oxygen circulation.

Plate 1. Jetty with cages (December, 2010)

4.2 Cage construction

Nine used frame cages by previous postgraduate students were repaired and used for the study. The size of each cage was 1 m^3 (1m x lm x lm) and the frame was made from light and durable material, PVC tube and nylon net with a mesh size of 4 cm were used as an enclosure material as suggested by Fitzsimmons (2004).

4.3 Landing stage construction

The landing stage was constructed to provide sufficient space for hanging all the cages and get easy access for monitoring. It was totally constructed from wood and had a U-shape with a total length of 20 m (Plate 2).

Plate 2. Landing stage construction (December, 2010)

4.4 Cage placement

Cages were placed side by side and tied up on the landing stage by a nylon rope at 1.50 meter intervals so as to make it easily accessible for sampling, feeding of fishes and maintenance of the cage and landing. The bottom of the cage were kept at a depth of >1.5 m above the reservoir bottom (Plate 3).

Plate 3. Placement of cages on the landing stage (January, 2010)

4.5 Juvenile collection and stocking

O. niloticus fingerlings of mixed sex were collected between January 9 and 22 2010 from Lake Hora. They were collected using beach seine hauls 50 m x 2.5 m (with stretched mesh size of 20 mm) as shown in Plate 4. Immediately after capture, screening from other species was done by using external morphological features and total length (TL, nearest 1 mm by measuring board) and total weight (TW, nearest 1g by Ohaus balance) of each fish was measured.

Plate 4. Juvenile collection from Lake Hora(January, 2010)

The collected fingerlings were transported in plastic bag with oxygen to the site as shown in Plate 5. At the study site, the fry inside the plastic bags were gradually acclimatized to water of the reservoir. This was done by floating the sealed bags in the receiving water for 15 to 30 minutes to allow the water in the bag to attain the same temperature as the water outside the bag. The bags were then opened, and some of the receiving water was added, so as to accustom the fish to the new environment. Finally, the openings of the bags were lowered into the receiving water, and the fingerlings were slowly released into the receiving water inside the cage.

Fingerlings of 40-50 gm weight and 100-120 mm length were stocked in the proposed density of 25F, 50F, 75F, 25N, 50N, and 75N fish were stocked in combination of 25 fingerlings x 3 cages, 50 fingerlings x 3 cages, and 75 fingerlings x 3 cages in January 23, 2010. Of these, one cage of each was taken as control group. Cages with different stocking densities were coded as 25N, 50N, 75N, 25F, 50F, 75F; where N – non feeding and F – feeding.

Plate 5. Juvenile transportation techniques (January, 2010)

4.6 Supplementary feeding

Locally available feed was used because there is no prepared feed for fish aquaculture in Ethiopia. Mixture of mill sweeping, blood bone meal and oil seed cake was used in proportion of 60%, 20% and 20%, respectively. Feed was pelleted by using manual and electric meat grinder in Fisheries Laboratory of the Department of Biology, Addis Ababa University as shown in Plate 6. The composition of ingredients of the experimental diets was analyzed by Bahir Dar University (Chemical Engineering School) laboratory and the results are shown in table 1. This composition of dry feed was given two times a day (early morning at 8:00 am and late afternoon at 4:00 pm) as suggested by Chapman (2006) and Cruz (1997). Feed ration was placed in feeding trays, which were suspended at the mid point in each cage. Feeding started on January 30, 2010 and ended May 9, 2010. The stocks had free access to the natural feeds that passed through cages.

Feeding rate tables were adjusted every two weeks based on the average weight of fish. Feed was offered to the caged fish only at 3% of the body weight for the feed treatments except for the controls where fish fed directly from the natural environment only.

A

B

Plate 6. Feed preparation (A. mixing, B. pelleting, February, 2010).

Table 1. Feed types and their nutritional composition

Feed type	% protein	% fat/oil/	% moisture	% fiber	% ash
Mill sweeping	11.9	5.8	14.0	10.9	10.6
Dried and ground abattoir waste	52.5	11.4	10.9	4.3	30.9
Oil seed cake	17.1	9.2	4.1	12.9	7.8

Feed ration was placed on feeding plastic trays which were suspended at mid depth in each cage. Rations were adjusted every two weeks interval based on fish growth change for each cage.

4.7 Data collection and analysis

4.7.1 Fish

Initial weight, length and number of the stocks were recorded. Dead fish was removed and recorded daily. About 30% of fishes in each treatment were sampled randomly by using scoop net every 2 weeks. Their length (by measuring board to the nearest 1 mm) and weight (by Ohaus portable balance to the nearest 1gm) was recorded. At the end of the experiment, the fishes were harvested; all fish were weighted, measured and counted.

4.7.2. Statistical analysis

Growth performance parameters of the fish were calculated from the biweekly weight data.

$$\text{DGR (g/fish/ day)} = \frac{Final\ weight(g) - Initial\ weigth(g)}{No\ of\ culture\ days}$$

Where- DGR is Daily growth rate

$$\text{SGR (\%/day)} = \frac{In\ Final\ weight(g) - In\ Initial\ weigth(g)}{No\ of\ culture\ days} x100$$

Where-SGR is Specific growth rate

Weight gain (gm) = Final weight (gm) − Initial weight (gm)

$\text{Survival rate}(\%) = \frac{N_2}{N_1} x100$; where N_2 is number of fish harvested and N_1 is number of fish stocked.

Assuming that all given feed was consumed, Feed Conversion Ratio (FCR) was calculated from the amount of feed used to produce one kilogram of fish. Calculating the FCR shows whether the fish are overfed or underfed.

$$\text{FCR} = \frac{\text{Feed taken (Kg)}}{\text{Weight gain (Kg)}}$$

Also, the well being of fishes was studied by calculating the Fulton's Condition Factor (FCF). FCF (%) was calculated as:

$$\text{FCF} = \frac{\text{TW X 1OO,}}{\text{TL}^3}$$

Where- FCF is Fulton's condition factor, TW: is total weight in gram, TL: is total length in cm.

$$\text{Net Yield} = \frac{\text{Biomass gain (Kg) x 365}}{\text{Cage area (size) x time (culture days)}}$$

4.7.3 Physical parameter

Water temperature was measured with thermometer *in situ* monthly (from January to April, 2010) at 25 cm below the surface and pH was measured with pH meter and DO was measured using oxygen meter at Sites 1 and 2.

4.7.4 Plankton

To estimate zooplankton abundance in the experimental reservoir, water was collected at 2 m depth at the two Sites (1 and 2) starting from January to April, 2010. Zooplankton samples were collected with a net mesh size of 67 µm and diameter of 31 cm. The samples were immediately preserved in 5% formalin. The volume of the water filtered through the net was determined by using the formula ($V = 3.14\ r^2h$) where, r is the radius of the net mouth and h is the depth from which the sample is taken.

Based on this, the number of organisms per m^3 of the reservoir was calculated and then the number of each category of zooplankton of the reservoir was expressed as per m^3. 20-25 ml of sub-sample was taken for counting using pipette with wider mouth and poured into a gridded petri dish. Three grids were counted for each sample after allowing the sample to settle and checking the uniform distribution throughout the grids and then extrapolation was made. Counting was done with stereoscope microscope (magnification of 50*X*) in the Limnology Laboratory of the Department of Biology, Addis Ababa University. Zooplankton species were identified using keys Fernando (2002).

According to Edmondson and Winberg(1971); Green, (1986) the number of individual per 1ml was calculated using the formula.

$$V_{net}\ (m^3) = \pi r^2 d$$

$$\text{No. }/m^3 = \frac{C \times TG \times F}{CG \times V_{net}}$$

Where, C= count of zooplankton,

TG= total grid (15),

F= factor of sub-sample,

CG= counted grids,

V_{net} = Volume of net

r= radius of the net,

d = the length of the course of the net through the water column (depth of sampling), π = 3.14.

Phytoplankton sampling was also done monthly using phytoplankton net of 10-micron mesh size at 1.0 m depth. The samples were taken from the three different sites within more or less similar time (10:00 am) of a day through out the study period.

The samples were stored in brown bottles preserved using Lugol's solution (Wetzel and Likens, 2000) and placed in a refrigerator. The samples were examined with an inverted microscope and the identification of phytoplankton to the genus or the species level was made using different identification keys including those of Whitford and Schumacher (1973), Talling (1987) and Willen (1991).

Counting of phytoplankton was done by using Sedgwick-Rafter cell under an inverted microscope following the procedures outlined in Hotzel and Croome (1999). Four grids (2 vertical and 2 horizontal) were counted and the result was extrapolated to the sample volume, and to the volume of the water filtered to get the abundance of phytoplankton per meter cube of the reservoir.

The number of cells per 1ml was calculated using the formula developed by Hotzel and Croome (1999).

$$C\left(ml^{-1}\right) = \frac{N \ x \ 1000 \ x \ m^3}{A \ x \ D \ x \ F}$$

Where N = Number of cells, A is area of field (mm^2), D the depth of field (mm), F is the number of cells counted.

Analysis of variance (ANOVA) was used to determine differences between treatments in mean final weight, daily growth rate, and feed conversion ratio, survival rate of

harvested fish and variation in water quality, zooplankton and phytoplankton abundance between the sites.

Duncan's multiple range tests were applied to compare the significance of means of the various parameters among the tested treatments. Differences were considered significant at P 0.05 as indicated in Sokal and Rohlf (1995). All data was analyzed using the SPSS 13 (1999) for Windows software program for statistical analysis.

5. Results

5.1 Growth performances

5.1.1 Mean weight

The mean initial length of fish was 104.36, 104.62, 104.87, 104.67, 104.43, 105.21 mm for 25F, 50F, 75F, 25N, 50N and 75N, respectively. Their mean weight was 43.70, 43.12, 43.38, 43.97, 43.51 and 43.98 gm for 25F, 50F, 75F, 25N, 50N and 75N, respectively. There was no significant difference in initial length and weight among the treatments (P>0.05).

The final fish length and weight in all treatments and controls are listed in Table 2. They attained mean final length of 178.11, 158.80, 151.25, 140.00, 142.50 and 140.73 mm in 25F, 50F, 75F, 25N, 50N and 75N, respectively. The mean final weight was 175.80, 154.92, 146.70, 86.67, 73.64, and 72.62 gm for 25F, 50F, 75F, 25N, 50N and 75N, respectively. The highest weight (175.80) of *O. niloticus* was attained at a density of 25F fish / m^3 followed by 50F fish / m^3 and 75F fish/m^3 (Fig. 2).

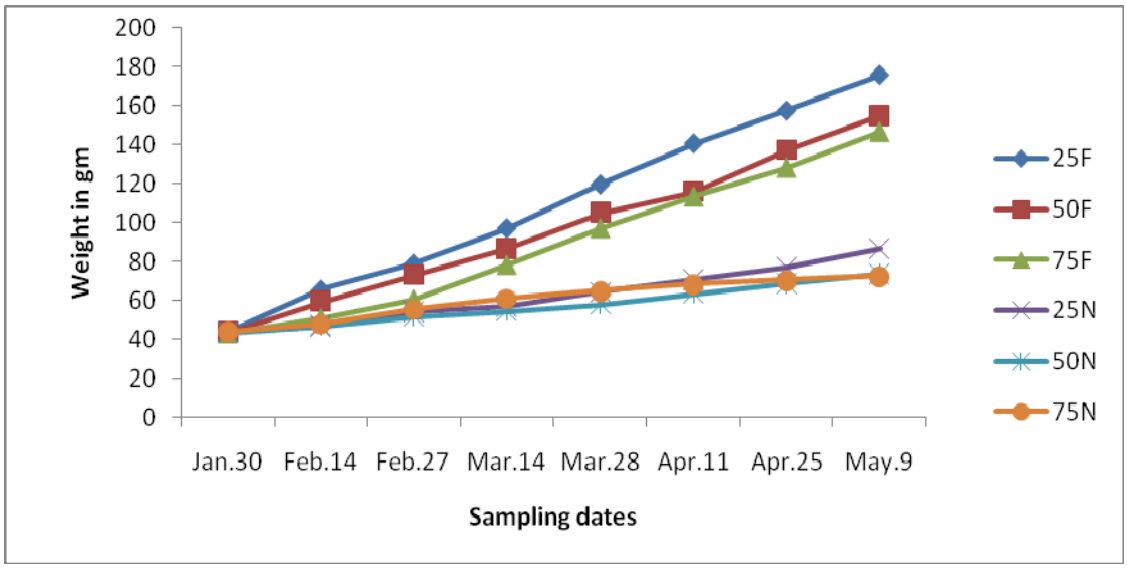

Figure 2. Change in weight of fish in the three treatments and three controls during the experiment period

Table 2. Initial and final mean length and mean weight, weight gain and yield of fish in three treatments and three controls during the experiment period (where: n^o –initial stocked number, n^f-final harvested number)

Treatment	Stocking density (cage/fish)	Final total harvest number	Mean length of initial stock (mm)	Mean weight of initial stock (gm)	Mean length of final stock (mm)	Mean weight of final stock (gm)	Total weight gain (Kg/cage)	Total net yield (Kg year-1
25F	25	23	104.36 ± 0.80	43.70 ± 0.19	178.11 ± 0.30	175.83±0.68	2.95	10.76
50F	50	48	104.61 ± 0.89	43.12 ± 0.5	157.84 ± 0.58	154.92±0.82	5.4	19.71
75F	75	72	104.87 ± 0.74	43.38 ± 1.14	151.25 ± 1.31	146.70±0.15	7.34	26.79
25N	25	22	104.67 ± 0.73	43.97 ± 0.36	140.00 ± 0.83	86.67±0.51	0.81	2.95
50N	50	47	104.43 ± 0.61	43.51 ± 0.33	142.50±0.94	73.64±0.26	1.28	4.67
75N	75	71	105.62 ± 0.36	43.98 ± 1.18	140.68±.67	72.62±0.46	1.87	6.82

The lowest weight (72.62 gm) was obtained at a density of 75 fish / m^3 without supplementary feeding (Fig. 9). The data were tested at 95 % confidence interval and their growths were significantly affected by stocking density and supplementary feeding ($P < 0.05$).

5.1.2 Daily growth rates

Mean daily growth rates were calculated between each sampling period for all treatments. The maximum (mean) (1.36 gm / day) and minimum (mean) (0.77 gm / day) daily growth rates were observed in 25F and 75F among the feeding treatments, respectively (Fig.3). A mean daily growth rate of 0.55 g / day, 0.28 g / day, and 0.27 g / day, was recorded in the controls (25N, 50N, 75N), respectively. Daily growth rate decreased with increasing stocking density with feeding (Fig.3) and without supplementary feeding (25N, 50N, 75N) (Fig. 3).

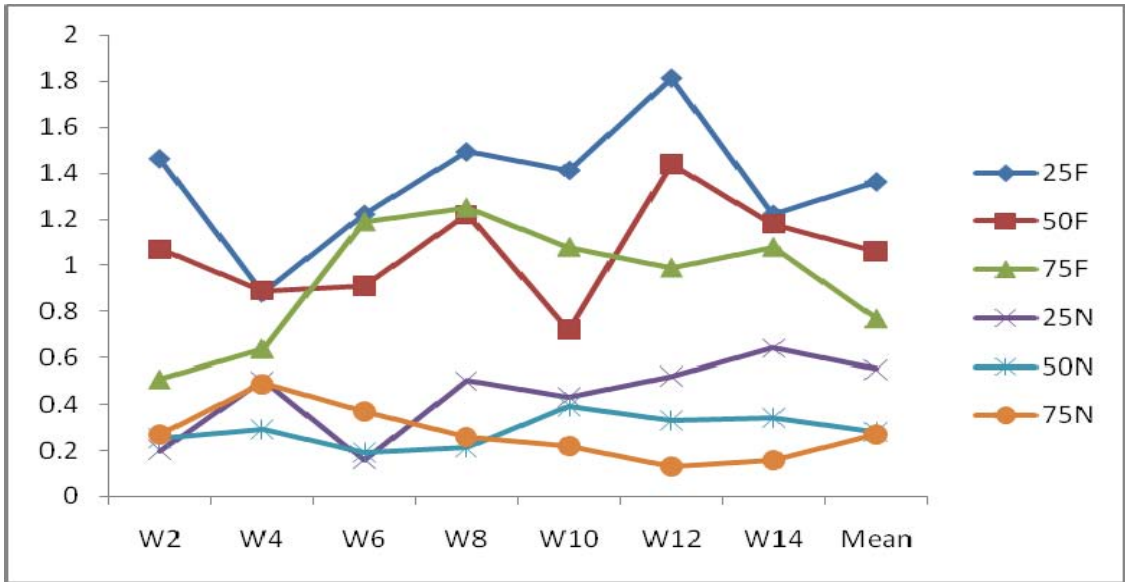

Figure 3. Mean daily growth rate comparison of treatments with and without supplementary feeding in each sampling week

Mean daily growth rate was significantly different in all treatments ($P < 0.05$). The feeding treatments (25F, 50F, 75F) had significantly higher ($P < 0.05$) mean daily growth rate than that of the controls (25N, 50N, 75N).

5.1.3 Specific growth rates

The variations of specific growth rates (SGR) with treatments are given in Table 2. 25F attained the maximum mean SGR (1.335% / day/fish) and 75F the minimum mean SGR (1.159 % / day / fish) among the feeding treatments. The treatments without supplementary feeding (25N, 50N, 75N) attained the least mean SGR (0.647%/day/fish, 0.500%/day/fish, 0.477%/day/fish, respectively).

Specific growth rates decreased as the stocking density increased (Table 3). The non-feeding (25N, 50N, 75N) had significantly lower specific growth rate than the feeding treatment (25F, 50F, 75F), although they had equal stocking density ($P < 0.05$). All treatments and controls were statistically different in their specific growth rates (ANOVA, $P<0.05$).

Table 3. Specific growth rate (% / day) of the three treatments at each sampling week (where: W – sampling weeks).

Treatment	W2	W4	W6	W8	W10	W12	W14	Mean
25F	2.18	1.84	1.39	1.38	1.08	0.75	0.73	1.335
50F	2.09	1.35	1.15	1.27	0.65	1.14	0.81	1.208
75F	1.08	1.15	1.72	1.44	1.02	0.81	0.89	1.159
25N	0.46	0.98	0.29	0.82	0.63	0.57	0.78	0.647
50N	0.55	0.59	0.37	0.38	0.64	0.5	0.47	0.5
75N	0.58	0.95	0.64	0.42	0.34	0.19	0.22	0.4771

5.1.4 Feed conversion ratio (FCR)

Results of feed intake and feed conversion ratio of the different feed treatments and controls are shown in Table 3. The feed conversion ratio ranged from 0.68 to 2.13 for 25F, 1.67 to 3.89 for 50F, 4.45 to 5.27 for 75F. As indicated in Table 4, the best mean FCR obtained (1.45) was for stocking density of 25 fish / m^3 and the poorest mean FCR (4.45) obtained was from the highest stocking density (75 fish/m^3) (Table 6). FCR was significantly affected by stocking density ($P < 0.05$).

Table 4. Total amount of feed supplied, the feed conversion ratio, and mean daily growth rates for three treatments and three controls during the experiment period (January 30 –May 9, 2010).

Treatment	Parameters	Jan.30	Feb.14	Feb.27	Mar.14	Mar.28	Apr.11	Apr.25	May.9
25F	Weight of feed (Kg)	0.983	1.474	1.772	2.184	2.69	3.165	3.544	3.956
	Mean weight of fish	43.7	65.53	78.77	97.11	119.57	140.7	157.51	175.82
	FCR	-	0.68	1.36	1.19	1.21	1.51	2.08	2.13
	Mean daily growth rate		1.46	0.88	1.22	1.49	1.41	1.81	1.22
50F	Weight of feed (Kg)	1.962	2.684	3.285	3.901	4.723	5.206	6.176	6.971
	Mean weight of fish	43.62	59.65	73	86.71	104.95	115.69	137.25	154.92
	FCR		1.67	2.47	2.85	2.58	4.81	2.88	3.89
	Mean daily growth rate		1.07	0.89	0.91	1.22	0.72	1.44	1.18
75F	Weight of feed (Kg)	3.029	3.444	4.092	5.294	6.564	7.656	8.654	9.753
	Mean weight of fish	43.12	51.02	60.62	78.43	97.25	113.42	128.21	146.7
	FCR		4.45	4.27	2.98	3.49	4.78	5.88	5.27
	Mean daily growth rate		0.51	0.64	1.19	1.25	1.08	1.99	1.08
25N	Mean weight of fish	43.97	47.04	54.54	56.94	64.39	70.84	77.09	86.67
	Mean daily growth rate		0.2	0.5	0.16	0.5	0.43	1.42	0.64
50N	Mean weight of fish	43.51	47.26	51.65	54.58	57.75	63.64	68.6	73.64
	Mean daily growth rate		0.25	0.29	0.19	0.21	0.39	0.33	0.34
75N	Mean weight of fish	43.98	48	55.38	60.95	64.87	68.23	70.24	72.62
	Mean daily growth rate		0.27	0.49	0.37	0.26	0.22	0.13	0.16

5.1.5 Fulton condition factor (FCF)

The mean Fulton's condition factors calculated for different experimental periods ranged from 3.83 to 5.18 for 25F, 3.81 to 4.33 for 50F, 3.63 to 3.96 for 75F, 3.13 to 3.66 for 25N, 2.57 to 3.52 for 50N and 2.30 to 3.44 for 75N. The Fulton condition factor decreased as the stocking density increased and in treatments that had supplementary feeding. Similarly, lower Fulton's condition was observed in controls (Fig. 4).

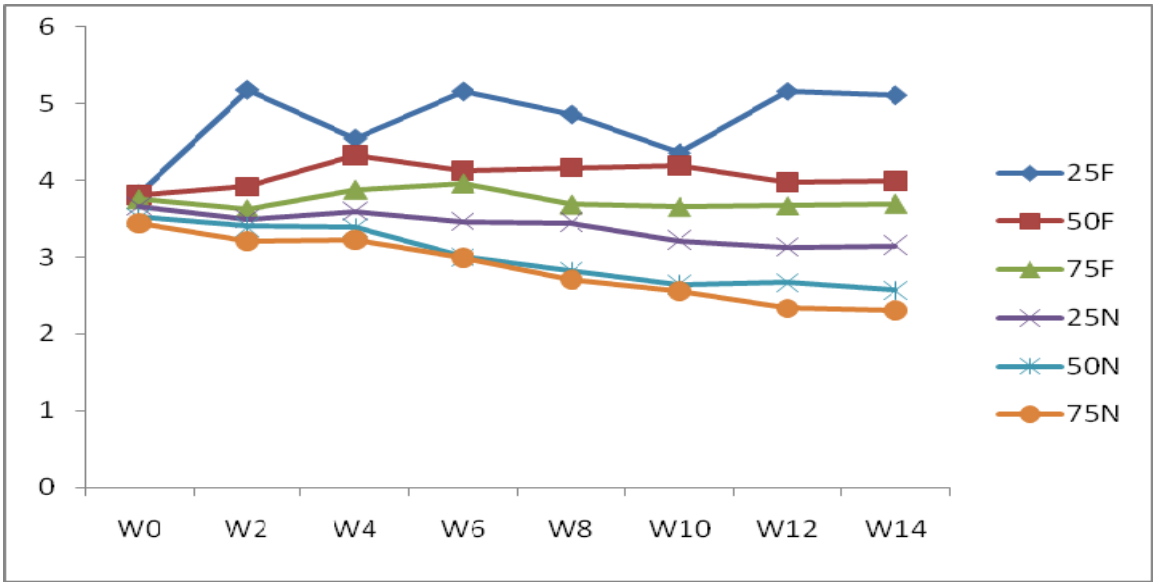

Figure 4. Fulton condition factor using the three feeding treatments and the three controls in the sampling weeks

Fulton condition factor was statistically different with sampling dates in all treatments ($P<0.05$). However, at the initial stocking period, Fulton condition factor of fish in all treatments was not significant ($P>0.05$). The variation in Fulton condition factor between treatments was observed as culturing period increases. Moreover, significant differences of the Fulton condition factor with different stocking densities and supplementary feeding were obtained during the experimental period ($P<0.05$)

5.1.6 Survival rate

Survival rate was 92 % for 25, 96 % for (50F and 75F), 88 % for 25N, 94% for 50N, and 94.7% for 75N during the culturing period (Table 5). Most of the deaths were encountered in the first three weeks of the experiment period. The survival rate was not significantly affected by stocking density, supplementary feeding or experimental period ($P > 0.05$).

Table 5. Number of deaths and survival rates of fishes at each treatment during the experimental periods

Treatment	Jan.30	Feb.14	Feb.27	Mar.14	Mar.28	Apr.11	Apr.25	May.9	Total death	Survival rate (%)
25N	2	-	1	-	-	-	-	-	3	88
50N	-	1	-	2	-	-	-	-	3	94
75N	1	2	-	-	-	1	-	-	4	94.7
25F	-	-	2	-	-	-	-	-	2	92
50F	-	1	1	-	-	-	-	-	2	96
75F	1	1	-	-	1	-	-	-	3	96

5.1.7 Yield/Production

The total weight gained (yield) for each treatment per cage is listed in Table 2. These weight increases were significantly different with and without supplementary feeding ($P<0.05$). Net yield per fish was negatively affected by stocking density. However, the weight gained (net yield) per individual fish was highest in 25F followed by 50F, 75F, 25N, 50N, and 75N.

5.2 Physical parameters

Water temperature, pH, and Dissolved oxygen measured at monthly interval for a period of four months are summarized in Table 6. The water temperature was relatively high during January, medium in February and April, relatively low in March in the reservoir (Table 6). Water temperature, pH, and Dissolved oxygen were not significantly affected by culture conditions ($P > 0.05$), but was affected by experimental dates alone ($P <$

0.05). There was no significant difference (P>0.05) in mean water temperature between the sampling dates (Fig 14).

Figure 5. Water temperature records of Wonji Reservoir in Site 1 and Site 2 from January 30, 2010 to April 25, 2010

Table 6. Physical parameters in the Wonji Reservoir during the experimental period

Sampling Dates	Water Temperature (°C)	pH	Dissolved Oxygen (mg/l)	Stations
Jan.30	26.8	7.32	6.78	Site 1
	26.4	7.3	6.76	Site 2
Feb.27	25.1	7.41	7.4	Site 1
	25.3	7.43	7.41	Site 2
Mar.28	23.2	7.53	7.61	Site 1
	23.3	7.54	7.6	Site 2
Apr.25	25.2	7.21	8.56	Site 1
	25.1	7.2	8.54	Site 2

The pH in the culture reservoir varied from 7.21 to 7.53, and there were no significant differences (P>0.05) in the values. There were no significant differences (P>0.05) in the DO levels, the values varied from 6.7 to 8.5 mg/l during the experimental period.

5.3 Planktons

5.3.1 Zooplankton abundance

The taxonomic group of zooplankton identified during the study period is given in Table 7. In all sites, rotifers contributed the maximum No/m^3 to the total abundance followed by c1adocerans. The copepods contributed the least to the total abundance.

The zooplankton standing stock varied (Fig. 6) over the study period. The total zooplankton number at the site was 37,025 m^{-3} (site 1) and 36,909 m^{-3} (site 2), respectively.

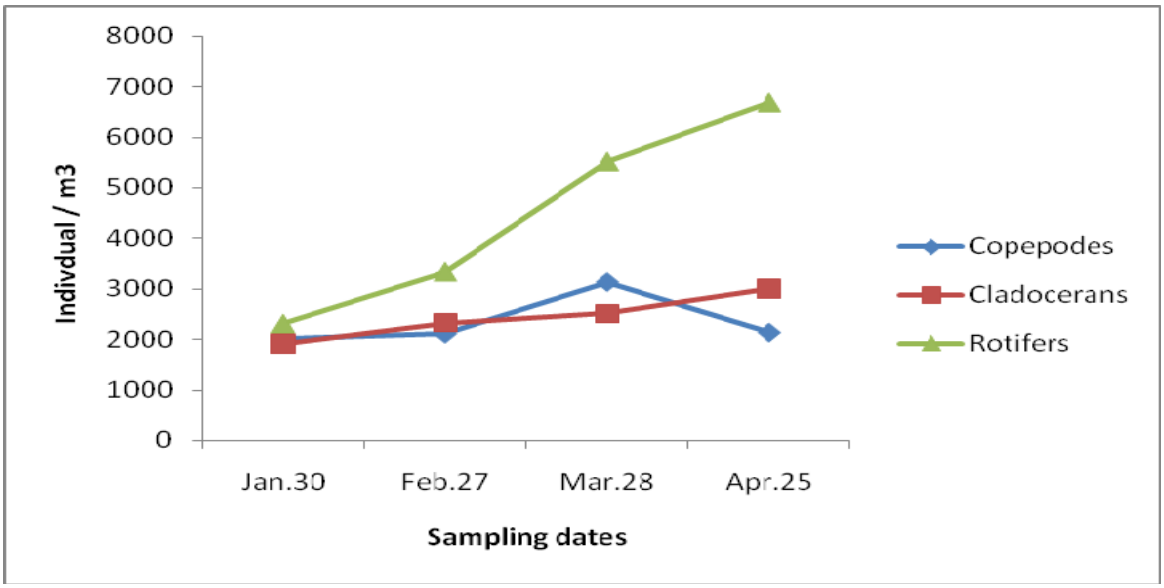

Figure 6. Zooplankton abundance of Wonji Reservoir during the experimental period

Table 7. Zooplankton taxa identified from Wonji Reservoir during the experimental period.

Rotifera	**Copepods**	**Cladocera**
Asplanchna sieboldi	*Tropocyclops prasinus*	*Daphina* [a]
Horaella brehmi [++]	*Megacyclops viridis*	
Brachinus falcatus		
Brachinus angularis		
Tricocerca pusilla		
Brachinus caudatus		
Keratella tropica		
Trichosphaera aequatorialis		

Key: [++] most dominant, [a] rare occurrence

5.3.2 Phytoplankton abundance

The list of species of phytoplankton identified during the study period is given in Table 8. Four phytoplankton groups were identified over the study period. Diatoms, blue-green, dinoflagellates and green algae were the dominant groups in terms of abundance. The phytoplankton standing stock varied (Figure 16) over the study period. In all the sampling periods Cyanophyceae (52%) were the most abundant followed by Dinoflagellates (22%) and Bacilarophyta (20%) and others including Chlorophyta constitute the remaining 6%. Blue green algae were the most dominant in almost all the months at the site.

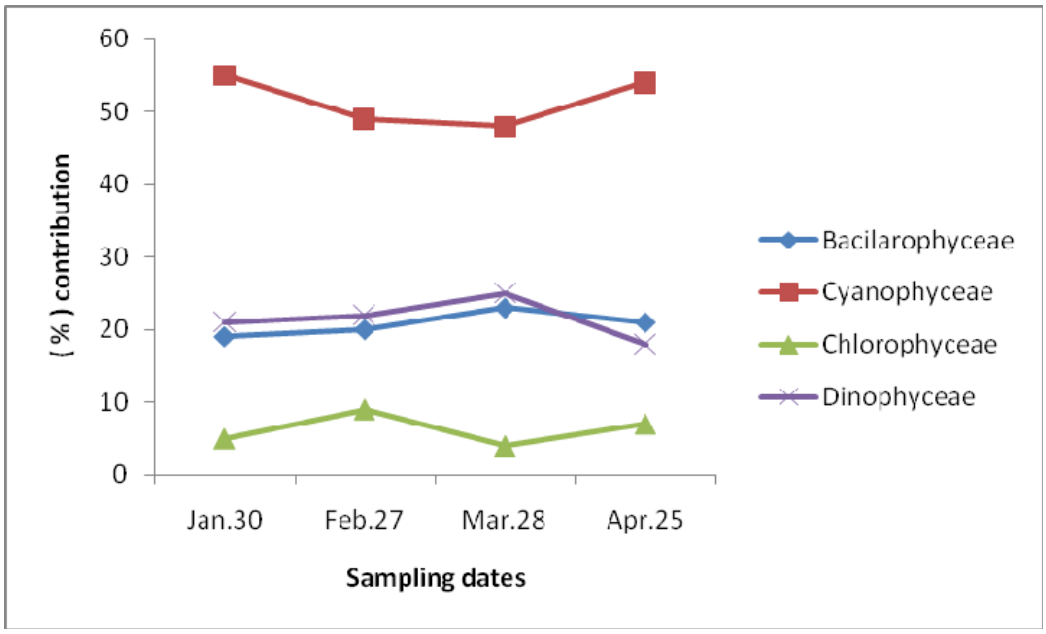

Figure 7. Percent contribution of phytoplankton abundance at Wonji Reservoir during the experimental period.

Table 8. List of phytoplankton identified from Wonji reservoir during the experimental period.

Phytoplankton group	**Species name**
Bacilariophyceae (Diatoms)	*Cyclotella catenata*
	Cyclotella comensis
	Diatoma heimala
	Fragilaria capucina
Cyanophyceae (Cyanobacteria)	*Anabaenopsis raciborskii* [++]
	Cylindrospermopsis curvispora
	Myxobaktron salinum
Chlorophyceae (Green algae)	*Ampora ovalis*
	Cylindrocystis grassa
	Excentrosphaera viridis
	Koliella speculiformis
	Volvox dissipaturix [a]
Dinophyceae (Dinoflagellates)	*Peridinium galunense*

Key: [++] most dominant, [a] rare occurrence

6. Discussion

In this study, there was a significant difference in growth ($P < 0.05$) with increasing stocking density in all feed treatments. This result is in agreement with the findings of Ashagrie Gibtan *et al* (2008) and Abebe Tadesse (2007) who studied the effects of stocking density (50, 100, 150 and 200 fish/m^3 cages) for the same species, and found that the fish size and production were to be significantly affected by stocking density.

Ouattara *et al*. (2003) also studied the effects of stocking density (20, 50, 100 and 150 fish/m^3 cages) for tilapia, and found that the fish size and production were to be significantly affected by stocking density. Canario *et al*. (1998) also studied the effect of stocking density (0.35, 1.3 and 3.2 kg / m^3) on the growth of gilthead sea- bream, *Sparus aurata*, and found that fish in the highest density group grew 25% slower than fish in the lowest density group. Moreover, other fish species [Chinook salmon *Oncorhynchus tshawytscha* (Walbaum) (Martin and Wertheimer, 1989), African catfish (Haylor, 1991) and Arctic charr, *Salvelinus alpines* (Jorgensen *et al.*, 1993)] also showed an inverse relationship between stocking density and growth parameters. Silva *et al.* (2000) also studied the effect of stocking density (2, 3 and 4 kg/m^3) on the growth of tetra-hybrid red tilapia, and found that final body weight gain was significantly higher at density of 2 and 3 kg/m^3, while the biggest biomass and feed consumption were observed at density of 4 kg/m^3.

The growth differential between non-fed and fed tilapia (*O. niloticus*) started during the first two weeks of culture (Table 3). Similar results were reported in the study of cage culture system in Lake Kuriftu by Ashagrie Gibtan *et al.* (2008); Lake Elen by Abebe Tadesse (2007); Lake Babogaya by Belsti Fetene (2008) and Solomon Hailu (2008). However, Moav *et al*. (1977) did not find a significant difference in growth of cultured fish with and without supplemental feeding, which was likely due to lower densities of stocked fish (Diana *et al*., 1994). Present study showed that the growth of *O. niloticus* that were fed with supplementary feed resulted in significantly higher growth compared to corresponding controls.

The results of this study showed that under the present conditions (feed type, feed preparation and feeding frequency), the supplemental feed could make a substantial contribution to the growth of this species. Clearly, the fish analyzed in the feeding treatment (25F, 50F, 75F) of the same stocking density did not even come close to growth encountered when kept without supplementary feed (25N, 50N, 75N). It is possible to confirm that addition of feed in present proportion (3% per body weight of fish), twice a day, brought a substantial growth difference. However, different feeding regime involving more frequent feed applications must be studied. Although in the present study, the presentation of feed was improved (feed was in pelleted form), the used supplemental feed for *O. niloticus* in Wonji reservoir should be reviewed critically, partly from the aspect of availability of feed but also from a cost-benefit point of view.

These need not be based on a ban on the use of feed but could also rely on distinct improvements in the culture methods and techniques like quality of feeding, demand feeding regime (automatic feeders) which are not included in this experiment. This would allow a reduction in supplementation levels, making culture cheaper, as well as minimizing eutrophication from wasted feed. Regardless of the supplementation levels and the way of supply used (with feeding tray) in the present study, the fed cages with low stocking density gained higher weight than those with higher stocking density. This is in agreement with the findings of Ashagrie Gibtan *et al* (2008) ; Abebe Tadesse (2007) and El - Sayed (2002) that fish density could affect the efficiency of feed utilization in which the number of fish stocked in a cage/pond increases the amount of feed available to each fish decreases.

The higher initial size and weight of the 75N at stocking is likely to have the contribution to the relatively higher weight gain encountered in the present experiment compared to the other two controls. Similar results were obtained by Ashagrie Gibtan *et al* (2008); Abebe Tadesse (2007) and Akbulut *et al*. (2003) who found that the growth rate and final biomass of rainbow trout were significantly affected by initial stocking size. In addition, Duston *et al*. (2004) also found that the final biomass of juvenile striped bass was significantly affected by initial stocking size.

In the present study, the mean daily growth rate observed in 25F (1.36 g/day) was more than that of the other two treatments and three controls (1.06 g / day, 0.77 g / day, 0.55 g / day and 0.28g / day, 0.27 g / day for 50F, 75F, 25N, 50N and 75N, respectively). This might be due to the influence of stocking density (for feeding treatments) and absence of supplementary feeding (for controls). In this regard, Smith *et al.* (1978) stressed the importance of taking fish density into account when ranking families or progeny groups for growth performance where fish density is an important factor affecting growth and maturation of wild and laboratory fish, besides feed supply and its quality, genetics and environmental conditions.

Daily growth rates observed in this study (Table 3) were comparable to the daily growth rates reported earlier by Ashagrie Gibtan *et al* (2008); Abebe Tadesse (2007); Belsti Fetene (2008); Solomon Hailu (2008); Zonneveld and Fadholi (1991) and Green (1992). The faster daily growth rate obtained in 50F treatment would allow the fish to attain a weight of 103.29 g difference in the culturing period than the 50N thus, shortening the duration of the production cycle by less than half from the natural setting. The production time of *O. niloticus* is 12 months in most of East African lakes (Dadzie, 1992).

The decline in growth rates at W10 (10^{th} week of the experiment) of the treatments (Figure 11 and 12) resulted from the decline of water temperature of the reservoir which made the difference between the exponents for feed intake and metabolism. Similar results were reported by Ashagrie Gibtan *et al* (2008). Chervinski (1982) also reported that the optimum range of temperature for *O. niloticus* is 25 ^{o}C to 29^{o}C and a decrease from this level resulted in reduction on growth. Similar observations have been made in previous studies by Francis *et al*. (2001) that growth rate of fish declined from 2.5 to 1.3 g/day with decrease in temperature from 30 to 20^{o}C under intensive culturing condition.

The relatively lower daily growth rate observed in the controls without supplementary feeding (0.55 g / day, 0.28 g / day, and 0.27 g / day) for 25N, 50N and75N, respectively during the 100 days of culture is higher than the daily growth rate of *O.niloticus* in most rift valley lakes of Ethiopia under natural conditions. The daily growth rate of *O.*

niloticus in Lake Awassa is 0.25 g / day (Yosef Tekle Giorgis and Casselman, 1995), Langeno 0.15 g/day, Ziway 0.20 g/day (Demeke Admassu and Ahlgren, 2000). This difference might be due to the difference in feed quantity and quality which result in growth variation in *O. niloticus* (Cruz, 1997). This might be due to higher temperature in Wonji Reservoir than most rift valley lakes of Ethiopia.

Additional evidence on growth difference of the effect of stocking density and with and without the application of supplementary feed can be obtained from the results of specific growth rates (Table 2). In the present study, SGR in the six treatments were negatively correlated ($P<0.05$) with stocking density; further increase in stocking density resulted in significant decrease in growth rates. Similar results were obtained by Ashagrie Gibtan *et al* (2008); Abebe Tadesse (2007). Ashagrie Gibtan *et al* (2008) found the SGR of 50F treatment as 1.115.This value is lower than the result of present study (1.208) for the same stocking density.

FCR values obtained in the 25F were better than values obtained in other feeding treatments (Table 3). This enhancement in FCR suggests efficient feed utilization through the extraction of more nutrients from the feed and converting it into flesh (Bhijkajee and Gobin, 1997). FCR value obtained in the 50F treatment of this study was better than the best FCR (12.64) reported by Ouattara *et al*. (2003) for tilapia at the same stocking density (50 fish / m^3). In this study, FCR increased significantly ($P < 0.05$) under low stocking density than at high stocking density and the best FCR for *O. niloticus* was obtained for 25F (under low density). This result is in agreement with those obtained by Ashagrie Gibtan *et al* (2008); Abebe Tadesse (2007); Ouattara *et al.* (2003), Liti *et al.* (2005) and Bolivar *et al*. (2006) who reported that FCR decreased with increasing stocking density.

Moreover, the FCR trends which were seen in this experiment are in agreement with that obtained by Al-Hafedh (1999) and Khattab *et al*. (2004). Similar results were also obtained by Akbulut *et al*. (2003) who found that the FCR of rainbow trout were significantly affected by stocking density. Mohammad (2006) also observed a decline of feed intake in *O. niloticus* with increasing body mass and stocking density. This high FCR in this study confirms that the fish growth benefited from the supplementary feed.

On the contrary, Siddiqui *et al.* (1989) reported that no difference in growth or FCR of *O. niloticus* (40.3 g average weight) reared in brackish water (3.5 - 3.9 ppt) tank for 164 days fed on supplementary feeding at densities of 16, 32 and 42.6 fish/m^3. Watanabe *et al.* (1990) also reported that feed conversion of Florida red tilapia fed supplementary feed did not differ at densities ranging from 100 to 300 / m^3. The considerable variations in the results of FCR recorded previously in Siddiqui *et al.* (1989) and Watanabe *et al.* (1990) for FCR might be due to the variations in fish size and age, stocking density, feed quality, hygiene and environmental conditions or other unknown factors, which mask the results of their work (Diana *et al.*, 1996).

Condition factor, which is used to compare the well-being or the fatness of fish, is based on the fact that the heavier fish of a given length is in a better condition. Mean Fulton condition factors in this study was higher in 25F than the other two feeding treatments (Fig. 4). Thus, the fish in25F had the best condition factor than fish in other treatments. The difference between the conditions of fish in feeding treatment (25F, 50F, 75F) and controls (25N, 50N, 75N) (having the same stocking density) is due to absence of supplementary feeding in the controls.

Moreover, better Fulton condition factor in feeding treatments also indicate that the fish were supplied with good quality of supplementary feed (highly digestible). This was reflected by the significant variation (ANOVA, $P < 0.05$) in Fulton condition factor of *O. niloticus* in the treatments and controls in the experiment. There was also variation with stocking density (Fig. 4).

At the beginning of the experiment (up to week three), low mortality of fish was encountered in all treatments and controls. No pronounced mortality was observed during the progress of the experiment except the death of five fish at the remaining 10 weeks for all treatments and controls (Table 5). The mean survival rate in the treatments and controls (93.45 %) was higher than the 70 % and 75 % reported by Liti *et al*. (2005) and by Abou *et al*. (2007), respectively, for *O. niloticus* reared in cages. However, it was lower than the 95.2% reported by Ashagrie Gibtan *et al*. (2008).

However, the results of this study (94 and 96% survival rate for 50N and 50F, respectively) are more or less similar to that of Ouattara *et al*. (2003) who found 98% survival rate for 50 fish / m^3. This clearly showed that in the present experiment and in other works, survival rate was not affected significantly by stocking density in the present study. Consequently, the high survival rate of *O. niloticus* at high density indicates its amenability to intensive culture practice.

There was a strong trend for total production increment with increasing stocking density and in presence of supplementary feeding. This is in agreement with Ashagrie Gibtan *et al.* (2008); Abebe Tadesse (2007); Kebede Alemu (2003) and Watanabe *et al* (1990) for tilapia. The positive relationship between stocking density and yield has been also described in culture based fisheries in reservoirs (Silva *et al,* 2000)

Values of water temperature, pH, and dissolved oxygen (Table 6) were within the permissible limits, as recommended for tilapia culture (Boyd, 1982). Generally, there were no significant differences in water temperature, pH, and dissolved oxygen during study period. This is in agreement with Ashagrie Gibtan *et al.* (2008); Abebe Tadesse (2007); Belsti Fetene (2008); Solomon Hailu (2008) and Diana *et al*. (1996) who emphasized that the efficient use of supplementary feed at a limited rate, along with natural feeds does not adversely affect water quality.

The zooplankton abundance in both sites indicates that rotifers were the most abundant, followed by cladocerans and copepods. The insignificant variation in zooplankton abundance between site 1 (cage site) and site 2 (control site) shows the less incidence of adverse effect of the experiment on the reservoir zooplankton abundance. Similar result was reported in the study of cage culture system in Lake Kuriftu by Ashagrie Gibtan *et al.* (2008); Lake Elen by Abebe Tadesse (2007); Lake Babogaya by Belsti Fetene (2008) and Solomon Hailu (2008). However, further study should be done to investigate the effects of cage culture practice on the zooplankton community in reservoirs.

Percentage composition of the different algal groups to the total abundance of the phytoplankton community in the reservoir were observed, the blue-greens accounted for over 52% of the total phytoplankton abundance through out the study period. Among the

blue greens, *Anabaenopsis* were the most important contribution to the total phytoplankton abundance in this study. The insignificant variation in phytoplankton abundance between site 1 (cage site) and site 2 (control site) shows that the experiment did not bring any adverse effect on the reservoir phytoplankton abundance. This is in agreement with Ashagrie Gibtan *et al.* (2008); Abebe Tadesse (2007); Belsti Fetene (2008) and Solomon Hailu (2008). However, further study should be done to investigate the effects of cage culture practice on the phytoplankton community.

7. Conclusion and Recommendations

7.1 Conclusions

- ❖ In this study, the best stocking density with regard to growth performance, condition and feed conversion efficiency was 25 fish / m^3 of cage. Gross production increased with increasing stocking density but the net yield per individual decreased with increasing density. So, statistically 25F (25 fish / m^3) was the best stocking density in this experiment. However, if the fish weight of >140 gm / fish is desirable as table size, the density of 75 fish / m^3 is most effective because of high gross production.

- ❖ Stocking density in this experiment had no significant effect on the survival of fish.

- ❖ The supplementary feed had a positive effect on the growth performance, yield, and condition of fish hence; the presentation of supplementary feed had substantial contribution to the growth of fish. No adverse effect of the experiment on the reservoir plankton abundance was observed.

7.2 Recommendations

- ✓ The results of present study are not sufficient to generate enough data, therefore, detailed studies are required on other aspects like feed preparation, rate of feeding, frequency of feeding, type and quality of feeds, and cost of feed, and on other fish species like catfish and carp, as well as tilapia in other reservoirs.

- ✓ In addition, similar studies using other production systems, such as, pen, pond and tank, should be conducted and compared with cage culture. Furthermore, other aspects of cage aquaculture, for instance cage size and type should be investigated.

- ✓ Moreover, having the same healthy cohort is an ideal requirement for cage aquaculture and getting of fingerlings was a big challenge at beginning of this study; hence development of hatchery center should be taken into consideration to benefit from the sector.

- ✓ Study on the bio-volume of the plankton should be investigated. Furthermore, study on economic feasibility, culture period, rate of feeding and feed type in relation to market/table size should be investigated.

- ✓ In addition, effect of cage culture on the reservoir nutrient loading, plankton community benthos community needs profound investigation.

- ✓ The goal in the country, to continue to reduce poverty and eliminate hunger among the people, expand commercialized and diversified agriculture, together with the present results, seem to be appropriate for aquaculture practices in the country.

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