COMPERATIVE EVALUATION OF GROWTH PERFORMANCE AND YIELD OF FOUR TILAPIA SPECIES UNDER CULTURE CONDITIONS

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN TROPICAL ANIMAL PRODUCTION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

This study was undertaken on-station at Magadu Research Farm, Sokoine University of Agriculture and on-farm at Changa and Kibwaya villages, Mkuyuni ward. The objective of the study was to evaluate growth performance of four tilapia species under culture conditions. The tilapia species used were *Oreochromis niloticus*, *O. hornorum*, *O. ruvumae* and *O. jipe* which were collected from Kingolwira Fish Farming Center, River Wami, River Ruvuma and Lake Jipe, respectively. Eight hapas (6m^2 each) and six earthen ponds (50 to 200 m^2) were used for the on-station and on-farm experiments respectively. Stocking density was 2 fish /m^2 in both experiments. The experiment lasted for 90 days in both locations. Results from the present study indicated that, *O. niloticus* showed the highest final body weight (FBW) (67.6 ± 2.4g) and average daily gain (ADG) (0.7 ± 0.03g /day) in the on-farm experiment than in the on-station (27 ± 3.1g and 0.3 ± 0.04g /day). *O. hornorum* ranked second in both on-farm (41.2 ± 2.4 g, 0.4 ± 0.03 g/day) and on-station (26.4 g ± 3.8, 0.2 ± 0.04 g/day) experiments. *O. ruvumae* showed the lowest FBW and ADG in both on-farm (17.6 ± 2.4g, 0.15 g/day) and on-station (23.4 ± 3.3g, 0.2 ± 0.04 g/day) experiments. *O. jipe* showed the lowest FBW and ADG (16.3 ± 2.0g, 0.02g /day) among the species studied in the on-station experiment. The CP content in the fish body was highest (62.86 ± 2.5%) for *O. niloticus* reared on-station and lowest (52.23 ± 2.5%) for *O. ruvumae* reared on-farm. Ether extract (EE) was highest for *O. hornorum* in both experiments. Results from the present study proved the superiority of *O. niloticus* over other tilapia species followed by *O. hornorum* and *O. ruvumae*. *O. jipe* had the lowest growth performance, making the species unsuitable for aquaculture despite its highest survival rate.

DECLARATION

I, ESTER EMANUEL MEILUDIE, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other Institution.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
ADG	Average Daily Gain
BW	Body Weight
CP	Crude Protein
DM	Dry Matter
DO	Dissolved Oxygen
EE	Ether Extract
FAO	Food and Agricultural Organization
FCR	Feed Conversion Ratio
FBL	Final body length
FBW	Final Body Weight
FBWd	Final Body Width
GLM	General Linear Model
GR	Growth Rate
ha	Hectare
IBW	Initial Body Weight
l	Litre
L	Lake
LG	Length Gain
Mg	Milligram
NO_2	Nitrite
NO_3	Nitrate

pH	Hydrogen ion concentration
SAS	Statistical Analysis System
SGR	Specific Growth Rate
SUA	Sokoine University of Agriculture
T	Time
USA	United State of America
WG	Weight Gain

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Tilapia culture is practiced in tropical and subtropical regions of the world and has been growing at an outstanding rate during the past two decades (El Sayed and Kawanna, 2008). The worldwide production of tilapia in resent years has increased significantly and this increase has been influenced by the fast expansion of the *O. Niloticus* species raised in China, Philippines, Thailand, Indonesia and Egypt (Neves *et al*., 2008). Pond culture of tilapias has received great attention in recent years (El Sayed, 2003), with Nile tilapia, *Oreochromis niloticus* dominating fresh water aquaculture. This species is preferred due to its rapid growth rates, high tolerance to low water quality, efficient feed conversion, ease of spawning, resistance to disease and good meat taste (El Sayed and Gaber, 2005).

In Africa, aquaculture is still at its early stages of development due to lack of traditions of fish farming. Only recently appropriate models have been employed to foster aquaculture growth (Kapertsky, 1994) including development of domestic and export markets for fish in sub-Saharan Africa. This made investment in aquaculture attractive (Jamu and Ayinla, 2003). Freshwater aquaculture production dominates the region where one-third of its total production is tilapia, especially the Nile tilapia (*O. niloticus*), with Egypt being the leading country producing almost more than half of the total tilapia production in this Region (Brummett and Williams, 2000; FAO, 2007).

Sub-Saharan Africa is a minor player in aquaculture, contributing less than 2% of world fish supply. Nigeria is the leading country in aquaculture production, followed by Egypt and Madagascar (World Bank, 2006; FAO, 2008). The prevailing political and socio-economic constraints facing African agriculture in general, have resulted into small contribution of aquaculture to food security and economic development despite Africa's natural endowment of aquatic genetic resources and adequate water supply in many parts (Kapertsky, 1994; FAO, 2008).

Aquaculture industry in Tanzania started in 1940s with experimental ponds at Korogwe and Malya (FAO, 2005). Like in many other African countries, aquaculture industry in Tanzania was not well productive in the past due to lack of proper management and use of incorrect technology coupled with physical problems such as drought and poor infrastructure (FAO, 2005). In recent years aquaculture production started to rise up and it is dominated by *O. niloticus* (Kaliba *et al*., 2006; FAO, 2007) whereby small-scale fish farmers practice both extensive and semi- intensive aquaculture (Lamtane *et al*., 2008).

Research in tilapia culture in Africa has focused on *O. niloticus*, e.g. in Egypt (El-Sayed and Gaber, 2005; A-S Goda *et al*., 2007; Abdel-Tawwab *et al*., 2010; Kenya (Liti *et al*., 2005a; Liti *et al*., 2005b; Kaliba *et al.*, 2007); Tanzania (Kaliba *et al.*, 2006) and Democratic Republic of Congo (de Graaf, 2004). Studies on other tilapia species like *O. karangoe* and *O. shiranus* have also been carried out in Malawi (Maluwa *et al.*, 1995; Kang'ombe *et al.*, 2007); *O. variabilis* in Tanzania (Shoko, 2002) and *O. galilaeus* in Egypt (A-S Goda *et al*., 2007).

The species of tilapia native to Tanzania inland waters include *Oreochromis korogwe, O. urolepis hornorum, O. urolepis urolepis, O. jipe, O. ruvumae, O. variabilis* and *O. esculentus* (Trewavas, 1983; Eccles, 1992) but little research on their performance in ponds have been conducted. Currently there is shortage of *O. niloticus* fingerlings from hatchery centres and there is no enough documented information on the growth performance of other native tilapias which are found in Tanzanian inland waters all over the country. Hence, the present study aimed at investigating the growth performance, yield and body chemical composition of introduced tilapia, *Oreochromis niloticus* and three native tilapias namely, *Oreochromis urolepis hornorum, O. ruvumae* and *O. jipe* under on-farm and on-station conditions.

1.2 Problem Statement and Justification

The availability of *O. niloticus* fingerlings is still a problem in Tanzania. Most of the fish farmers have resorted to producing and selling fingerlings of *Oreochromis niloticus* to other farmers. However, most farmers are producing only small sized fish probably because of inbreeding. Other tilapia species exist almost in all freshwater bodies in the country but their performance in culture conditions is not known. Thus, there is a need for looking for alternative tilapias that can be used in places where *O. niloticus* is not readily available. Furthermore, information on growth performance of tilapias native to Tanzania like *Oreochromis urolepis hornorum, O. jipe, O. urolepis urolepis, O. ruvumae, O. variabilis, O. korogwe* and *O. esculentus* is scanty. Also, there is no research which has been conducted to compare the growth performance of *O. niloticus* with the species native to Tanzania under the same conditions. This study was undertaken to compare the growth performance of different tilapias native to Tanzania so as to come up with the species that will complement *O. niloticus.* The information from this study will assist fish farmers to culture tilapia species which are native to Tanzania so as to improve fish farming in areas where these species are readily available and reduce the costs which could be incurred by getting *O. niloticus* fingerlings from far-off hatchery centres. In this case the farmers will be able to increase production of fish and improve income of fish farmers through sales of fish and fish products. By so doing fish farmers will improve their living standards and alleviate poverty.

1.3 Objectives

1.3.1 General objective

To identify native tilapia species suitable for aquaculture production at farmers conditions in Tanzania.

1.3.2 Specific objectives

(i) To compare growth rate, survival, and final yield at harvest of four different tilapia species.

(ii) To compare body chemical composition of four different tilapia species.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Position of Tilapias in Aquaculture

Tilapias are a group of tropical freshwater fish species native to Africa and the Middle-East, but have been introduced to many countries around the world (Trewavas, 1983; Asiah *et al*., 1996). More than 77 known tilapia species exist (Trewavas, 1983; Asiah *et al*., 1996; Thomas and Michael, 2005) and are classified into three genera, namely; *Tilapia*, *Sarotherodon* and *Oreochromis*. Classification is based on their breeding behaviour and food preferences. Tilapia is a substrate spawner and feeds mainly on water plants. *Sarotherodon* is a paternal mouth brooder and feeds mainly on algae. *Oreochromis* is a maternal mouth brooder and feeds on algae.

Worldwide, tilapia is the third most cultured fish group after Carps and Salmonids (Yonas, 2006). The genus *Oreochromis* is the most commonly cultured and among the species in this genus *Oreochromis niloticus* was the first species to be cultured in Africa and about 90% of all commercially farmed tilapia outside Africa is *O. niloticus* (Thomas and Michael, 2005). Other species used in aquaculture globally include *O. mossambicus* and *O. aureus* (Yonas, 2006). Selection of species for culture depends on various biological and economical factors including adaptation to local environment, growth rate and ability to reproduce under captivity, food preference, availability, simple culture of fingerlings, market price and demand (Asiah *et al*., 1996; Sweilum *et al*., 2005; Sorphen *et al*., 2010).

2.2 Distribution of Native Tilapia Fishes in Tanzania

Nile tilapia, *Oreochromis niloticus*, is naturally found in Lake Albert, Yarkon River, the Nile, Jebel Marra, Lake Chad basin, Niger system, Volta River, Gambia River, Senegal River, Lake Edward and Lake Kivu (Trewavas, 1983). This species was introduced in Lake Victoria between 1950s and 1960s and later on distributed to many ponds and some reservoirs all over the country (Trewavas, 1983). *O. niloticus* is preffered for aquaculture due to its indiscriminate appetite, high prolificacy, tolerance even to poor water quality (de Graaf, 2004; FAO, 2005), proven superior growth, hardiness and good taste, making the species attractive for culture worldwide (FAO, 2007).

Oreochromis ruvumae is confined in Ruvuma River which flows along the Tanzania-Mozambique border from the upper Ruvuma to Kionga at the mouth, Lake Rutamba, Lupululu system and the Lukuledi found in west of Lindi. *Oreochromis hornorum* is naturally found in River Wami system while *Oreochromis jipe* is native to Lake Jipe in north Pare - Kilimanjaro Region and River Pangani system (Trewavas, 1983).

2.3 Growth Performance of Tilapias in Aquaculture

Growth performance of fish includes parameters such as final body weight, daily weight gain, survival rate, specific growth rate and weight at harvest. Growth rate of fish under culture conditions depends much on management practices applied during the culture period (A-S Goda *et al*., 2007; Sorphen *et al*., 2010). Some of the factors which determine the growth performance of the fish include species cultured, stocking density, fertilization of the pond, control of water quality parameters and type of food supplemented (Asiah *et al*., 1996; Thomas and Michael, 2005; A-S Goda *et al*., 2007; Sorphen *et al*., 2010). Some tilapias (e.g. *O. niloticus*, *O. mossambicus*) under captivity mature early (2 to 3 months), at that time they are 6 to 10cm long and weighing about 30 to 100g (Asiah *et al*., 1996; Thomas and Michael, 2005). In natural environment *O. niloticus* matures late (10 to 12 months) and reach the weight of 350 - 500g (Thomas and Michael, 2005).

Florida red tilapia grows nearly as fast as *O. niloticus* while *O. aureus* (Blue tilapia) grows at the slowest rate under tropical conditions; but has the greatest cold tolerance and may have the highest growth rate in temperate regions at temperatures below optimum (James, 2005). Blue tilapia (*Oreochromis aureus*), Nile tilapia (*Oreochromis niloticus*) and their hybrids are common in mixed-sex cultures due to their high growth rates and sometimes may attain a marketable size before commencement of spawning. Under captivity and good management pure *O. mossambicus* matures early at about 3 months and weighs 60 -100g (Thomas and Michael, 2005). Among the tilapias, *O. niloticus* have been reported as a superior species in terms of growth performance under culture conditions in USA (Tidwell *et al*., 2000); Cambodia (Sorphen and Preston, 2001); Kenya (Liti *et al*., 2005a); (Liti *et al*., 2005b and Liti *et al*., 2006); Egypt (A-S Goda *et al*., 2007) and in Ivory Coast (Koumi *et al*., 2009). Other species which have been reported to attain higher growth rate include *O. aureus* in the Netherlands (Rojas and Verreth, 2003) and *galileus* in Egypt (A-S Goda *et al*., 2007). Studies done on other tilapias in different regions of the world indicated that these species exhibit low growth performance compared to the *O. niloticus*. The lowest final weight has been reported on *O. rendalii* in Mexico

(Olivera-Novoa *et al*., 2002); *O. zillii* in Egypt and Turkey (Abdel - Tawwab, 2008 and Yildirim *et al*., 2009); *O. niloticus* in Malasya (Iluyemi *et al*., 2010) and Egypt (Zaki *et al*., 2010).

The survival rate of the fish depends much on the quality of the environment in which they are raised, species and age of the fish. *O. niloticus* can attain the highest survival rate ranging from 90 to 100% as it is reported by various authors under different culture systems. The highest survival rate has been obtained by Al - Hafedh (1999) in concrete and fiber glass tanks; Tidwell *et al*. (2000) in earthen ponds; El Sayed (2002) using fibre glass tanks; El Sayed and Gaber (2005) in glass aquaria; Ridha (2006b) in fiber glass tanks; Thy *et al*. (2008) in poly-culture ponds; Azaza *et al*. (2008) in plastic tanks and Abdel-Tawwab *et al*. (2010) in concrete tanks. On the other hand, the lowest survival rate ranging from 49.4 to 63% have been reported for *O. niloticus* in Kenya (Liti *et al*., 2006) and for *O. zillii* (43.3 to 46.7%) in Egypt (Abdel – Tawwab, 2008). In Mexico, *O. aureus* have been reported to have the highest survival rate of 93% (Olivera-Novoa *et al*., 2002). Red tilapia can do well even in brackish water and may have the survival rate of 85% (Zaki *et al*., 2010).

Feed conversion ratio (FCR), determined as weight of the feed consumed per weight gained by the fish, differs according to experimental conditions, culture system and species differences (Ridha, 2006b). For the fish with higher growth rate like *Oreochromis niloticus*, FCR can be below 3 as reported by different researchers in USA (Tidwell *et al*., 2000); Germany (Hossain *et al*., 2003); Kuwait (Libert and Portz, 2005; Ridha, 2006a; Ridha, 2006b); Tunisia (Azaza *et al*., 2008) and Egypt

(A-S Goda *et al*., 2007 and Abdel-Tawwab *et al*., 2010). However, under certain conditions it may be as higher as 3 and above (Fasakin *et al*., 1999; El-Sayed, 2002 and Liti *et al*., 2005a). The highest FCR ranging from 3.6 to 7.14 have been observed for *O. zillii* in Egypt (Abled Tawwab, 2008) and Turkey (Yildirin *et al.*, 2009). On the other hand, *O. rendalii* in Mexico (Olivera-Novoa *et al*., 2002) and *O. aureus* in the Netherlands (Rojas and Verreth, 2003) have been reported to have low FCR.

2.4 Factors Affecting Growth Performance of Tilapias in Aquaculture

Several factors affect the growth performance of tilapia in aquaculture including stocking density; water quality parameters like dissolved oxygen, ammonia, pH and temperature; fertilizer and feeds. High stocking densities result in low growth performance and survival of individual fish but final yield increases (Sorphen *et al*., 2010). Increasing stocking density leads to diminishing social dominance resulting into higher survival but lowers individual growth rate (Dambo and Rana, 1992). On the other hand, low stocking densities lead to low feed utilization efficiency due to lack of competition for food or difficulty of tracing feed particles or flush of uneaten food by drainage water (El Sayed, 2002). Feed consumption increases with increasing stocking density (de Silva *et al*., 2000), however, body size of tilapia fish cannot be affected by stocking density when water flow is uniform (Gall and Bakar, 1999).

Quality of the water determines the growth performance of tilapia fish (Lubambula, 1997). Excellent quality of water may lead to high survival, growth rate and yield of the fish (Lubambula, 1997). The temperatures preferred by tilapia fish range from 25 to 30ºC but, they may also do well in waters of 20 to 35°C (Hillary and Claudy, 1997). Moreover, tilapia may tolerate temperatures as low as 16 – 17ºC for short periods (Hillary and Claudy, 1997). The lower and upper lethal temperatures for most tilapia species are 11°C and 42°C, respectively (Hillary and Claudy, 1997; Xu *et al*., 2006 and A-S Goda *et al*., 2007). Temperature less than 22ºC inhibits growth and reproduction (Kapetsky, 1994; Al-Hafedh, 1999; Sorphen and Preston, 2001; Sorphen *et al*., 2010 and Chhay *et al*., 2010). In the study conducted by A-S Goda *et al*. (2007) *O. niloticus* and *Tilapia galilae* fingerlings performed well when the temperature was held between 23.8ºC and 28ºC.

Another factor that affects the growth performance of tilapia fish is dissolved oxygen (DO). Prolonged depletion of oxygen is often a major cause of mortality in pond systems. However, tilapias are able to survive long periods of up to 6 - 8 hours of low oxygen concentration by gulping at the air-water interface (Lubambula, 1997). The recommended level of dissolved oxygen for fish is 5 to 8 milligram per litre (mg /l) (Bolorunduro and Abba, 1996; Hillary and Claude, 1997; James, 2005; Liti *et al*., 2005a and Xu *et al*., 2006). Tilapia exhibits an abnormal behaviour of approaching the water surface for aquatic respiration when the level of dissolved oxygen drops to 1.5mg /l (Xu *et al*., 2006). According to Balarin and Hatton (1979) tilapia can survive under extremely adverse DO condition and the lowest limit which has been recorded is 0.1mg /l for *O. mossambicus* and *O. niloticus*.

It is possible that all tilapias can survive at oxygen level as low as 1mg /l (Lamtane *et al*., 2008), but with reduced growth rates (Bhujel, 2000). According to Liti *et al*.

(2006) and Sorphen *et al*. (2010) *O. niloticus* perform well when dissolved oxygen level is maintained at above 3mg /l. Fouling of water, especially in hapa system, leads to low level of oxygen, hence, reduced growth rate of the fish, but this can be corrected by frequent hapa exchange (Bhujel, 2000).

High levels of nitrogen in the form of un-ionized ammonia or nitrite may be toxic to the fish (Klontz, 1995; James, 2005). The accepted tolerance level of nitrite in the fish pond is 0.55mg /l. Fish start to die when nitrite levels reach 5mg /l (Klontz, 1995; James, 2005). Levels exceeding this amount create a problem in which iron in the haem molecule become reduced and cannot transport oxygen, thus inhibit the satisfaction of the oxygen demand for the fish (Klontz, 1995). According to Liti *et al*. (2005a) and Liti *et al*. (2006) *O. niloticus* shows good performance when the levels of nitrite range between 0.06 and 0.08mg /l. Nitrates are non - toxic to fish and can contribute to algae bloom. Basically nitrates are fertilizers but the concentration should not exceed 10mg /l (Klontz, 1995).

Hydrogen ion concentration (pH) of the water is also important for the growth performance of Tilapias. The fish can survive in a wide range of water pH between 3.5 and 12. However, the recommended pH level for good growth ranges between 6.5 and 9 (Lubambula, 1997; Satya and Timothy, 2004 and Liti *et al*., 2005a). High growth performance of tilapia has been recorded at pH above 8 (Bolorunduro and Abba, 1996; Liti *et al*., 2005a; Xu *et al*., 2006 and Sorphen *et al*., 2010). Fertilization of the fish pond is considered vital for fast growth of fish. Addition of fertilizer/manure in water boosts the natural food production in the pond and ultimately fish growth (Lubambula, 1997; Sorphen and Preston, 2001 and Liti *et al*., 2006). High growth performance and yield have been reported in Cambodia by Sorphen and Preston (2001) for *O. niloticus* which were grown in ponds fertilized using effluent and chemical fertilizers. Also, Lubambula (1997) reported higher weight and yield for *O. niloticus* grown in $3m^2$ tanks fertilized with cow dung at the rate of 0.5kg per tank at monthly interval.

Like any other farm animal, fish require food to grow (Lubambula, 1997). Studies conducted in many parts of the world have indicated that the type of feed offered affect the growth performance of the fish (Rojas and Verreth, 2003; Liti *et al*., 2005a; Liti *et al*., 2006 and Thy *et al*., 2008) but not all diets which produce fastest growth are always profitable for tilapia (Tidwell *et al*., 2000). Some ingredients are more expensive and processing may also increase the cost of feeds leading to low profitability of tilapia fish (Tidwell *et al*., 2000). High protein content of the diet improves the growth performance of the fish (Lubambula, 1997; Al-Hafedh, 1999; Fagbenro and Davies, 2001; El-Sayed and Gaber, 2005; AS-Goda *et al*., 2007; Koumi *et al*., 2009; Abdel-Tawwab 2010 and Jabir *et al*., 2011), but amino acid balance of the diet should be considered (Fasakin *et al*., 1999; Olivera-Novoa *et al*., 2002; Azaza *et al*., 2008). Care should be taken when feeding the fish with diets containing protein of plant origin due to the presence of anti-nutritional factors (Shiau *et al*., 1987; Shiau *et al*., 1990; Ogunji and Manfred, 2001; Abdelghany, 2003; Hossain *et al*., 2003; Koumi *et al*., 2009).

2.5 Tilapia Production

Higher yield that reached 7 116 kg /ha (Liti *et al*., 2006) in earth ponds and 2 328 kg / ha (Offem *et al*., 2009) in poly-culture system has been reported for *O. niloticus*. Shoko *et al*. (2011) reported higher yield (4 704.27kg /ha /yr) in an integrated fish and vegetable culture system and low yield (1 405.95kg /ha) in a non-integrated culture system. It seems that supplementation of the fish by using green vegetables favours their growth. In Thailand, Diana *et al*. (1996) reported the highest yield of 28 178 kg /ha for *O. niloticus* in an experiment which started with fertilization alone, followed by supplementation after the fish attained a certain weight. In Kenya, Liti *et al*. (2005b) obtained the yield of 11 360kg /ha /year at low density (150 fish per cage) and 18 795kg /ha /year at high density (300 fish per cage) for *O. niloticus*. Overpopulation of tilapia in confined ponds is a major problem which causes stunted growth due to shortage of space and natural food (Offem *et al*., 2009). It has been reported that stocking density and type of culture affect tilapia production (Liti *et al*., 2005b; Liti *et al*., 2006; Kaliba *et al*., 2006 and Offem *et al*., 2009).

2.6 Nutritive Value of Tilapias

Like other fish species Tilapia has high crude protein (CP), ether extracts (EE) and mineral (Ash) contents. Studies conducted by different researchers for *O. niloticus*, *Tilapia zillii*, and red tilapia revealed high nutritive value of the fish as indicated in Table 1. Body chemical composition is much affected by the diet offered to the fish. The highest CP level ranging from 69.18 to 73.4% (average 70%) have been reported in Malasya by Jabir *et al*. (2011) for *O. niloticus* fed diet containing different levels of super worm meal. However, Libert and Portz (2005) reported low CP ranging from 50.95 to 52.75% (average 51.8%) for *O. niloticus* fed on plant based diets (a mixture of soybean meal 24.5%, wheat gluten 11.5%, corn 22.5% and wheat 32.5%) and supplemented with graded levels of different sources of microbial phytase. The highest ether extract (EE) ranging from 26.2 to 34.6% (average 30.03%) have been reported for *O. niloticus* supplemented with the diet containing fish meal, soybean meal, wheat meal, vitamin and mineral premix (Focken *et al*., 2000). Jabir *et al*. (2011) reported the lowest EE for *O. niloticus*. *Tilapia zillii* have been observed to perform poorly and contain higher amount of ash averaging 30.37% (Abdel-Tawwab, 2008).

Table 1: Nutritive value of three tilapias

Species	CP %	EE %	Ash %	Sources
O. niloticus	53.73	30.03	11.50	Focken *et al*. (2000)
O. niloticus	56.45	23.50	19.65	Tidwell *et al*. (2000)
O. niloticus	59.80	26.4	17.40	EL Sayed (2003)
Red tilapia	60.66	24.64	15.03	Abdelghanny (2003)
O. niloticus	51.80	-	-	Libert and Portz (2005)
Tilapia zillii	57.00	11.16	30.37	Abdel Tawwab (2008)
O. niloticus	62.90	22.26	15.33	Koumi *et al*. (2009)
O. niloticus	59.23	23	13.98	Iluyemi *et al*. (2010)
O. niloticus	70.38	11.78	14.1	Jabir *et al*. (2011)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Locations

The study comprised of two experiments which were undertaken in two locations. The first experiment was done on-station at Magadu Research Station, Sokoine University of Agriculture, situated in the Western part of the University along the Morogoro-Mzinga road. The climatic condition of Morogoro is characterized by bimodal rainfall pattern, with short rains received from November to December and long rains starting in March and ending in June. Magadu area receives 767mm rainfall per annum. Relative humidity and temperature ranges from 30 to 96% and 26 to 35.5^{o}C respectively, (SUA Meteorological station, personal communication, 2012). The second experiment was done on-farm at Changa and Kibwaya villages, Mkuyuni division, Morogoro rural district. Mkuyuni is located on the eastern slopes of the Uluguru Mountains, about 50km south of Morogoro municipal town at latitude 6^{0}48'S and longitude 37^{0} 42'E. The area has a bimodal rainfall pattern with short rains received from November to December and long rains from March to June. Temperature ranges from 15^{o}C to 40^{o}C with a mean of 25^{o}C.

3.2 Tilapia Species used in the Experiments

Fingerlings used in the present study belong to four tilapia species; *Oreochromis niloticus, O. hornorum, O. ruvumae and O. jipe*. *O. jipe* was not used in the on-farm experiment due to lack of enough ponds at farmers' level. *Oreochromis niloticus* fingerlings were collected from Kingolwira Fish Farming Centre in Morogoro. The centre is under the Ministry of Livestock and Fisheries Development. *O. hornorum* fingerlings were collected from River Wami while *O. ruvumae* fingerling were obtained from River Ruvuma at Litapwasi village in Ruvuma region and *O. jipe* fingerlings were obtained from Lake Jipe found in North Pare, Mwanga District, Kilimanjaro Region. The fingerlings from each source were kept in plastic containers containing water and oxygen added and transported to Sokoine University of Agriculture (SUA), Morogoro by road. The fingerlings were then acclimatized separately in concrete tanks at Magadu Research Station, Sokoine University of Agriculture for one month prior to commencement of the experiment.

3.3 Experimental Design

An experiment was conducted for 90 days in a 2 x 3 factorial experiment. The factors considered were two locations and three fish species which were replicated two times in each location. Body weight (BW) measurements were taken monthly to determine growth performance.

3.3.1 On-station experiment

Eight hapas, each with six square meter surface area and one meter depth (3m x 2m x 1m) were used during the experiment. The hapas were installed in two earthen ponds each with a size of three hundred square meters ($300m^2$). Four hapas were installed in each pond and each hapa was allocated one tilapia species and two replicates were made for each species. Stocking density was two fish per square meters (2 fish /m^2). Prior to commencement of the experiment the ponds were drained, cleaned and allowed to dry for one week. The hapas were set and ponds refilled with water. Poultry manure was added at a rate of 5kg per pond per month.

During the rearing period, fish were supplemented with a diet comprised of soybean meal (30%) and maize bran (70%). Soybeans were boiled without de-hulling and then sun dried prior to milling. Feeding rate was 10% of body weight from the beginning of the experiment up to one month and then reduced to 7%. This amount was fed for another one month, then reduced to 5% of body weight and then maintained at that level till the end of the experiment. Feeding was done once at 11.00 am every day.

3.3.2 On-farm experiment

A total of six farmers from Changa and Kibwaya villages, three from each village participated in the experiment. The criteria used to select the farmers were possession of a pond that has reliable source of water. Tilapia species, *Oreochromis niloticus, O. hornorum and O. ruvumae* were distributed to farmers, each species to two different farmers making two replicates for each species. Since each farmer owned only one pond, a total of six ponds were used. The ponds were filled with water by using channels available in the villages and fertilized by using chicken manure at the rate of 4kg /200m^2 and goat manure at the rate of 7kg /200m^2 depending on which type of manure the farmer can access easily. The fingerlings were stocked at a density of two fish per square meter (2 fish /m^2) in each pond. The farmers were allowed to feed the fish as they used to do by using local feed materials available in the farm including vegetables, fodder tree leaves and kitchen leftovers. The farmers were supported by being given maize bran which was fed at the rate of 5% body weight per day as an additional energy supplement and feeding was done once a day at 11.00 am throughout the experimental period.

3.4 Data Collection

3.4.1 Body measurements

Fish body weight was measured using an electrical weighing balance to the nearest grams while body length and body width were measured by using a measuring board with a ruler to the nearest centimetres (cm). All measurements were carried out at the start of the experiment and then at monthly intervals for a period of 90 days.

3.4.2 Body chemical composition

Body chemical composition of the fish was determined at harvest through laboratory analysis using standard methods (AOAC, 1990). Crude protein (CP) content of the fish body was determined by Kjeldahl method. Ether extract (Crude lipid) was determined by using Soxtec extraction machine by using petroleum ether (40 to 60ºC boiling range) and ash by incineration of the fish in the muffle furnace at 550ºC for 3 hours.

3.4.3 Water quality parameters

Water quality parameters were monitored in both experiments to ensure the survival of the fish. For the on-station experiment the measurements were taken weekly, but for the on-farm experiment they were taken at monthly interval due to the difficult in accessing the area. Measurements were taken at different points of the ponds and then average. The water quality parameters monitored were temperature, dissolved oxygen (DO), pH and transparency. Temperature and dissolved oxygen measurements were measured using YSI oxygen meter (model 55, YSI industries - USA) while pH were measured using test strips (JBL Easy Test). Water transparency was measured by using a locally made 100 cm Secchi disk.

3.5 Data Processing and Analysis

3.5.1 Growth data

Growth parameters determined were:-

- Final body weight (g)

- Body weight gain expressed as the final weight minus initial weight (g)

- Average daily body weight gain expressed as weight gain per fish per day (g /d)

$$ADG = \frac{FBW - IBW}{T} \quad \text{.......... (1)}$$

Where: ADG = average daily gain (g /day)

FBW = Final body weight (g)

IBW = Initial body weight (g)

T = Total time (days)

- Specific growth rate expressed as the percent growth per day (% / d)

$$SGR = \frac{100[\text{In(Final body weight)} - (\text{In(Initial body weight)}]}{\text{Days of experimental period}} \quad \text{.......... (2)}$$

- Survival of the fish

$$SR = \frac{\text{Total number stocked} - \text{total number died}}{\text{Total number stocked}} \times 100 \quad \text{.......... (3)}$$

Where: Total number stocked = total number of fish at stocking

Total number died = total number of fish died

SR = Survival rate

3.5.2 Statistical analysis

Data were analysed by using the General Linear Model (GLM) of the Statistical Analysis System (SAS, 1998) software. Two way ANOVA was used to determine the effect of species and location on quantitative variables (body weights, lengths and width) and growth rate of the fish. Descriptive statistic was used to compute the means and standard errors. The Duncan multiple range test was used to compare the means. Factors considered were species, location and their interactions. Initial body measurements were used as a covariate during analysis of growth data. Chi square analysis was used to analyze the data for survival of the fish.

The model for growth performance data was:

$\mathbf{Y}_{ijk} = \mu + P_i + L_j + (PL)_{ij} + b(X_{ij} - \mathit{X}) + \varepsilon_{iik}$

Where $\mathbf{Y}_{ijk}$ = dependent variable to be analyzed (Body weight, growth rate, length)

$\boldsymbol{\mu}$ = overall mean

$\mathbf{P}_i$ = effect of i^{th} Species (*Oreochromis ruvumae, O. niloticus, O. jipe* and *O. hornorum)* on the dependent variable (body weight, growth rate, Length)

$\mathbf{L}_j$ = effect of j^{th} location (on-farm and on-station)

$\mathbf{(PL)}_{ij}$ = effect associated with interaction between Species and location

$\mathbf{b(X}_{ij} - \boldsymbol{X}\mathbf{)}$ = effect of initial weight / length/ width as a covariate

b = regression of $\mathbf{Y}_{ij}$ on initial measurements

$\mathbf{X}_{ij}$ **=** Initial measurements (body weights, length, width) of individual fish

$\boldsymbol{X}$ **=** Initial measurements means (means of body weights, length, width) of fish

$\boldsymbol{\varepsilon}_{ij}$ = error term

CHAPTER FOUR

4.0 RESULTS

4.1 Growth Performance

Table 2 summarizes the growth performance of four tilapias in terms of final body weight (FBW), daily weight gain, specific growth rate (SGR) and survival rate (SR) under two experimental conditions, on-farm and on-station. The effects of species and experimental locations were significant ($P<0.05$). *O. niloticus* had the highest growth performance, followed by *O. hornorum*, *O. ruvumae* and *O. jipe* in both experiments (Table 2, Figure 1 and 2). The highest mean growth rate (0.7g /day), specific growth (2.04%) and eventually final weight (67.6 ± 2.4g) were observed on *O. niloticus* in the on-farm experiment while the lowest (0.2g /day, 1.6% and 17.6 ± 2.4g) were found on *O. ruvumae*. Mean length and width were highest for *O. niloticus* grown on-farm, followed by *O. hornorum* (Table 2).

4.2 Survival Rate of Tilapia Species in both Experiments

Mean survival rate was higher for the fish cultured on-station than for the fish cultured on-farm for all species (Table 2, Appendix 10). It was observed that *O. niloticus* had the highest survival rate for both on-station (100%) and on-farm experiments (85.6%). The lowest survival rate (63.5 – 66.7%) was observed on *O. hornorum* in both experiments.

Table 2: Comparison of Growth performance of tilapias grown on-station and on-farm

	On – Farm			On – Station			
	Oreochromis niloticus	***O. hornorum***	***O. ruvumae***	***O. niloticus***	***O. hornorum***	***O. ruvumae***	***O. jipe***
IBW (g)	4.4 ± 0.4 [b]	5.2 ± 0.5[a]	5.0 ± 0.4[a]	2.5 ± 0.6[c]	4.6 ± 0.6[b]	6.0 ± 0.6[a]	2.9 ± 0.6[c]
FBW (g)	67.6 ± 2.4 [a]	41.2 ± 2.4 [b]	17.6 ± 2.4[d]	26.7 ± 3.1 [c]	26.4 ± 3.8 [c]	23.4 ± 3.2[c]	26.4 ± 3.8 [c]
FBl (cm)	15.1 ± 0.2 [a]	12.7 ± 0.2 [b]	10.0 ± 0.2[d]	11.5 ± 0.3 [b]	12.1 ± 0.4 [b]	11.0 ± 0.3 [c]	12.1 ± 0.4 [b]
FBWd (cm)	4.5 ± 0.1 [a]	3.8 ± 0.1 [b]	2.8 ± 0.1 [d]	3.3 ± 0.1 [c]	3.4 ± 0.1 [c]	3.0 ± 0.1 [d]	3.4 ± 0.1 [c]
WG (g)	61.3 ± 2.5 [a]	35.3 ± 2.5 [b]	13.8 ± 2.5[d]	24.2 ± 3.2 [c]	21.8 ± 4.0 [c]	17.4 ± 3.3[c]	21. 8± 4.0 [c]
LG (cm)	8.5 ± 0.3 [a]	6.0 ± 0.3 [b]	4.1 ± 0.3 [c]	6.3 ± 0.4 [b]	6.0 ± 0.5 [b]	4.0 ± 0.5 [c]	6.0 ± 0.5 [b]
GR (g /day)	0.7 ± 0.03 [a]	0.4 ± 0.03 [b]	0.15 ± 0.0[d]	0.3 ± 0.04[c]	0.2 ± 0.04[c]	0.2 ± 0.04[c]	0.2 ± 0.04[c]
SGR (%)	2.2 ± 0.14 [a]	2.04 ± 0.14[a]	1.61 ± 0.1[b]	2 .± 0.2 [a]	2.0 ± 0.22 [a]	1.7 ± 0.2 [b]	2.0 ± 0.22 [a]
SR (%)	85.6 ± 2.9[b]	63.5 ± 2.93[c]	78.2 ± 2.93[a]	100 ± 2.93[a]	66.7 ± 2.93[c]	95.8 ± 2.93[a]	66.7 ± 2.93[c]

IBW = initial body weight, FBW = final body weight, FBL = final body length, FBWd = final body width, WG = weight gain, LG = length gain, GR = growth rate, SGR = specific growth rate, SR = survival rate.

[abcd] = Different superscript letters in the same row indicate significant (P<0.001) difference among treatments while same superscript letters indicate non significant difference among the species

Figures 1 and 2 show the growth patterns of tilapia species studied for the on-farm and on-station experiments, respectively. For the on-farm experiment significant (P<0.05) different patterns were observed whereby *O. nilotcus* showed the fast growth compared to the other species. *O. ruvumae* showed the slowest growth pattern throughout the study period (Figure 1). For on-station experiment the growth patterns of *O. niloticus, O. hornorum* and *O. ruvumae* did not differ significantly (P>0.05) while *O. jipe* showed the lowest growth rate (Figure 2).

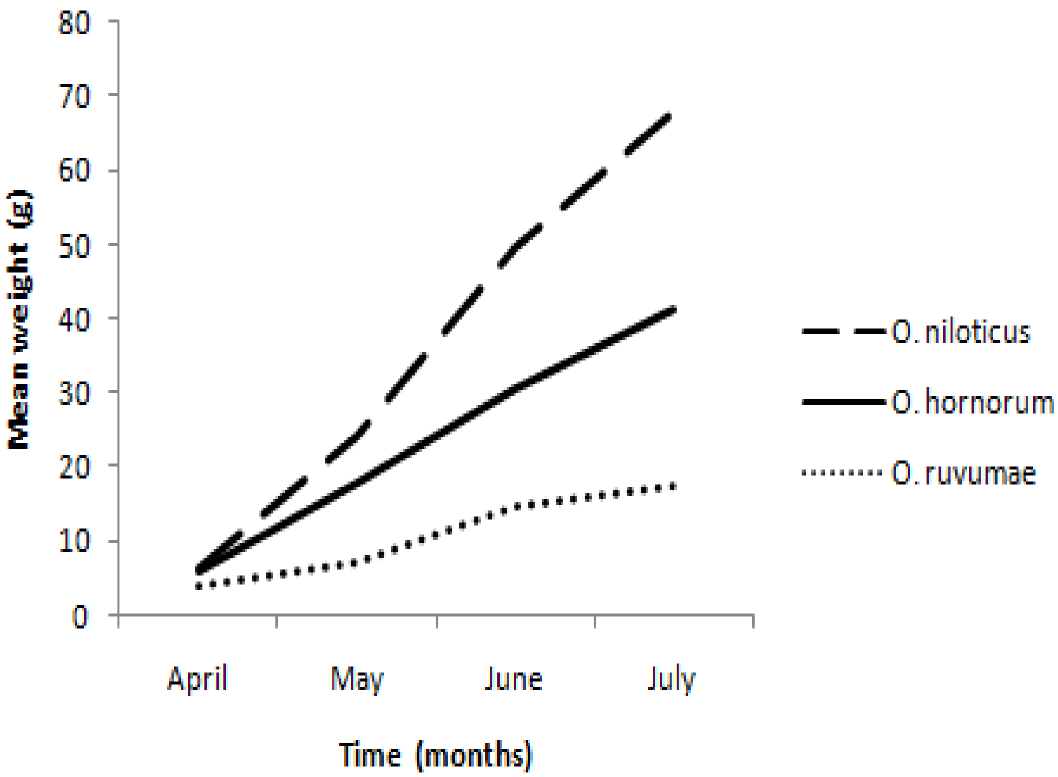

Figure 1: Growth patterns of tilapia species during the on-farm experiment

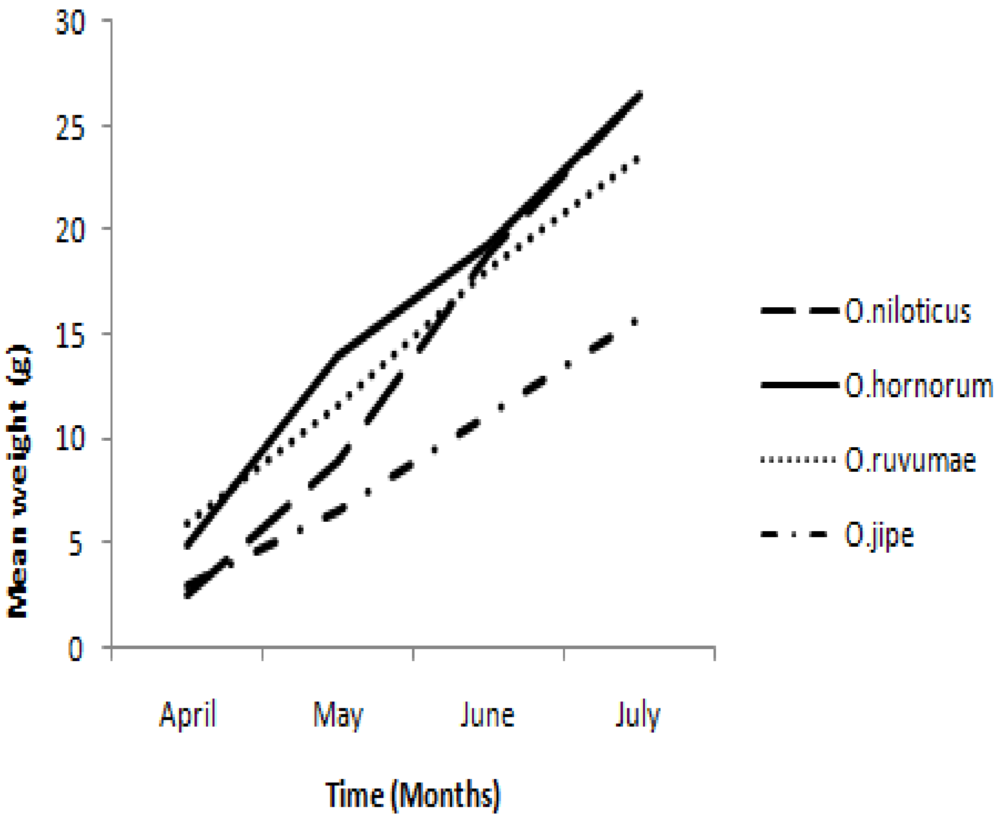

Figure 2: Growth patterns of tilapia species during the on-station experiment

4.3 Yields of the Four Tilapia Species

Table 3 shows yields of the four tilapia species for the on-farm and on-station experiments. The results indicate that there were significant differences (P<0.05) in fish yield between locations and among species. In both experiments, *O. niloticus* had the highest yield (Table 3, Appendix 13). The estimated yields from on-farm and on-station experiments for *O.niloticus* were 1 158kg /h and 534.2kg /ha, respectively. For the on-farm experiment *O. ruvumae* had the lowest yield while for the on-station *O. jipe* showed the lowest yield among the four tilapias.

Table 3: Yields of four tilapias in the on-farm and on-station experiments

	On-farm			On-station			
	O. niloticus	***O. hornorum***	***O. ruvumae***	***O. niloticus***	***O. hornorum***	***O. ruvumae***	***O. jipe***
Area (m^2)	125	100	50	6	6	6	6
IBW(g)	4.4 ± 04^c	5.2 ± 0.5^b	5.0 ± 0.4^b	2.5 ± 0.6^d	4.6 ± 0.6^c	6.0 ± 0.6^a	2.9 ± 0.6^d
FBW(g)	67.6 ± 4^a	41.2 ± 2.4^b	17.6 ± 2.4^d	26.7 ± 3.1^c	26.4 ± 3.8^c	23.4 ± 3.2^c	16.3 ± 2.0^d
Yield(kg /ha)	1 158 ± 25.3^a	523.9 ± 25.3^b	274.7 ± 25.3^c	534.2 ± 25.3^b	351.7 ± 25.3^c	449.1 ± 25.3^b	301.5 ± 25.3^c

IBW = Initial body weight, FBW = Final body weight

^{abcd} = Different superscript letters in the same row indicate significant (P<0.001) difference among treatments while the same superscript letters indicate non significant differences among the species

4.4 Body Chemical Composition

Table 4 shows body chemical composition of the four tilapias. No significant differences (P>0.05) were observed for ash content among the species in both experiments. Significant differences (P<0.05) were observed on crude protein (CP) and ether extract (EE) contents (Table 4, Appendix 14 and Plate 5). The CP was higher for the fish grown in the on-station experiment than for those grown in the on-farm experiment. For the on-station experiment, *O. niloticus* had the highest CP value (62.86 ± 2.5%), followed by *O. hornorum* (61.46 ± 2.5%). *O. ruvumae* and *O. jipe* had the lowest CP values (Table 4). For the on-farm experiment, *O. niloticus* had the highest CP content (58.1 ± 2.5%) while *O. ruvumae* had the lowest value (52.23 ± 2.5%). Ether extract content (EE) was highest for *O. hornorum* in both experiments.

Table 4: Body Chemical composition of four tilapias in the on-farm and on-station experiments

	On-farm			On-station			
	O. nilotics	*O. hornorum*	*O. ruvumae*	*O. niloticus*	*O. hornorum*	*O. ruvumae*	*O. jipe*
Percentage							
CP	58.1 ± 2.5^a	53.2 ± 2.5^b	52.2 ± 2.5^b	62.9 ± 2.5^a	61.5 ± 2.5^a	56.3 ± 2.5^a	55.9 ± 2.5^a
EE	16.8 ± 3.5^b	30.1 ± 3.5^a	17.9 ± 3.5^b	16.9 ± 3.5^b	39.8 ± 3.5^a	18.8 ± 3.5^b	17.5 ± 3.5^b
ASH	13.3 ± 0.8^a	14.5 ± 0.8^a	13.6 ± 0.8^a	14.1 ± 0.8^a	15.8 ± 0.8^a	14.4 ± 0.8^a	14.9 ± 0.8^a

^{ab}=Different superscript letters in the same column indicate significant ($P<0.05$) difference among treatments while the same superscript letters indicate non significant ($P>0.05$) difference, CP = Crude protein, EE = Ether extract.

4.5 Water Quality Parameters

In the on-farm experiment water quality parameters monitored were temperature (25.10 ± 0.26^{o}C), dissolved oxygen (5.14 ± 0.27mg / l), pH (7.35 ± 0.1) and water transparency (34.44 ± 1.6cm) (Table 5, Appendix 1). In the on-station experiments water quality parameters monitored were temperature (25.20 ± 0.23^{o}C); dissolved oxygen (5.36 ± 0.24mg /l), pH (6.70 ± 0.1) and water transparency (42.17 ± 1.4cm) (Table 5, Appendix 2).

Table 5: Water quality parameters in the on-farm and on-station experiments

	On-farm	**On-station**
Temperature (^{o}C)	25.10 ± 0.26	25.20 ± 0.23
DO (mg /l)	5.14 ± 0.27	5.36 ± 0.24
pH	7.35 ± 0.1	6.70 ± 0.1
Transparency (cm)	34.44 ± 1.6	42.17 ± 1.4

DO = dissolved oxygen, pH = acidity / alkalinity

CHAPTER FIVE

5.0 DISCUSSION

5.1 Growth Performance

The results from the present study indicated significant differences of growth rate and final body weight of the four tilapias. This might be due to species differences in genetic makeup, culture systems used and diets used to feed the fish. The superiority in growth performance shown by *O. niloticus* compared to the other species in the present study is supported by the literature (Sorphen and Preston, 2001; A-S Goda, 2002; Koumi *et al*., 2009; Offem *et al*., 2009).

Generally, the growth performance for all species was higher in the on-farm experiment than in the on-station experiment. The result on final body weight for *O. niloticus* from on-farm experiment in the present study is very close to the findings reported by other authors in different culture systems. Sorphen and Preston (2001) reported final body weight of 71.4 ± 1.76g in earthen ponds fertilized with effluent and Liti *et al*. (2005b) growing *O. niloticus* in cages at high density obtained final body weight of 71.5 ± 2.12g. However, the observed results on final weight in the current study are higher than that reported by Rojas and Verreth (2003) for the tilapia fed on coffee pulp (45g); Hossain *et al*. (2003) who used aquaria systems (56.76g); Neves *et al*. (2008) in concrete tanks (48.77g) and Zaki *et al*. (2010) in fibreglass tanks (49.33g). The difference might be due to the type of the diets used to feed the fish where the above mentioned authors used different diets and different feeding regimes (coffee pulp, fish meal + sesbania seed endosperm, commercial bran fish-food, myo-isonital supplement mixed in the diet at the rate of 500 mg /kg). On the other hand, the final body weight for *O. niloticus* in the current study is lower than the final body weight reported by A-S Goda (2002) in cement ponds (307g); Koumi *et al*. (2009) in plastic tanks (140g) for *O. niloticus* fed on the diet containing soybean meal; Offem *et al*., (2009) in a poly-culture system (355.8g) for *O. niloticus* raised with *Heterobranchus longifilis*. The difference may be caused by diet and the method used to formulate, initial body weight and the type of culture system. Koumi *et al*. (2009) used 100% soybean meal while in this study the inclusion level of soybean meal was 30%. Offem *et al*. (2009) started with the highest initial weight of 50.4g while in the present study initial weight was 4.4g.

Daily weight gain was higher for *O. niloticus* cultured in the on-farm experiment. Other studies also have demonstrated similar results. For example, the daily weight gain observed in the on-farm experiment in the present study is almost similar to the growth rate reported by Liti *et al*. (2006) when fed maize bran as supplementary feed to mixed-sex of *O. niloticus*. However, the growth rate observed in the present study is lower than the growth rate of 1.3 – 1.5g /day reported by Liti *et al*. (2005a) who used different supplementary diets. The difference, therefore, might be linked to the difference in the feeds used where Liti *et al*. (2005a) used four different feed formulations. The poor growth performance observed in the on-station experiment compared to the on-farm experiment might have been contributed by the difference in culture systems used to raise the fish and the diets. The main disadvantage of hapa system is that hapa may sometime be clogged by organic material from the fertilizers used and this prevents continuous exchange of water between the inside and outside of the hapas (Bhujel, 2000). Fouling of hapas might affect water quality due to reduced water exchange and this may lead to low level of dissolved oxygen inside the hapas (Bhujel, 2000). This situation might impose stress to the fish, hence, reduced growth performance (Bhujel, 2000).

Surprisingly, specific growth rate for *O. niloticus* did not differ between the experiments although inputs were different. This might be due to the variation in weights of the fish at the start of the experiment. In comparison with the works done by others on *O. niloticus*, the findings from the present study agrees with the results on specific growth rate reported by Fasakin *et al*. (1999) who used different inclusion levels of duckweed as protein source in the fish diet; Tidwell *et al*. (2000) who supplemented the fish with pelletted and unpelleted distillers grains in cages and Azaza *et al*. (2008) who fed the fish with the diets containing graded levels of green algae Ulva meal (*Ulva rigida*).

The observations from the present study showed that *O. hornorum* ranked second after *O. niloticus* in growth performance in both experiments. The mean final weight, specific growth rate and daily weight gain observed for *O. hornorum* in the on-farm experiment are higher than that observed in the on-station experiment. The difference might be due to type of culture system and type of manure used to fertilize the ponds which favoured the growth performance of the fish in the on-farm experiment, as was also the case for *O. niloticus*. The observations from the present study shown that *O. ruvumae* and *O. jipe* had the lowest growth performance. Since inputs applied in the on-station experiment in the present study were similar to all fish species, the difference in growth rate observed for these two species might be caused by their genetic makeup differences.

5.2 Survival Rate of the Four Species of Tilapia

Survival rate of the fish in the present study was higher for the on-station than for the on-farm experiment, especially for *O. niloticus* which showed 100% survival. However, survival rate of *O. niloticus* did not differ from the other species in the on-station experiment. Studies have shown that *O. niloticus* have the ability to survive for a long time without feeding, but it will be losing weight (Sweilum *et al*., 2005). Similar results as those observed in the on-station experiment on survival rate have been reported by other authors for different tilapia species and culture systems. *O. rendalii* (86.7 to 96.7%) in Mexico (Olivera Novoa *et al*., 2002) have been reported to have higher survival rate which was almost similar to the observed results from the on-station experiment in the present study. Tidwell *et al*. (2000) grown *O. niloticus* in earth ponds found survival rate of 96.3 – 97.2%; El Sayed and Gaber (2005) obtained survival rate of 96.5 – 99.5% in concrete tanks; Ridha, (2006b) in fibre glass tanks observed survival rate of 99.2 – 100%; Thy *et al*. (2008) in pond system found survival rate of 92.4% and Abdel - Tawwab, (2010) in glass aquaria found survival rate of 96 – 100%. The survival rate value observed for *O. niloticus* in the on-station experiment in the present study is higher than the survival rate reported by Al Hafedh (1999) (80 to 89%); Sorphin and Preston (2001) (72.7 to 87.7%); Azaza *et al*. (2008) (91.11 to 93.33%) and Koumi *et al*. (2009) (67.3%) for *O. niloticus*. Mean survival rate for *O. hornorum* was lower than that observed for the other species in both experiments. This low survival rate might be attributed to species differences. For example *O. zillii* in Egypt have been reported to have the lowest survival rate ranging from 43.3 to 46.7% (Abdel – Tawwab, 2008).

5.3 Fish Yield in both Experiments

In aquaculture, fish growth and yields depend on initial density and weight whereby the higher the initial density and weight the higher the yield (Lamtane *et al*., 2008). The yields observed in the present study provide an insight on the productivity of tilapia species cultured under smallholder farmer's and on-station conditions. Yield was higher under smallholder farmer's conditions than in the on-station culture system. Although stocking density was the same in both experiments, initial body weight differed. It was higher for the on-farm experiment than for on-station. This might be the cause for the difference in yield at harvest. Since productivity is measured as the net fish yield expressed as the weight of the fish at the end of the experiment less the weight at the beginning as stated by Sorphen *et al*. (2010), it is obvious that survival rate also has a significant effect on fish productivity. Higher survival rate observed for *O. niloticus* in both experiments in the present study might be another reason why its yield was higher than that of *O. hornorum, O. ruvumae* and *O. jipe*. However, the observed yield from the on-farm experiment was lower than the results reported by Liti *et al*. (2006) for *O.niloticus* in a mixture of mixed-sex and sex-reversed males which ranged from 1 891 to 2 036kg /ha and Liti *et al*. (2005a) in Kenya reported the yield ranging from 4 411 to 5 433kg /ha for sex-reversed *O. niloticus* males. Moreover, higher yields have also been reported in Tanzania by Shoko *et al*. (2011) in a fish-vegetable integrated system for *O. niloticus*.

In both experiments, the yield of *O. hornorum* ranked second after *O. niloticus*. Since stocking density did not differ among the species in both experiments, the difference in yield between the sites for *O. hornorum* might be due to differences in initial body weight whereby it was higher in the on-farm than in the on-station experiment. Difference in culture systems might have, also, contributed to the difference in yield. For the on-farm experiment, growth rate and yield were higher than in the on-station experiment. Other studies on *O. niloticus* in earthen ponds have observed higher growth performance and yield of the fish (Tidwell *et al*., 2000; Sorphen and Preston, 2001; Liti *et al*., 2005a and Liti *et al*., 2006). It can, therefore, be assumed that earthen pond system produces higher growth rates in tilapia fish. No similar studies on *O. hornorum* have been reported.

O. ruvumae ranked third in terms of growth rate and yield, especially for the on-station. Similarly its growth performance was higher for the on-station than on-farm experiments. Differences on initial body weight and growth rate might have contributed to differences on yield. For on-station experiment where the yield for *O. ruvumae* was higher than for on-farm, initial weight and growth rate were also higher for this species. Also the supplemental diet offered to the fish had an effect on the growth performance and yield of the fish. Soybean containing diet which was used in the on-station experiment might have produced higher growth rate, hence, higher yield for *O. ruvumae* depending on the acceptance of the diet by the fish. Soybean have been reported to have higher protein content (Koumi *et al*., 2009) and is the best protein quality among plant protein feedstuffs used as alternative protein source in tilapia diets (Fagbenro and Davies, 2001).

O. jipe, had the lowest yield and since it was studied only in the on-station experiment, comparison was done among the species and not between the experiments. Although survival rate was higher for this species, its growth rate was lowest among the four species studied on-station, despite the fact that all inputs like fertilizer and feed applied were similar for all the species in this experiment. This shows that the growth potential of *O. jipe* is low, making the species unsuitable for aquaculture.

5.4 Body Chemical Composition of Tilapia Species

The results in the present study indicated that crude protein (CP) content was higher in all the species grown in the on-station experiment, with *O. niloticus* having the highest value. The diet used in the on-station experiment contained soybean (30%) which is one of the plant protein rich in amino acids. As reported by Koumi *et al*. (2009) soybean protein in the diet does not alter proteins of the fish, therefore, significant differences observed for CP between the on-station and on-farm experiments for *O. niloticus* and *O. hornorum* might be due to species differences. The observed higher CP values for the species grown in the on-station experiment in this study agrees with the results reported by El Sayed (2003) (59.8%); Koumi *et al*. (2009) (62.9%) and Iluyemi *et al*. (2010) (59.2%) for *O. niloticus*. The findings in the present study are lower than the observations reported by Jabir *et al*. (2011) (70.4%) for *O. niloticus*. The difference might be due to diets used.

In the on-farm experiment *O. niloticus* was observed to have the highest CP content. This might be due to the type of manure used to fertilize the ponds which might produce high amounts of natural food in the ponds and the superiority and high ability of *O. niloticus* to consume a wide range of feed stuffs. The observed CP content for *O. niloticus* in the on-farm experiment is very close to the findings reported by El Sayed, (2003) (59.8%) and Iluyemi *et al*. (2010) (59.2%), but lower than the results reported by Koumi *et al*. (2009) (62.9%) and Jabir *et al*. (2011) (70.4%). On the other hand, the observed CP value for *O. niloticus* for the on-farm experiment in the present study is higher than the findings reported by Focken *et al*. (2000); Tidwell *et al*. (2000) and Libert and Portz (2005) (51.8%) for this species. The difference might be due to the supplemental diets offered to the fish. For the on-farm experiment, *O. hornorum* and *O. ruvumae* recorded the lowest CP value. Compared to the findings reported by other authors, CP observed for *O. hornorum* and *O. ruvumae* in the present study are very close to the CP content reported by Focken *et al*. (2000) (53.7%) and Libert and Portz (2005) (51.8%) for *O. niloticus*.

Ether extract value was highest for *O. hornorum* in both experiments. Probably the diets consumed by this species were not efficiently utilized for growth but increased body fat deposition. There is no information on *O. hornorum* which have been reported by other authors. The results from the present study indicated that ether extract values observed for *O. hornorum* are in agreement with the results reported by Focken *et al*. (2000) (30.03%) for *O. niloticus*. However, the findings are higher than the results reported by Tidwell *et al*. (2000) (23.5%); El Sayed (2003) (26.4%); Koumi *et al*. (2009) (22.3%); Iluyemi *et al*. (2010) (23.0%) and Jabir *et al*. (2011) (11.8%) for *O. niloticus*. Ash values were more or less the same for all species in both experiments. The findings in this study are within the range reported by El

Sayed (2003) (17.4%); Koumi *et al*. (2009) (15.3%); Iluyemi *et al*. (2010) (14.0%) and Jabir *et al*. (2011) (14.1%) for *O. niloticus*.

5.5 Water Quality

Water quality parameters were monitored in the on-farm and on-station experiments throughout the study period. The values for different water quality parameters remained within the safe limits accepted for tilapia growth. In both experiments the mean temperature (22 to 28^{o}C) and dissolved oxygen concentration (5 to 8mg /l) are within the safe limits recommended for aquaculture, (Bolorunduro and Abba, 1996; Hillary and Claude, 1997; James, 2005; Liti *et al*., 2005a and Xu *et al*., 2006). However, *O. niloticus* have been reported to be able to survive in a very low DO of about 0.1mg /l (Balarin and Hatton, 1979). In the present study pH value was higher in the on-farm experiment than in the on-station but in both experiments the observed pH values are in agreement with the recommended levels for aquaculture (6.5 to 9) (Lubambula, 1997; Satya and Timothy, 2004 and Liti *et al*., 2005b). Water transparency in the on-station experiments in the present study lies within the recommended levels for aquaculture (40 to 80cm), but in the on-farm experiment transparency is lower than the recommended levels for good growth performance of tilapia fish (Bolorunduro and Abba, 1996).

5.6 Implication of using other Tilapia Species Apart from Nile tilapia in Aquaculture

Aquaculture development is primarily focused on socio-economic objectives such as nutrition improvement in rural areas, income generation, diversification of farm activities (integrated farming) and creation of employment, especially in rural communities. Although *O. niloticus* dominates the aquaculture industry and is highly preferred all over the world, the supply of enough good seeds to fish farmers is now a problem. Like other fishes, tilapias offer nutritionally, the cheapest and direct sources of protein and micro nutrients for people. It is envisaged that *O. niloticus* alone cannot meet the high demand for animal protein due to the fast growing population. This study has demonstrated that other species of tilapia native to Tanzania can be used in aquaculture to complement production of *O. niloticus* and increase total production in the country. The Wami tilapia (*O. hornorum*) showed the growth performance that is close to that of Nile tilapia (*O. niloticus*), hence, it can be used in aquaculture, especially in areas where *O. niloticus* is not available. Further comparison studies between *O. niloticus* and other tilapia species native to Tanzania like *O. urolepis urolepis, O. variabilis, O. korogwe, O. esculentus* is vital so as to ensure high production of fish in the country and helps to fight against malnutrition and poverty, especially in the rural areas of Tanzania where the supply of protein foods is inadequate.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions can be drawn from the present study:-

i. *Oreochromis niloticus* is superior to other tilapia species in terms of growth performance, yield, survival and body chemical composition.

ii. *Oreochromis hornorum* has higher growth performance and yield, second to *O. niloticus*.

iii. Growth performance and yield of *O. ruvumae* and *O. jipe* are the lowest among the tilapias used in this study.

iv. Earthen pond production system results into higher growth rate of tilapia than hapa culture system and, therefore, might be the better system for semi-intensive aquaculture in rural areas.

6.2 Recommendations

i. It is recommended that further studies should be conducted to evaluate other tilapias native to Tanzania so as to come up with the species that can do well in areas where it is difficult to get *O. niloticus* fingerlings.

ii. Fish hatchery centres in Tanzania should be improved so as to produce good fish seeds for fish farmers in the rural areas.

iii. Since it has been shown that *O. hornorum* cannot be a suitable candidate for aquaculture due to its low survival under culture conditions, hybridization between *O. niloticus* and *O. hornorum* should be done in hatcheries centres so as to get hybrid fish which can survive better than *O. hornorum* and be distributed to fish farmers for aquaculture.

iv. Fish farmers in the rural areas should be encouraged to continue using earthen ponds for aquaculture for easy of management of the fish during grow out periods.

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APPENDICES

Appendix 1: The Means for Water quality parameters for the experiment on – farm

Variable	N	Mean	Std Dev	Coeff of Variation	Minimum	Maximum	Range
Temp	18	25.0888889	1.3203782	5.2628008	23.00	27.80	4.80
DO	18	5.1383333	1.3902571	27.0565760	2.77	7.80	5.03
pH	18	7.3500000	0.6608818	8.9915886	6.00	8.40	2.40
Transp	18	34.4444444	8.1761649	23.7372531	20.00	50.00	30.00

Appendix 2: The Means for Water quality parameters for the experiment on station

Variable	N	Mean	Std Dev	Coeff of Variation	Minimum	Maximum	Range
Temp	24	25.1895833	2.0226962	8.0298914	22.60	28.60	6.00
DO	24	5.3575000	0.9659069	18.0290597	3.27	6.85	3.58
pH	24	6.7083333	0.1954185	2.9130714	6.40	7.20	0.80
Transp	24	42.1666667	7.6480555	18.1376811	30.00	56.00	26.00

Appendix 3: ANOVA for variable final weight in both experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	258.87123	258.87123	0.78	0.3804
InL	1	0.25365	0.25365	0.00	0.9780
InWdth	1	18.30990	18.30990	0.05	0.8152
SITE	1	6580.36127	6580.36127	19.76	<.0001
SPECIES	2	16512.09874	8256.04937	24.79	<.0001
Error	85	28303.70485	332.98476		
Corrected Total	91	57285.21739			

Appendix 4: ANOVA for variable final length in both experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	3.2390695	3.2390695	0.96	0.3308
InL	1	0.3960245	0.3960245	0.12	0.7332
InWdth	1	1.4188269	1.4188269	0.42	0.5192
SITE	1	29.4646301	29.4646301	8.70	0.0041
SPECIES	2	176.5633028	88.2816514	26.07	<.0001
Error	85	287.8274615	3.3862054		
Corrected Total	91	549.1891304			

Appendix 5: ANOVA for variable final width in both experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	0.16294147	0.16294147	0.49	0.4859
InL	1	0.41998486	0.41998486	1.26	0.2643
InWdth	1	0.38549821	0.38549821	1.16	0.2847
SITE	1	3.59458428	3.59458428	10.81	0.0015
SPECIES	2	23.93045945	11.96522972	35.97	<.0001
Error	85	28.27136465	0.33260429		
Corrected Total	91	61.9872826			

Appendix 6: ANOVA for variable body weight gain in both experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	30.41409	30.41409	0.09	0.7632
InL	1	0.25365	0.25365	0.00	0.9780
InWdth	1	18.30990	18.30990	0.05	0.8152
SITE	1	6580.36127	6580.36127	19.76	<.0001
SPECIES	2	16512.09874	8256.04937	24.79	<.0001
Error	85	28303.70485	332.98476		
Corrected Total	91	55404.9021			

Appendix 7: **ANOVA for Variable length gain in both experiments**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	3.2390695	3.2390695	0.96	0.3308
InL	1	13.9180869	13.9180869	4.11	0.0458
InWdth	1	1.4188269	1.4188269	0.42	0.5192
SITE	1	29.4646301	29.4646301	8.70	0.0041
SPECIES	2	176.5633028	88.2816514	26.07	<.0001
Error	85	287.8274615	3.3862054		
Corrected Total	91	662.8195652			

Appendix 8: ANOVA for Variable growth rate in both experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	0.00387802	0.00387802	0.09	0.7600
InL	1	0.00000836	0.00000836	0.00	0.9887
InWdth	1	0.00220338	0.00220338	0.05	0.8179
SITE	1	0.80392870	0.80392870	19.47	<.0001
SPECIES	2	2.03931369	1.01965684	24.69	<.0001
Error	85	3.51058460	0.04130100		
Corrected Total	91	6.84997391			

Appendix 9: ANOVA for Variable specific growth rate in both experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
InWt	1	0.08602249	0.08602249	0.48	0.4894
InL	1	2.18645431	2.18645431	12.25	0.0007
InWdth	1	1.27861060	1.27861060	7.16	0.0089
SITE	1	1.39726836	1.39726836	7.83	0.0064
SPECIES	2	8.72585757	4.36292878	24.44	<.0001
Error	85	15.17230067	0.17849765		
Corrected Total	91	75.51659565			

Appendix 10: ANOVA for Area of production in the on-farm and on-station experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Site	1	22016.33333	22016.33333	13.70	0.0076
Species	3	2916.66667	972.22222	0.60	0.6324
Site*Species	2	2916.66667	1458.33333	0.91	0.4463
Error	7	11250.00000	1607.14286		
Corrected Total	13	42244.85714			

Appendix 11: ANOVA for tilapia species stocked in the on-farm and on-station experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Site	1	88065.33333	88065.33333	13.70	0.0076
Species	3	11666.66667	3888.88889	0.60	0.6324
Site*Species	2	11666.66667	5833.33333	0.91	0.4463
Error	7	45000.0000	6428.5714		
Corrected Total	13	168979.4286			

Appendix 12: ANOVA for survival of tilapia species in the on-farm and on-station experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Site	1	417.248133	417.248133	24.31	0.0017
Species	3	1811.131117	603.710372	35.17	0.0001
Site*Species	2	117.528617	58.764308	3.42	0.0919
Error	7	120.170150	17.167164		
Corrected Total	13	2709.042036			

Appendix 13: ANOVA for tilapia species yields in the on-farm and on-station experiments

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Site	1	128717.8317	128717.8317	100.45	<.0001
Species	3	573055.5322	191018.5107	149.06	<.0001
Site*Species	2	320413.0372	160206.5186	125.02	<.0001
Error	7	8970.215	1281.459		
Corrected Total	13	1104496.950			

Appendix 14: ANOVA for Variable Crude protein

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Site	1	44.8533	44.8533	3.58	0.1002
Species	3	32.355	10.7851	0.86	0.5039
Error	7	87.583	12.5118214		
Corrected Total	11	277.254			

Appendix 15: ANOVA for Variable Ether Extract

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Site	1	59.9874	59.9874	2.43	0.1633
Species	3	793.305	264.435	10.70	0.0052
Error	7	173.0715	24.7245		
Corrected Total	11	1674.5	41086		

Appendix 16: ANOVA for Variable Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Site	1	2.99	2.99	2.25	0.1773
Species	3	4.731	1.577	1.19	0.3817
Error	7	9.30445	1.3292		
Corrected Total	11	17.91275			

Plates for tilapia species

Plate *1*: *Oreochromis jipe*

Plate 2: *Oreochromis ruvumae*

Plate 3: ***Oreochromis u hornorum*** **(male and female)**

Plate 4: ***Oreochromis niloticus***

Plate 5: Measuring water quality perameters at Changa village – Morogoro rural

Plate 6: Collecting fish from the hapas - Magadu Research Farm, SUA - Morogoro

Plate 7: Final harvesting of tilapia fish – Kibwaya village – Morogoro rural

Plate 8: Measuring quantitative variables - Kibwaya village – Morogoro rural

Plate 9: Drying fish in the oven – Animal Science Laboratory – SUA Morogoro

Plate 10: Dried fish ready for milling – Animal Science Laboratory – SUA Morogoro