GROWTH PERFORMANCE, YIELDS AND ECONOMIC BENEFITS OF NILE TILAPIA *OREOCHROMIS NILOTICUS* AND KALES *BRASSICA OLERACEA* CULTURED UNDER VEGETABLE-FISH CULTURE INTEGRATION

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ABSTRACT

An experiment was conducted for 210 days to demonstrate the role of vegetable-fish culture integration in the growth, yields and economic benefits of fish and vegetables. Two 200 m^2 earthen fishponds were stocked with Nile tilapia Oreochromis niloticus *at 20,000 fish fingerlings per hectare. Pond A was fertilized with chicken manure and stocked fish fed on 35% crude protein supplementary diet referred to here as treated fish pond (TFP). Another fish pond was not fertilized and the fish stocked in it did not receive any supplementary diet referred to here as non treated fish pond (NTFP). Twelve vegetable plots of 7.2 x 3 m were planted with kale seedlings at a spacing of 0.45 x 0.6 m. The first, second and third sets of three vegetable plots were irrigated by water from stream (SW), treated fish pond (TFP) and non treated fish pond (NTFP) respectively. The last three vegetable plots were not irrigated (NI). Sampling of kale leaves was done by removal of the lowest three leaves per plant every four days. Results showed that fish reared under integrated systems attained significantly higher growth than those reared under non integrated systems (t-test, $t=14.38$, d.f. = 118, $P<0.001$). One way Analysis of Variance showed a significant difference in kale leaf yields and income (ANOVA: $F=63.17$; $P<0.05$; d.f.=3) among plots receiving different sources of water with plots receiving water from treated fish pond (TFP) attaining highest yield and income. Gross and net yields of 2,806.969±198 and 2706.569±194 $kgha^{-1}$ (for fish) and 51,970.49 and 51,968.63 $kgha^{-1}$ (for vegetables) respectively attained were highest from integrated than non-integrated systems. Partial enterprise budget analysis showed that net returns were higher from integrated than non integrated systems. Results from this study demonstrate that fish farmers could improve yields and profits by integrating fish farming with other on-farm activities.*

INTRODUCTION

The majority of the population in East Africa and the Lake Victoria basin in particular is composed of small-scale farmers whose livelihoods depend on seasonal rain-fed cereal crops such as maize, millet and sorghum. Under such fragile socio-economic and environmental conditions this type of farming is not sustainable and increases risk due to the vagaries of climate. Agricultural production can be increased by increasing availability of water throughout the year and this can be done by integrating fish farming with other on-farm agricultural activities which, optimizes utilization of available resources (Lightfoot and Pullin 1995). Fish farming is practiced in East Africa mainly for nutritional needs and to some extent for income generation. Fish farming for the most part of East Africa including Tanzania is practiced as stand-alone activity.

Stand-alone fish farms can be risky ventures, especially for resource-poor farmers because of their environmental effects (e.g. pollution) and economic factors such as the price volatility. Such ventures have resulted in environmental and financial disasters in Africa and Asia (Cross 1991, Brummett 2002). Integrated farming systems that include semi-intensive aquaculture can be less risky because they are managed efficiently, benefit from synergies among enterprises, diversity in produce and their environmental soundness (Prein *et al*. 1998; Brummett 2002). Integrated farming is a practice that involves making better and fuller utilization of all the resources held by small farmers where the output of one (sometimes by-products or wastes) becomes an input to the other (Deomampo 1998). Due to interaction and/or synergy, integration results in greater efficiency and an increased output of a wide range of products than otherwise would be obtained per unit area. In addition to increasing total production, income and employment, integrated farming systems enhance ecological sustainability since wastes are recycled, thus reducing their potential for environmental pollution (Jayanthi et al. 2003). Moreover, farm generated inputs are biodegradable, unlike those of industrial origin, thus making integrated systems a safer aquaculture model for small-scale farmers.

Integrating fish farming with other on-farm activities has been practiced in other parts of the world such as Asia-Pacific with varying degree of success (see Gupta 1992, Soetjipto 1992). There are few successful reports of integrated fish farming in Africa, for example, in Ghana and Malawi (Ofori et al. 1993; Lightfoot and Noble 1993; Prein *et al*. 1996). Little work has been reported in East Africa on the use of fish pond water in increasing crop yields (e.g. Wood et al. 2001; Pokorn_ *et al*. 2005, Kaggwa 2006, Lamtane 2008). The present study was designed to gain an insight into the effects of: (a) integration of fish with vegetables on the fish growth performance; (b) integration of fish with vegetables on yields and economic benefits of both fish and vegetables, and (c) fish pond water on yield of kales *Brassica oleracea.*

MATERIALS AND METHODS

Study Site and Design

The study was conducted at Rebu village, Tarime District, Mara region in the Lake Victoria basin Tanzania (Fig. 1). Tarime is one of the districts of Mara Region and is situated in the north of Tanzania, between latitudes 1°00"– 1°45" S and longitudes 33°30"-35°0" E. The district has bimodal rainfall that starts in September to December (short rains) and March to May (long rains). The district has a total area of 11,137 km^2 and the land surface is divided into three zones (i.e. highland, midland and lowland zones). The highland zone has an altitude that ranges from 1500 to 1800 m above sea level (asl). This zone receives an average annual rainfall of 1200 – 1500 mm and average annual temperature is between 14 and 20^{o}C. The midland zone lies between 1200 and 1500 m asl and has average annual rainfall and temperature of 900 – 1200 mm and 20 – 25^{o}C, respectively. The lowland zone includes areas that lie between 1000 and 1200 m asl and receives rainfall of about 700 - 900 mm per year and the temperature ranges from 20 to 28^{o}C (Ngowi *et al.* 2008). Rebu village is located in the midland zone of Tarime district.

In this study two 200 m^2 earthen fish ponds were used and each pond was limed at 2,500 kg ha^{-1} and stocked at a rate of 2 fish m^{-2} (20,000 Nile tilapia *Oreochromis niloticus* fish ha^{-1}) of initial weight (mean ± S.E.) of 5.02 ± 0.13 g. Mixed sex juvenile Nile tilapia fish were obtained from Sang'oro Aquaculture Station of the Kenya Marine and Fisheries Research Institute. Pond A was fertilized using manures and stocked fish were fed a supplementary diet; the pond is referred to here as treated fish pond (TFP). Pond B, referred to here as non-treated fish pond (NTFP) was not fertilized and stocked fish did not receive any supplementary diet. Twelve vegetable plots of 7.2 x 3 m were planted with kale seedlings at a spacing of 0.45 x 0.6 m and irrigated using a watering can with normal water from the stream referred to here as stream water (SW) for seven days to facilitate establishment. Thereafter the first, the second and the third sets of three vegetable plots were irrigated by water from the stream (SW), treated fishpond (TFP) and non-treated fishpond (NTFP), respectively. The last set of three vegetable plots was not irrigated (NI) at all, thus served as control.

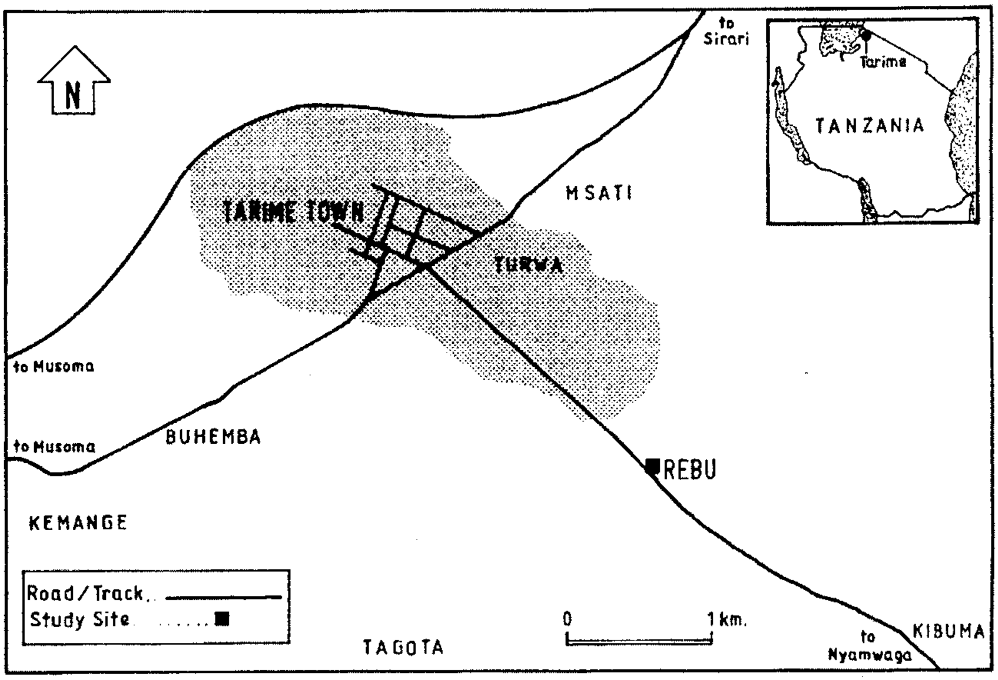

Figure 1: The Map of Tarime district, Mara region showing study site. Lightly shaded area indicates township (source: University of Dar Es Salaam Cartographic Unit).

Fish in treated fish pond (TFP) were fed on 35% crude protein diet made from locally available ingredients that included 70% and 30% cotton seed cakes and maize bran, respectively as described by Shoko (2002). They were fed at 5% of their average body weight twice a day (between 0900 and 1000 hrs and from 1600-1700 hrs). Feeding allowances were adjusted after monthly sampling was done. Fertilization was done at the rate of 20 kgN/ha/wk and 5 kgP/ha/wk with chicken manure once per week using the compost crib method. In addition, fish in the treated pond were fed vegetable leaves from the vegetable plots irrigated with water from treated fish pond (TFP) in order to recycle the nutrients from TFP to vegetables and vice-versa which is one of the advantages of integrated aquaculture-agriculture (IAA). Some remnants of kale leaves were placed in the pond crib in the treated fish pond (TFP) to be naturally recycled and to add nutrients to the pond water. Kales were grown for a period of 120 days from the date of transplanting and in two seasons. There was a transition period of 30 days used for preparations of the second growing season and the watering for establishment.

Data Collection
Fish were sampled monthly using a small mesh seine net and their wet weight (g) as well as total length (cm) recorded. Fish wet weight was recorded to the nearest 0.01 g (Table 1) with a weighing machine (Soenhnile, Mignon; Made in West Germany) and total length (TL) determined using a graduated ruler to the nearest 0.01 cm. Before weighing, the specimens were blot dried to ensure accuracy (Anderson and Gutreuter 1983). The weight measurements were used to adjust the feeding ratio of the experimental fish.

Table 1: Individual fish weight (g) (mean ± standard error) of the monthly sampling data during the entire culture period

Sampling periods (Months)	Pond A (Integrated)	Pond B (Non integrated)
At stocking	5.02 ± 0.13	5.02 ± 0.13
1	16.22 ± 0.81	10.61 ± 0.49
2	26.13 ± 1.43	16.05 ± 0.29
3	39.44 ± 1.33	22.18 ± 0.79
4	53.43 ± 2.16	31.97 ± 0.74
5	64.98 ± 1.51	39.38 ± 1.06
6	81.54 ± 1.43	44.47 ± 1.14
7	102.55 ± 0.89	53.77 ± 1.53

Kale harvesting began 21 days after transplanting by removal of the lowest three leaves per plant every four days as explained by Wood *et al.* (2001). Harvested fresh kale leaves were weighed to the nearest 0.01 g by using a spring weighing balance at the desired harvesting period from each of the plots receiving different treatments and summed over the harvest period.

Water samples for phytoplankton species diversity, numerical abundance and chlorophyll-*a* analyses were taken as described by Boyd and Tucker (1992) from three points in each pond on monthly basis using water column sampler (La Motte Water Sampler). These samples were pooled and preserved using 0.7% Lugol's solution and 2.5% formalin for laboratory analyses later. Water quality parameters were monitored to ensure that they were within the recommended limits for fish growth (Greenberg *et al*. 1992). Samples for temperature, pH and dissolved oxygen (DO) measurements were taken at 25-, 50-, and 75-cm depths by using T-pH-DO meter (type KTO, HQ, 40D PHC 101-LD 101-01 Conductivity probe STD, Made in USA by Hach Company Ltd) biweekly twice per day (in the morning between 0830-0930 hrs and afternoon between 1430-1530 hrs).

Data Analysis
Net Fish Yields (NFY), Net Annualized Production (NAP) and Specific Growth Rates (SGR) were calculated using the following formulae:

1. $Net\ fish\ yield\ (NFY) = Total\ fish\ harvested\ (kg) - Total\ fish\ stocked\ (kg)$

2. $Net\ annualized\ production\ (NAP) = \dfrac{NFY\ x\ 365}{Pond\ surface\ area\ (m^2)\ x\ Growth\ period\ in\ days}$

3. $Specific\ growth\ rate\ (SGR) = \dfrac{\ln Final\ Weight - \ln Initial\ Weight}{Growth\ period\ in\ days}$

Kale yield recorded as total fresh leaf yield over the experimental period was determined for all treatments as the sum of fresh leaf yield. Yield comparison in kg ha^{-1} against income in US$ was done among the vegetable plots that received different sources of water using One Way Analysis of Variance (ANOVA). Tukey multiple comparisons test was used to determine the significant difference between different pairs of vegetable plots (Zar 1999).

In the laboratory water samples for phytoplankton species diversity and numerical abundance were examined under an inverted microscope, at 40x magnification. Identification of plankton species was done using available keys and manuals (Mosille 1994, John *et al.* 2002) and the phytoplankton numerical abundance was calculated as described by Greenberg et al. (1992). Water samples for chlorophyll-*a* analysis was filtered through a filter paper (Whatman GF/C, pore size 0.45 _m), using a water jet vacuum pump to get a filtrate. In the laboratory samples were prepared and examined for chlorophyll-*a* using a spectrophotometer. From the spectrophotometer chlorophyll-*a* (μgl^{-1}) was calculated using the following formula:

$$\text{Chlorophyll-}a\ (\mu gl^{-1}) = \frac{(Eo665 - Eo750) - (Ea665 - Ea750)\ x\ 2.43\ x\ 11.49\ x\ v}{(V\ x\ L)}$$

where, Eo665 = Absorption at 665 nm before acidification, Eo750= Absorption at 750 nm before acidification; Ea665= Absorption at 665 nm after acidification; Ea750=Absorption at 750 nm after acidification; v= volume of the extract in ml; and V = volume of the sample filtered (l), L = length of the cuvette (cm).

Partial and enterprise budgets were used to compare the relative profitability between the integrated and non-integrated systems following Engle (2005). All the costs were converted into monetary values and the net returns to investments were determined. The analyses were based on local market prices and expressed in US$ (US$ 1= Tzs 1,297.00).

Data analysis was done with the use of SPSS Statistical package and the differences at $P<0.05$ were considered significant (Zar 1999).

RESULTS

Results from the study showed that fish cultured under an integrated system exhibited higher growth rates than those in non-integrated systems. Separation of treatments became apparent during the early days of the first month of culture (Fig. 2).

Fish growth was relatively slower at first as it took almost one month for the water colour from treated fish pond to green; an indication of a phytoplankton bloom. After 210 days of culture, fish growth rates reached a maximum average weight of 102.55 ± 0.89 g and 53.77 ± 1.53 g with average specific growth rates of 1.44 ± 0.43 gd^{-1} and 1.13 ± 0.43 gd^{-1} from integrated and non-integrated treatments, respectively (Table 2).

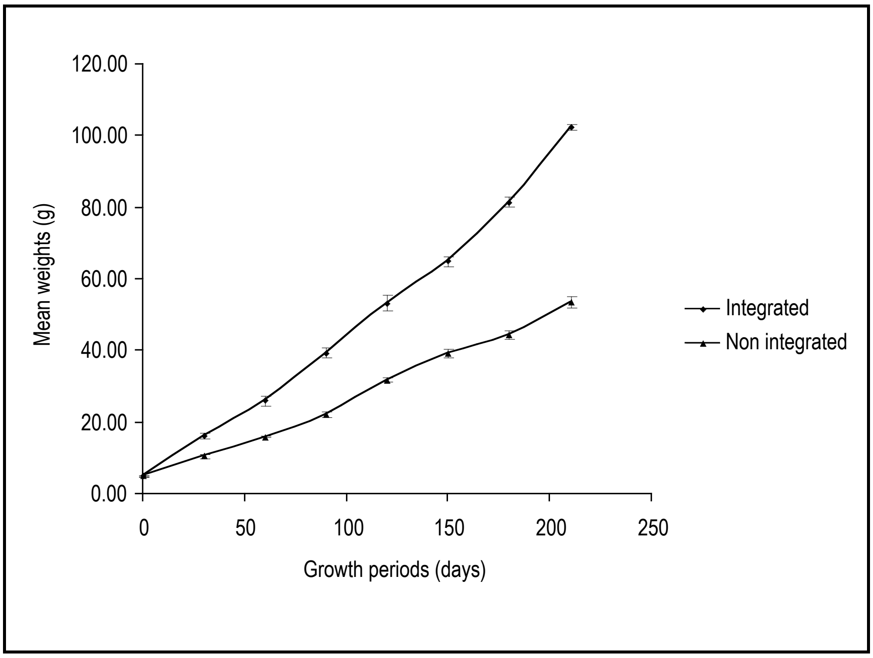

Figure 2: Growth trends (± SE) of Nile tilapia reared under integrated and non-integrated systems.

Table 2: **Initial weight at stocking, final weights at harvest and Specific Growth Rates of Nile tilapia cultured under integrated and non-integrated systems** (mean ± standard error)

Parameter	Integrated	Non Integrated
Stocking size (g)	5.02 ± 0.13^{a}	5.02 ± 0.13^{a}
Harvest size (g)	102.55 ± 0.89^{a}	53.77 ± 1.53^{b}
Specific Growth Rate (%)	1.45 ± 0.02^{a}	1.13 ± 0.02^{b}

Mean values followed by different superscripts in a row are significantly different

The t-test showed that final average weights differed significantly between fish reared under integrated and non-integrated systems (t=test, t=27.61, d.f.=118, P<0.001). There was also a significant difference in specific growth rates between the fish reared under the two culture systems (t test, t=14.38, d.f. = 118, P<0.001). Fish yields were higher in integrated than non-integrated systems (Table 3). Survival rates of fish cultured under the two different systems were high for both systems (TFP: 83 ± 1.64%; NTFP: 92.3 ± 3.76%).

Table 3: Gross, Net yields and Net Annualized Production of Nile tilapia reared under integrated and non integrated systems (mean ± standard error)

Parameter	Integrated	Non Integrated
Gross Yield (Kgha-1)	2806.969 ± 198	909.30 ± 89.24
Net Fish Yield (Kgha-1)	2706.569 ± 194	808.90 ± 57.45
Net Annualized Production (Kgha-1yr-1)	4704.27 ± 287	1405.95 ± 86.34

One way Analysis of Variance (ANOVA) showed a significant difference in kale leaf yields and income ($F=63.17$; $P<0.05$; d.f.=3) among plots receiving different sources of water. Vegetable plots receiving water from treated fish pond (TFP) attained the highest yield followed by those that received water from non-treated fish pond (NTFP) and stream (SW). The lowest kale leaf yields were attained from plots that did not receive any irrigation water (NI) (Fig. 3).

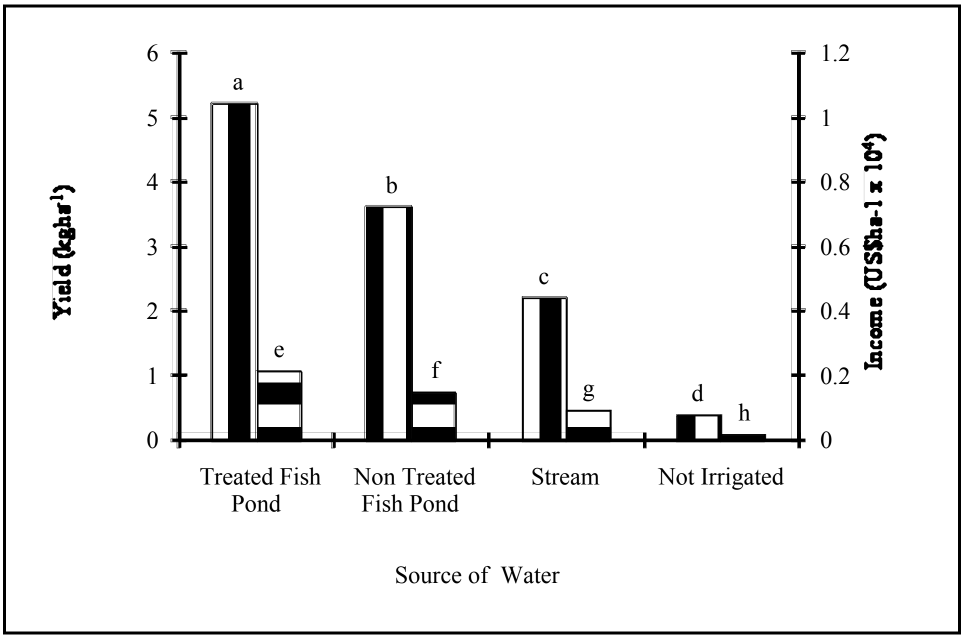

Figure 3: Total fresh leaf yield (kgha^{-1}) and income (US$) of Kales as affected by different sources of water. Different letters on the histograms indicate significant differences for yield (a-d) and income (e-h) following Tukey multiple comparisons test.

Partial enterprise budget analysis showed that net returns of US$ 5,996 from the integrated system were highest compared to almost US$ 0 from the non-integrated system. However, further economic analysis showed that break-even yields and price for both variable and total costs between the two fish ponds that received different treatments were not attained (Table 4).

Table 4: Economic comparison between fish harvested from integrated and non-integrated systems

Parameter	Unit	Integrated	Non Integrated
Gross Revenue	US$	20,770[a]	2,694[b]
Variable Cost	US$	12,775[a]	3,389[b]
Income above Variable Cost	US$	7,995[a]	0[b]
Fixed Cost	US$	2,780[a]	2,780[b]
Total Cost	US$	14,773[a]	6,170[b]
Net Return	US$	5,996[a]	0[b]
Break-even Yields (above Variable cost)	$Kgha^{-1}$	8,296.46[a]	2,200.84[b]
Break-even Yields (above Total cost)	$Kgha^{-1}$	9,593.38[a]	1,805.81[b]
Break-even Price (above Variable cost)	US$	4.55[a]	3.73[b]
Break-even Price (above Total cost)	US$	5.26[a]	3.06[b]

Values followed by different superscripts in a row are significantly different

The phytoplankton community was dominated by Chlorophyceae in the beginning and later by Euglinophyceae in both ponds, exhibiting a strong seasonal succession. When all results were combined at the end of the experiment Euglinophyceae dominated the overall percentage composition of phytoplankton community in both ponds. Total phytoplankton community in terms of percentage numerical abundance was highest in the treated than non-treated ponds (Fig. 4).

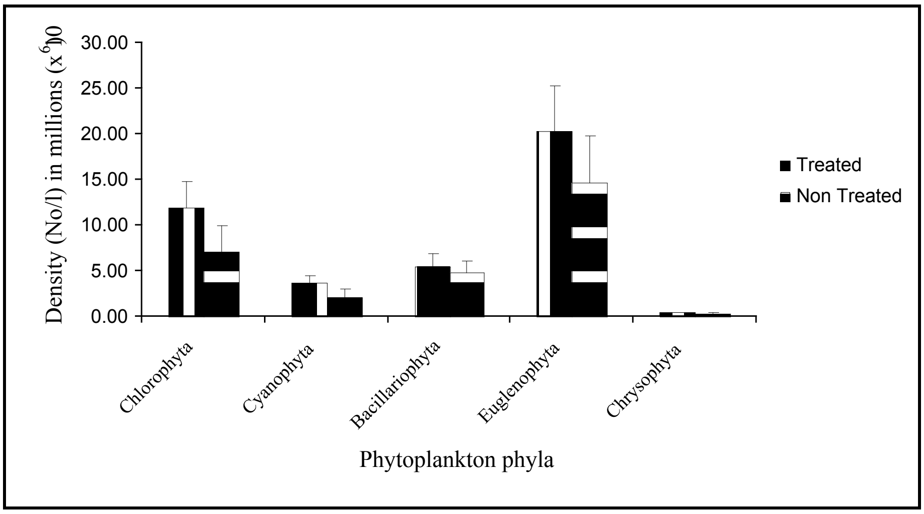

Figure 4: Mean (± standard error) numerical abundance of phytoplankton from treated and non-treated fish ponds

The mean values (mean ± standard error) of water temperature, pH and dissolved oxygen recorded from treated and non- treated ponds are presented in Table 5. Mean primary productivity (mean ± standard error) showed that water samples collected for chlorophyll-*a* analysis from treated fish pond had the highest productivity (59.22±9.54 μgl^{-1}) than those from a non-treated pond (28.27±3.29 μgl^{-1}) (Table 5).

Table 5: Mean water quality parameters (mean ± standard error)

Water quality parameters	Integrated	Non integrated
Dissolved Oxygen (mg/l)	5.46 ± 1.52	5.26 ± 1.81
pH	7.08 ± 0.01	7.30 ± 0.31
Minimum Temperature (^oC)	22.98 ± 0.71	22.78 ± 0.61
Maximum Temperature (^oC)	23.27 ± 0.70	23.34 ± 0.72
Chlorophyll-*a* (μgl^{-1})	59.22 ± 9.54	28.27 ± 3.29

DISCUSSION

The present study has demonstrated that fish reared under an integrated system attained higher growth rates and net yields than those reared under a non-integrated system. The study also showed that vegetable plots that received water from the pond where fish were fed and fertilized (TFP) attained the highest leaf yields and income. The results from the present study are in agreement with other studies where fish reared under fish-cum-vegetable integration attained highest yields of both fish and vegetables (Ofori *et al.* 1993, Lightfoot and Noble 1993, Prein *et al.* 1996, Wood *et al.* 2001). These results demonstrate the importance of integrating fish with other on-farm activities such as vegetables in increasing overall farm yields and income.

Fish are known to convert fertilizers (e.g. crops, livestock and household wastes) and un-eaten feeds into high quality protein and nutrient rich mud (Prein *et al.* 1998). It has been reported elsewhere that pond mud is so rich in nutrients that it can replace fertilizer completely in small vegetable gardens (Prein *et al.* 1998). It is worth pointing out that fish activities and their excreta increase nutrients such as nitrogen, phosphorus and total dissolved solids in treated pond water. Thus the use of nutrient rich water from fish ponds to irrigate the vegetables alleviates a potential problem of polluting existing streams in the area.

Apart from integrating fish with vegetables such as in the present study there are other forms of fish-crops and/or animal integration systems commonly referred to as integrated aquaculture-agriculture (IAA) which could be tested to increase the overall farm yields and income in Tanzania (see Lightfoot 1990, Prein *et al.* 1996, Prinsloo *et al.* 1999, Xiuzhen 2003). Integrated aquaculture-agriculture production systems have been largely developed in south-east Asian countries where they are well established as an important source of plant and animal protein (Gupta 1992, Edwards and Pullen 1990 cited in Prinsloo *et al.* 1999, Xiuzhen 2003). Some progress on integrated aquaculture-agriculture systems has been reported in a few African countries such as duck-fish-vegetable integration in Southern Africa (Prinsloo *et al.* 1996) and vegetable-fish farming in Ghana (Ofori et al. 1993) and Malawi (Lightfoot and Noble 1993, Prein *et al*. 1996). This approach to food production could be used in combating the wide spread problem of malnutrition which prevails in most rural areas of Tanzania where about 37-40% of children under five years of age are suffering from malnutrition (see Leach and Kilama 2009). The production of animal protein from fish, poultry, ducks and other integrated animals could contribute significantly to wealth creation in these areas. Integrated farming systems also serve as a possible approach towards the conservation, reuse and efficient management of the scarce water resources (Steyn *et al*. 1995 cited in Prinsloo *et al*. 1999).

Despite encouraging results reported from this study, further economic analysis has revealed that breakeven prices and yields for both variable and total costs between the two fish ponds that received different treatments were not reached. Breakeven prices and yields are important aspects to be attained in any project because they indicate the profitability of the operation as long as the prices and yields obtained are above the breakeven prices and yields (Engle and Neira 2005). The most likely cause for the failure to attain these breakeven points is the small size of the fish harvested. Tilapia females are known to mature and reproduce early at a small size and this has remained a major biological constraint to improving yields and profitability in tilapia farming (de Graaf *et al*. 1996). This phenomenon leads to nutritional deficiencies and stress to the fish as a result of intra-specific competition for food and space (Mohseninia 1984). In order to obtain a big sized tilapia an investigation into techniques of controlling precocious reproduction in tilapias in fish ponds should be carried out. It should be pointed out that primary production and other water quality parameters that affect fish growth performance were within the recommended ranges for fish growth (Greenberg *et al.* 1992, Ayinla *et al*. 1994, Siddiqui and Al-Harbi 1995).

In conclusion, the fish reared under integrated systems exhibited higher growth rates and net yields thus higher income than those reared under non-integrated systems. The kale yields from the plots that were irrigated with water from the treated pond attained higher leaf yields than those irrigated with non-treated pond water. Thus it is recommended that in order to increase overall farm yields and promote aquaculture as an income generating activity more emphasis should be put on integrated fish farming.

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