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EVALUATION OF THE GROWTH PERFORMANCE OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN TWO FEED REGIMES AND RICE OUTPUT IN AN INTEGRATED RICE-FISH FARMING SYSTEM IN SUAKOKO, BONG COUNTY, LIBERIA

SAMPSON DENIA KERKULAH

2023

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EVALUATION OF THE GROWTH PERFORMANCE OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN TWO FEED REGIMES AND RICE OUTPUT IN AN INTEGRATED RICE-FISH FARMING SYSTEM IN SUAKOKO, BONG COUNTY, LIBERIA

BY

SAMPSON DENIA KERKULAH

Thesis Submitted to the Department of Fisheries and Aquatic Sciences, School of Biological Sciences, University of Cape Coast, in Partial fulfillment of the requirements for the award of Master of Philosophy Degree in Aquaculture

DECEMBER 2023

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature………………… Date………………………..

Name: Sampson Denia Kerkulah

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature…………………… Date……………………

Name: Prof. Joseph Aggrey-Fynn

Co-Supervisor's Signature……………………Date…………………………

Name: Dr. Kwadwo Kesse Mireku

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ABSTRACT

This study was conducted to assess the yield of two rice cultivars (Suakoko 8 and Nerica L19) and the growth of mono-sex tilapia (*Oreochromis niloticus*) in an integrated rice-fish farming system. The profitability of the fish-rice integrated system, percent survival and condition factor of the fish was also assessed. The study was conducted using a randomized block design with five treatments and three replicates. The culture pond was fertilized by application of cow manure at a rate of 4.5 kg / plot across the entire five (5) treatment blocks containing 15 experimental plots. Each plot measured 3 m x 3 m; and fish were stocked at a rate of four fish per square meter. Rice seedlings were planted at 0.2 m × 0.2 m spacing. Sixty-four (64) rice plants were initially planted in each plot. A twenty-one (21)-day-old seedling (rice) was used as planting material. The area containing the fish measured 1 m x 3 m and was 0.6 m deep, which served as a refuge pond for the fish. Fish were stocked at an average body weight of 5 g. Data on plant height, fish growth and yields, and water quality parameters were analyzed using Microsoft Excel, and significant differences between treatments were analyzed using analysis of variance (ANOVA). A one-way analysis of variance (ANOVA) was performed to test for differences in S8R, N19L, S8L, N19R, and S8 and the post hoc analysis were displayed using the Tukey HSD. S8 means Suakoko 8 and N19 means, New Rice for Africa variety 19 (N19). "R" denotes that fish in those plots were fed Raanan feed and "L" denotes that fish in those plots were fed the Local feed. The results show that treatments N19L and N19R had the best rice yield whilst treatment S8R had the best performance for fish growth. However, there were no significance difference in the weight gained of fish feed with Ranaan and those fed with the local feed (p>0.05). Overall, S8R obtained the profit margin of ($ 5,075), N19L ($ 5,949.82), S8L ($ 2,113.79), N19R ($ 9,205.83) and S8 ($ -3,938.15) per (ha) of cultivation – making N19R the most profitable rice-fish integrated aquaculture system.

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KEY WORDS

Body weight

Plant height

Profitability

Tilapia

Tillers

Total length

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DEDICATION

Dedicate to my loving daughter Gabriella Quita Kerkulah and my mother Quita M. David.

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CHAPTER ONE

INTRODUCTION

This chapter offers comprehensive details on the study's background, problem statement, significance, general and specific objectives, the delimitations and limitations of the study and the organization of the study.

Background of the Study

Between the 1940s and 1950s, colonial governments across Africa introduced aquaculture as a means of sustainable food production to improve nutrition in rural areas, generate additional income, diversify and reduce the risk of crop failures, and create jobs in rural areas (Brummett et al., 2008). As a result, many fish farms were developed by governments in the 1950s (FAO, 2017), and by the late 1950s, there were approximately 300,000 active production ponds across Africa (Satia, 1989). The FAO began fostering aquaculture development in the region in the 1960s in conjunction with governments, donor countries, national and global research institutes, and non-governmental organizations (Hecht et al., 2006). Efforts were concentrated on fundamental research and development to enhance knowledge on practical approaches for raising primarily native species. From the early 1970s to the early 1990s, significant financial and technical help from bilateral and multilateral donors totaling around $500 million aided the development of aquaculture in the region (Hecht et al., 2006). Consequently, donor priorities changed to other urgent issues, including education, health, HIV/AIDS, and good governance in Africa, which resulted in a significant reduction in financial support for aquaculture on the continent (Hecht et al., 2006).

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The region saw a twenty-fold increase in production from 1995 to 2018, from 110,200 to 2,196,000 metric tons, at a compound annual growth rate (CAGR) of 15.55% (FAO, 2016; Halwart et al., 2020). Despite this, Africa's contribution to global aquaculture production is still relatively small (~2.7%), though it is growing significantly with greater investments in Egypt, Nigeria, Uganda, and Ghana, which produce significant quantities of fish (Cai et al., 2017; FAO, 2018).

The creation and expansion of small and medium-sized businesses under private ownership is the driving force behind the increase in aquaculture production (Satia, 2011). The New Partnership for Africa expansion (NEPAD) Fish for All Summit in 2005 and the FAO-coordinated Special Program for the Development of Aquaculture in Africa (SPADA) actions have brought attention to the issue of fisheries and stimulated growth in the sector throughout the region (Adeleke et al., 2020).

Most of the advances in aquaculture in Liberia date back to the days of Peace Corps volunteers. There is still some knowledge about pond construction and a certain understanding of pond management. The only well-designed ponds date back to the Peace Corps era. Donors, including the European Union, which also employed former Peace Corps volunteers to supervise the project, have financed the fishpond building. Aquaculture efforts were financed in the past and are still being funded by several donors, non-governmental organizations, and other humanitarian groups. Little has changed since then; farming relied on the most basic inputs, such as leaves, grasses, and anything else that was available on the land (Veverica & Woyea, 2012). The Liberian Aquaculture and Inland Fisheries Federation was

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established in 2017. It is the goal of this state-level organization to serve as both an umbrella group for aquaculture cooperatives and a point of contact with the government (APDRA, 2021). Similar to other neighboring West African countries, Liberia produces a small portion of its potential fish yield. The production of aquaculture nowadays is quite low, at about 1,000 metric tons annually. About 300 small fish farmers in the nation operate in 1,700 ponds totaling 114 hectares of land, providing almost all of the nation's fish production. However, with the existing 5 kg per capita, aquaculture can help expand domestic production and greatly increase yearly fish consumption. The quantity of water throughout the year and the compacted soil with a 75% latosol concentration, which enhances water retention, are two of Liberia's natural advantages for aquaculture development. The goal of Liberia's 2014 Fisheries and Aquaculture Policy and Strategy was to raise aquaculture output to 15,000 metric tons by 2030. However, it appears that there is a desire to attain a larger figure before that date based on recent declarations and projections from government officials. According to a recent statement from the National Fisheries and Aquaculture Authority (NAFAA), aquaculture is expected to bridge the supply gap in Liberia, as the country currently imports 80% of the fish consumed domestically. Liberia should be able to minimize the inefficiencies that have plagued aquaculture production in other African nations while simultaneously maximizing production in a timely way with the help of efficient training for farmers and extension personnel (APDRA, 2021). Together with CATALYST Liberia Inc., APDRA Pisciculture Paysanne carried out the Inland Fish Farming Development Project (IFIDEP) from 2010 to 2013. The European Union provided funding for the initiative, which was

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carried out in three counties: Bonag, Nimba, and Lofa. Under this initiative, 275 reservoirs—both producing and usable reservoirs—with a combined 32 hectares of land was used for the building of 143 ponds in 37 municipalities across the three intervention counties. According to APDRA (2023), Bong County has 27 municipalities divided into 15 groups, Nimba County has seven municipalities divided into 6 groups, and Lofa County has four municipalities divided into 3 groups.

Liberia's aquaculture sector is poorly developed and poorly organized, resulting in limited benefits for food fish (MOA, 2014). *Oreochromis niloticus, Coptodon zillii, Clarias spp.,* and *Heterobranchu longifilis* are the most important species. In addition, *Heterotis niloticus* and *Mormyrus spp.* are species of interest to farmers but for which only sparse data are available. Some of these species of fish are caught in the wild and cultured in production ponds by farmers (Veverica et al., 2012).

Problem Statement of the Study

Tilapia is the second-most important farmed fish in the world and is farmed by many small farmers worldwide. The Nile tilapia (*Oreochromis niloticus*) is the sixth most important fish species, providing food, employment, and domestic and export revenue (FAO, 2017). The Nile tilapia (*Oreochromis niloticus*) is a valuable commercial fish. Nile tilapia is regarded as a species with high aquaculture potential in many poor nations, with the potential to significantly contribute to food security. The Nile tilapia (*Oreochromis niloticus*) has high yield potential, rapid growth, high disease resistance, the ability to survive in low oxygen conditions, the ability to feed on a wide range of foods, is easy to reproduce in captivity, and accepts

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artificial feed immediately after the yolk sac stage (Jatta, 2022). Aquaculture in several Sub-Saharan African nations is undeveloped, accounting for less than 1% of global aquaculture production (FAO, 2006). Among other things, the cost of fish feed has been cited as a critical constraint impeding the development of aquaculture in Sub-Saharan Africa (Munguti et al., 2020). Protein is the most expensive ingredient in fish feed. Traditionally, fishmeal is used as the main source of animal protein in fish feed and is the most preferred source of animal protein due to its balanced amino acid profile (Tacon, 1993). However, fishmeal prices are continually shifting, and competition from other feed manufacturers has an impact on aquaculture feed output and thus profitability. As a result, significant efforts have been made around the world to develop diets based on plant and alternative animal protein sources (Hossain et al., 2002). The quest for cheap and locally available feed is vital to raising fish farming yields, promoting food security, alleviating poverty in developing countries, and creating jobs (Munguti et al., 2020).

Depending on the level of intensity and species, feed typically accounts for 40–60% of operating costs (Limbu et al., 2014). Feed costs tend to increase when the fish requires higher protein content in their diet (Limbu, 2015). These restrictions are faced by most countries in the sub-Saharan region, with Liberia being no exception. The development of aquaculture in Liberia has largely been driven by donor support; it was largely a subsistence activity, with no major fish production or distribution-taking place. Despite this, little research has been done into the development of local species for culture (MOA, 2007). On the other hand, the fish feed industry in Liberia is poorly developed. Currently, no industry in the country is engaged in the

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production of commercial fish feed. Imported feed is very expensive, making it difficult for Liberian fish farmers to use it. The cultivation of *O. niloticus* in Liberia is mainly semi-intensive and uses locally available agricultural industry waste products such as rice bran. Imported feed comes mainly from Ghana and Sierra Leone (Hinneh et al., 2022). These limitations highlighted above pose a serious obstacle to the production and growth of aquaculture in Liberia.

Liberia's staple food is rice, for which the country consumes 75,000,025 kg per month (Tipoteh, 2022). The country spends almost a third of the national budget on rice imports in the fiscal year. This means that, the country spends an average of $ 200 to $ 250 million per year on rice imports (FrontPage Africa, 2021). The agricultural sector is underfunded, and local farmers are not motivated to invest in the sector (Sumaworo, 2022). Notwithstanding, there is a lack of an effective and efficient agricultural research and development package that should work with other relevant authorities to regularly identify challenges and opportunities in the sector (Sumaworo, 2022). Information on research on integrated culture is sparse, largely due to the unstable political climate. The lack of research in the areas of rice breeding and variety adaptation, agronomy, fertility, pest control, irrigation management, socio-economic analysis, and crop and post-harvest management has a serious impact on the livelihoods of most Liberians (Wailes, 2012). Therefore, there is a need to conduct research that maximizes the utility of farmland to provide the required source of protein as well as important sources of carbohydrates. This research aims to evaluate the growth

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performance of mono-sexual tilapia (*Oreochromis niloticus*) and the yield of two rice varieties in an integrated rice-fish farming system.

Study hypothesis

The following hypotheses were tested in this research:

H_o: Using commercial feed and locally formulated feeds does not significantly affect the growth and yield of fish and rice in an integrated aquaculture system.

H_0: The profitability of integrated aquaculture systems is not dependent on the type of fish feed and variety of rice used.

Objectives of the Study

General objective

The overarching objective of this research was to assess the yield of two rice cultivars (Suakoko 8 and Nerica L19) and the growth of mono-sex tilapia (*Oreochromis niloticus*) fed two different diets in an integrated rice-fish farming system.

Specific objective

1. Evaluate the growth and yield of mono-sex tilapia in an integrated rice-fish system
2. Determine the yield of two varieties of rice in the rice-fish system.
3. Estimate the percent survival and condition factor of the fish.
4. Estimate the profitability of the fish-cum-rice integrated system

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Limitations of the Study

Constraints encountered during this research are termed limitations, and they include:

1. Combating the situation of flooding in the field, especially during July, August, and September was a serious challenge.
2. Although the soil was prepared adequately before planting the rice, the type of soil could have affected the growth and yield of the varieties of rice used.
3. The presence of predatory birds on the farm and leeches in the pond may have affected the growth of the fish.
4. Transporting the industrial feed (Ranaan feed) from Ghana to Liberia was quite expensive therefore increasing cost of production.
5. Due to limited funding and lack of equipment, it was not possible in this work to conduct an initial soil analysis to determine soil nutrient concentration and a final soil nutrient analysis after completion of the work to determine whether this cropping system is capable of increasing soil nutrient concentration, improve nutrient storage capacity of the soil or whether it can degrade the soil.

Delimitation of the Study

This study was carried out in Suakoko district, Bong County, Liberia. Where two feed regimes was used to ascertain the growth performance of Nile tilapia (*O. niloticus*) and rice output in an integrated rice-fish system. The study focused on the set objectives. With data collection, morphometric data on fish length, body weight, and number of tillers, plant height, grain yield,

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plant biomass and profitability of the system using local market values was used.

Significance of the Study

With the growing concerns about food security that threaten the lives of majority of Liberians, this research will provide information that serves as a basis for developing integrated aquaculture in the country. The profitability of this venture was assessed and will enhance the development of the aquaculture sector. Aquaculture is a promising sector for Liberia, but without novel research that would foster national progress and growth and transform this sector from conventional subsistence farming to one that maximizes profits and provides adequate root for animal protein and a method of job creation in the non-coastal counties; this sector would require more focus and high-quality data to decongest it. Furthermore, this research was of great importance as it was the first of its kind to be carried out in Liberia's aquaculture sector and drew farmers' attention to mono-sex cultivation through hormonal sex reversal compared to the culling method practiced by the majority of farmers who do not use all male tilapia for their production.

Definition of Terms

DO: Dissolved Oxygen

pH: a measure of acidity or basicity of a solution

Organization of the Study

The study has been structured in the following manner: The first chapter, Chapter 1, provides an introduction of the study, background, problem statement of the study, Study hypothesis, Objectives of the study, limitations and delimitation of the study, significance of the study, definition

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of terms and organization of the study. Chapter 2 is a review of the literature, which provides an overview of Aquaculture development in Liberia, Global trend in aquaculture, overview of integrated aquaculture and an overview of integrated aquaculture in Liberia, the mode of feeding and feed constraints faced by fish farmers are all embedded in Chapter 2. Chapter 3 provides an overview of the procedures, equipment, and materials utilized in the research as well as the tool for the analysis of data. Study design, Plots preparation, conditioning of fingerlings and profitability measurement are all included in Chapter 3. In Chapter 4, the outcomes of the analysis are presented in tabular and graphical forms under the theme, Results. These results are explained, discussed, reasons are assigned to outcomes under Chapter 5, and summary recommendations and conclusions are provided in Chapter 6.

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CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter provides an overview of aquaculture in Liberia, global trends in aquaculture production, synopses of integrated aquaculture, and relevant literature pertinent to the study.

Aquaculture Development in Liberia

Fishponds were built at the Central Agriculture Experimental Station, now known as the Central Agricultural Research Institute, in Suakoko, Bong County, Liberia, in the 1950s, marking the beginning of the country's aquaculture industry. The three main species that were cultivated were catfish, carp, and Nile tilapia. Volunteers with the Peace Corps helped smallholder farmers to thrive in the production of these three species. Aquaculture production then increased because of the Nimba, Bong, and Lofa Counties Rural Agriculture Development Program. Within the said period, the combined output of the three counties was 29 metric tons. By 1989, more than 900 ponds were created across the country and stocked with juvenile fish. From the 1990s to 2004, a period marked by political unrest, the sector received enormous support from several donor-supported projects. Three hatcheries, Klay (Bomi County), Duoyee Town (Grand Gedeh County), and Salayea (Lofa County), received funding from the European Union between 1999 and 2002 for their renovation. To produce seeds and distribute them to farmers, brood stocks of *O. niloticus* were brought from India. About 380 farmers benefited from the project's pond development and rehabilitation, which involved rehabilitating ponds in six counties and providing training and

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extension services (FAO, 2010). The growth of aquaculture in rural Liberia has been supported by the technical and financial assistance provided by NGOs, and the most prevalent type of aquaculture in Liberia is pond-based fish rearing. Integrated aquaculture is practiced by most of the aquaculture farms in Liberia. 2009 saw the introduction of cage culture in Liberia's aquaculture sector. The number of fish farmers increased from 350 in 2000 to 1050 in 2004. A typical aquaculture farm in Liberia has 1 to 2 ponds ranging from 200 m^2 to 400 m^2 or even less, depending on land availability. The production is extensive to semi-intensive with the use of very low inputs.

Fingerlings left after harvest are usually used to restock fishponds. The stocking density practiced by most fish farmers is 2–3 fish per m^2. Fishponds are fertilized with poultry, goat, and cattle manure. Fish are also fed with leftover feed from livestock farming and agricultural by-products (BNF, 2007). Five main species are commonly farmed in Liberia: Nile tilapia (*O. niloticus*), African catfish (*C. gariepinus*), sampa (*Heterobranchus longifilis*), mango tilapia (*Sarotherodon galilaeus*), and red-bellied tilapia (*Coptodon zillii*). This accounts for approximately 95% of production, while *C. gariepinus* and *Heterobranchus longifilis* make up the remaining 5% (BNF, 2010).

Global Trends in Aquaculture

In the twenty-first, century, the fisheries and aquaculture industry is becoming more widely acknowledged for its major contribution to global food security and nutrition. To attain sustainable and equitable global fisheries and aquaculture, further expansion of this contribution will require faster revolutionary changes in policy, management, innovation, and investment

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(FAO, 2022b). Global aquatic animal production was estimated at 178 million tons in 2020, a slight decrease from the record of 179 million tons in 2018. Capture fisheries contributed 90 million tons (51 percent), and aquaculture contributed 88 million tons (49 percent). Of the total production, 63 percent (112 million tons) was harvested in marine waters (70 percent from capture fisheries and 30 percent from aquaculture) and 37 percent (66 million tons) in inland waters (83 percent from aquaculture and 17 percent from capture fisheries). The total initial sales value of global production was estimated at $ 406 billion, of which $ 141 billion came from capture fisheries and $ 265 billion from aquaculture. In addition to aquatic animals, 36 million tons (wet weight) of algae were produced in 2020, of which 97 percent came from aquaculture, predominantly marine aquaculture (FAO, 2022b). In 2020, the world's aquaculture output hit a record of 122.6 million metric tons, consisting of 35.1 million metric tons of algae valued at $ 16.5 billion and 87.5 million metric tons of aquatic animals valued at $ 264.8 billion. Of this amount, 68.1 million metric tons came from marine and coastal aquaculture, while 54.4 million metric tons were cultivated in interior waters (FAO, 2022a). Except for Africa, all areas saw a sustained increase in aquaculture in 2020, primarily due to expansion in Chile, China, and Norway, which are the top producers in their respective regions. The two major producing countries in Africa, Egypt and Nigeria, experienced a decrease in production, while the other countries reported 14.5 percent growth in 2019. Asia continued to dominate world aquaculture, producing over 90 percent of the total (FAO, 2022b). Africa still contributes very little (~2.7%) to the world's aquaculture production (Halwart, 2020), although it is increasing significantly with greater investments in

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Egypt, Nigeria, Uganda, and Ghana, which produce significant quantities of fish (Cai et al., 2017; FAO, 2018). The region experienced a twenty-fold increase in production from 1995 to 2018, from 110,200 to 2,196,000 metric tons, with a compound annual growth rate (CAGR) of 15.55% (FAO 2016; Halwar, 2020).

According to Satia (2011), the rise and expansion of privately owned small and medium-sized businesses (SMEs) was the primary driver of the increase in aquaculture production. Large commercial company expansion has also been mainly propelled by the confluence of increasing public support, knowledge, foreign direct investment, interest in aquaculture, and worldwide awareness created by the 2005 Fish for All Summit of the New Partnership for Africa expansion (NEPAD). The expansion of aquaculture in Africa was aided by the FAO, Special Program for the Development of Aquaculture in Africa (SPADA) (Satia, 2011). Though mariculture is a relatively new endeavor and a potentially lucrative subsector, it accounts for a pitiful 1% of the total production volume. The majority of the production (99%) originates from inland freshwater systems, where the culture of abundant native tilapia and African catfish species is predominant (FAO, 2016 & 2018). New aquaculture production systems, such as tanks and cages, were introduced and existing production systems were improved (Satia, 2017). According to Satia (2016), the aquaculture industry in Africa employs over 6.2 million people, including a significant share of women working on major commercial farms. The post-harvest and marketing phases of the aquaculture value chain are predominantly carried out by women (Satia, 2016). Therefore, the aquaculture industry has the potential to greatly enhance Africa's economic development,

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lower unemployment rates, and increase food security (Adelekeet al., 2020). As a development roadmap, several nations have created and enacted strategic frameworks and policies centered on aquaculture (Machena et al., 2001). While some governments have made it easier to provide low-interest loans and incentives, land ownership, inexpensive credit availability, and adequate input quality and quantity continue to be important obstacles to the growth and intensification of the aquaculture industry (Satia, 2011). The on-site participatory research approach using model farms and private companies results in the rapid transfer of aquaculture technologies through farmer-to-farmer pathways in the target countries managed by the Special Program for the Development of Aquaculture in Africa (Cocker, 2014). Advisory services are generally inadequate and weak; therefore, there is an urgent need to develop and strengthen the links between research and development (Satia, 2011). Socioeconomic research needs to be explored, including improving the governance of employment in aquaculture (Hishamunda et al., 2014), exploring new aquaculture models to promote and retain young people in the sector (Murekezi, et al., 2018), and improving the integration of aquaculture into the national economy and regional policy (Murekezi, et al., 2020). Public institutions in fisheries departments, universities, or research institutes conduct most aquaculture research; these institutions frequently concentrate their efforts on research related to agricultural science or natural resources. Most aquaculture research stations are in poor condition and have limited infrastructure, equipment, and support. Research funding is typically scarce, with foreign funding playing a major role in the majority of research operations. Although some major farms are becoming more involved in on-

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site research efforts connected to nearby universities, there is still a lack of collaboration between commercial aquaculture enterprises and aquaculture research (Mapfumo, 2022).

The interest and growth of aquaculture across the region have been revitalized by global awareness raised through the New Partnership for Africa's Development Fish for All Summit in 2005 and the Special Program for the Development of Aquaculture in Africa interventions coordinated by FAO. Because of commercial investments in Egypt, Nigeria, Uganda, and Ghana, aquaculture output has expanded twentyfold over the last 25 years. Numerous countries in Africa are supporting the growth of aquaculture by establishing frameworks and regulatory reforms that will serve as a roadmap for the industry and foster a favorable business environment. The establishment of favorable conditions resulted in the rapid growth of the aquaculture value chain under private-sector management, especially in Nigeria, Egypt, Uganda, and Ghana (Adeleke et al., 2020).

Integrated Aquaculture

With the increase in human population, the amount of land available on Earth is decreasing. The reason for this is the sharp rise in the dynamics of the world's population. It was estimated by the US Census Bureau that there were 1.6 billion people on the planet in 1901, 3 billion in 1960, 5 billion in 1987, 6 billion in 1999, 6.8 billion in 2009, and 7.9 billion in 2018. Buckner et al., (2016) reported that the population of the world increases by one billion people every 12 years. In general, rice-fish farming involves growing rice while introducing (stocked) or naturally, occurring (wild) fish populations, as well as other aquatic species obtained from fisheries, coexisting

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simultaneously or alternately (Freed et al., 2020). Nevertheless, an integrated aquaculture system links the many parts of farming systems to work together in a way that allows one farming system's output to be used as an input for another, resulting in an efficient use of water and land (CARDI, 2010). To maximize both economic and environmental potential, integrated aquaculture is growing in popularity (Ayoola, 2010).

The demand for fish is increasing every day around the world. To meet this demand for environmentally friendly production, it is recommended to practice rice co-culture with high-profit potential not only in Asian countries but also in other rice-producing countries (Bashir et al., 2020). One of the most practical approaches to long-term food production is to grow rice and fish in the same area while sharing the same water resources (Ahmed & Turchini, 2021). Integrated rice-fish farming can maximize resource utilization by making complementary uses of land and water. Additionally, the productivity, profitability, sustainability, intensification, and diversification of the rice agro-ecosystem are all enhanced by this practice. A balanced diet, consistent employment, healthy soil, mitigating extreme weather, raising agricultural productivity, and farming families' income—all of which eventually boost the farmer's purchasing power—would all be made possible by the farming system's inter- and multidisciplinary approach (Poonam et al., 2019). Fish has a high market value as food, which greatly boosts farmers' revenue, Al Mamun et al., (2011) found that the integration of fish feed helps, improve fertilizer and feed supply. With 0.6 t of fish per hectare of a farm, the rice-fish farming method can yield roughly 16 to 18 t of food crops a year (Poonam et al., 2019). Fish are efficient bio-control agents for the most

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significant rice pests, including leafhoppers, autumn worms; stem borers, gall midges, and leaf butterflies, in addition to snails. Studies conducted in labs, greenhouses, and fields indicate that carp are a useful bio-control agent for the main insects that feed on leaves (Sinhababu & Majumdar, 1981). Due to the feeding habit of fish, rice fields are kept weed-free due to increased water turbidity, mechanical damage, and frequent floods that have an indirect effect on weed growth. The most effective fish species for this system are *Cyprinus carpio, Oreochromis mossambicus, Trichogaster pectoralis, Puntius gononotus*, and *Ctenopharyngodon idella* (Poonam et al., 2019). When selecting a site for integrated aquaculture, certain criteria should be taken into account. The selected land should have an optimal rainfall of 80 cm per year; with an even contour and high water retention capacity. A low-lying area where water flows easily and is readily available when needed. A fertile soil, rich in organic fertilizers and generally medium and loamy, silty clay soils are best suited (Halwart & Gupta, 2004).When considering crop diversity and risk mitigation, an integrated farming system centered on rice and fish may be a better choice than rice or fish monoculture. The public and commercial sectors must take the appropriate steps and make the necessary investments for this system to reach its full growth potential (Poonam et al., 2019). The co-culture system appeared to have more net benefits than rice monoculture, with lower production costs and higher yields of both fish and rice. This was the conclusion of an experiment aimed at evaluating the viability of an integrated rice-fish co-culture system and its economic impact (Dey et al., 2005).

China has a long history of using rice-fish farming systems (Khoon & Tan, 1980). According to Cai et al., (1995), China possesses the earliest

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archaeological and archival proof of rice fish aquaculture. Recent reports of on-farm rice-fish culture trials have created a new avenue for the diversification of the rice-based cultivation system in Africa, where an Asian-based rice field cultivation system was introduced using an eco-technology approach (Ofori et al., 2005). When it comes to yields of rice and fish as well as the efficient use of resources (land, water, applied fertilizers, and capital investment), China is a leader in the field of co-culture systems. China has a comparatively high fish output of roughly 2.5 t/ha, according to earlier studies (Ofori et al., 2005). Vietnam (2.2 t/ha), India (2.0 t/ha), Thailand (1.1 t/ha), Bangladesh (1.08 t/ha), and Indonesia (0.89 t/ha) have the next highest fish yields. Madagascar published the first account of rice-fish cultivation in Africa in 1928. Natural fish stocks were used as the basis for the practice of both rotational and parallel systems. Nonetheless, an average value of 80 kg/ha suggested that farm-level cultural techniques still required improvement (Randriamiarana et al., 1995).

Malawi began growing rice and fish together, as well as fish and vegetables. The species used is tilapia (Mohanty et al., 2008). Egypt began rice-fish farming, relying solely on occasional stocks of fish supplied with irrigation water. The rice-fish farming area increased significantly using saline land, reaching a peak of 225,000 ha in 1989. By 1995, it fell again to 172,800 ha. By 1995, fish production from rice fields accounted for 32% of the total aquaculture production in the country. Since then, 58,000 ha of arable land have been added, producing 7,000 tons of *C. carpio* in 1997 (Wassef, 2000).

Rice-based fish farming is the main source of income in many parts of the world, although it is not widespread worldwide. Most information comes from

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Asian countries, particularly the Philippines, Indonesia, and Japan, where traditional methods of rice cultivation have been refined over centuries. The history of rice fishing culture is quite old, starting in ancient China about 200 years ago. Over time, this practice has been introduced in Indonesia, Vietnam, Thailand, India, Bangladesh, and many other countries around the world (Mohantay et al., 2008).

Integrated Aquaculture in Liberia

The EU commissioned a French NGO, Association Pisciculture et développement rural enAfriquetropica lehumide (APDRA), along with a Liberian NGO called Catalyst, to oversee a three-year integrated lowland rice fish farming project worth $1 million. These projects were located in Bong, Lofa and Nimba counties. However, there is no production data yet. The majority of farmers practice integrated aquaculture and farming technologies (Kpadeh, 2011). However, there is no data to quantify the production system. Furthermore, information about the integrated aquaculture system in Liberia is sparse.

To sustainably develop integrated climate-smart rice-fish production systems in Liberia, from 2020 to 2023, the Development Smart Innovation through Research in Agriculture (DeSIRA) project implemented by AfricaRice aimed to balance participatory research interventions on rice-fish farming. Also, to develop successful extension services and value chain development with particular attention to farmers' access strategies to the value chain, capacity building of the actors involved, and stakeholder platforms to create and maintain an enabling environment for the introduction of such integrated systems. Rice and fish system technologies were introduced and

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adopted in five counties by this project. The aim is to conduct experiments and introduce 15 climate-smart rice and fish technologies by 2022, with 164 households from 365 participating producers in the target area adopting the climate-smart rice and fish technologies. Special efforts have been made to strengthen national research capacities. To align this participatory research, the project supported functional multi-stakeholder innovation platforms capable of better connecting research and development efforts in the area of aquaculture, and integrated rice agriculture with gender-responsive aquaculture strategies and policies in Liberia. These platforms will also be used for enhanced knowledge sharing and learning, as well as facilitating advocacy meetings with authorities and value chain actors to create an enabling environment for the development and maintenance of an integrated fish farming system in Liberia (AfricaRice, 2020). Although integrated aquaculture is being practiced in Liberia, data is sparse. Findings from the ongoing AfricaRice project are not yet available to the public, as the project is not yet completed.

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CHAPTER THREE

MATERIALS AND METHODS

Introduction

This chapter provides basic information on the organization of this work. It also describes the study design, area, study subjects to be investigated, methods, and procedures of measurements, the raw materials, tools and subject used in the experiment and the statistical package used for data analysis.

Study Area

The research was conducted in the rice field of the Central Agricultural Research Institute (CARI) in Suakoko, Bong County; Liberia. Suakoko District is one of eight (8) districts in Bong County, Liberia. Its geographical coordinates are 6° 59' 20″ North, 9° 34' 53″ West (Figure 1). It is located in the south-central part of Bong County. The district is divided into three clans, namely, Kpartawee, Kporyoquelleh and Suakoko. The Suakoko clan is the largest and thus serves as the most important trading center. The land is located in the south-central part of Bong County and is primarily composed of partially loamy and loamy soil. The population is approximately 28,277 inhabitants (National Population Census, 2008).

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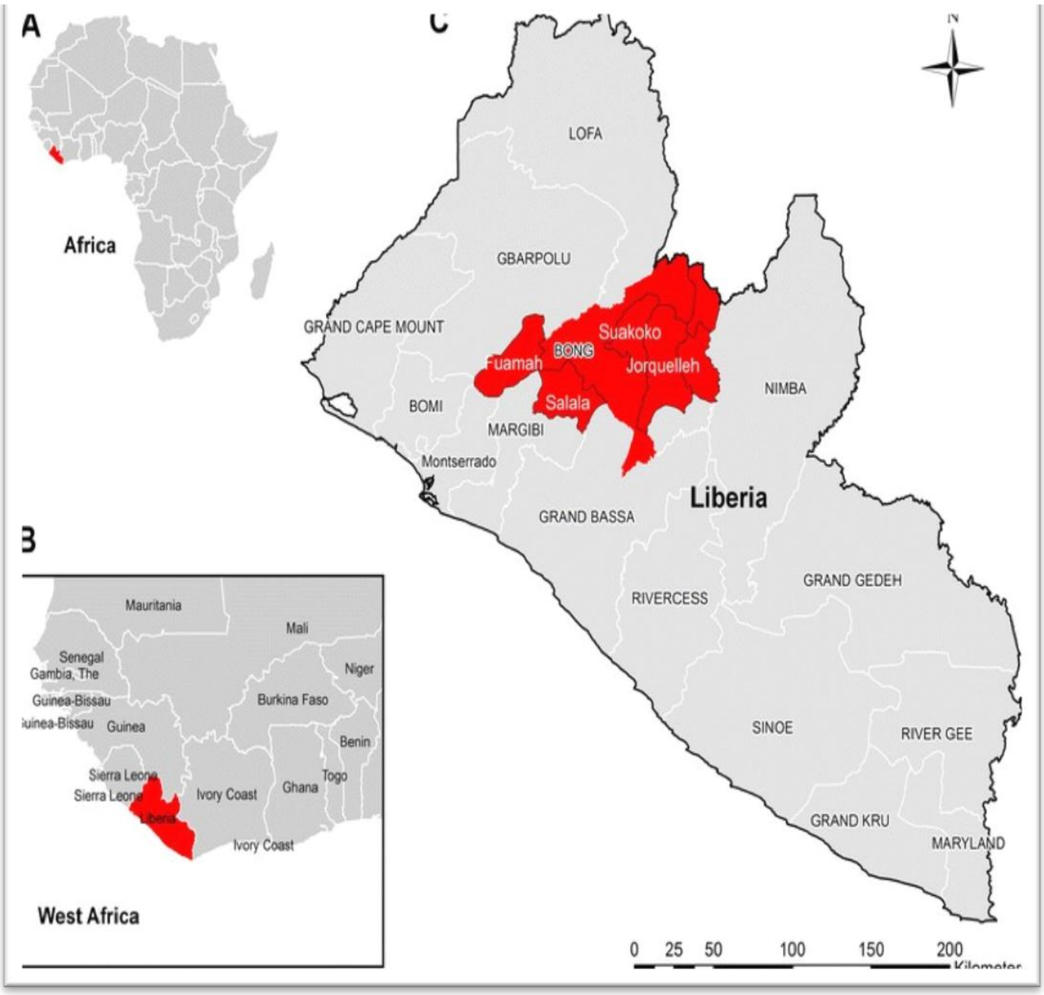

Figure 1: Map of Liberia showing the Bong County and Suakoko District where the study was conducted.
Source:(Weppelmann et al., 2016)

Study Design

The study was conducted using a fully randomized block design with three levels of fertility treatments and three replicates each on two rice varieties: Suakoko8 and Nerica L19 and one tilapia species, *Oreochromis niloticus* (red strain), in an integrated rice- fish system. Fingerlings were purchased from the Light for Liberia Hatchery on the Kokoyah road in Gbarnga, Bong County. The treatments were commercial feed (Ranaan), (F1), locally produced feed (F2) and no feed (F3), which is the control. Manure (cow dung) was spread in an amount of 4.5 kg on the entire 15 experimental

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plots. The manure was applied one month before the introduction of rice and fish into the experimental plots.

There were five (5) experimental blocks containing fifteen (15) experimental plots each measuring 3 m X 3 m (0.0009 ha). In each experimental plot, an L-shaped shelter pond with a size of 1 m X 3 m and a depth of 0.6 m was excavated on both sides of each plot (Figure 2). This was used for fish stocking at four (4) fish per square meter (m^2). There were twenty (20) fish per plot. At the first sowing, each plot contained sixty-four (64) rice plants. A twenty-one (21) day old seedling (rice) was used as planting material. The fish were stocked at an average body weight of 5 g. The remaining 2 m X 2 m, area in each experimental plot was used for planting of rice at 0.2 m X 0.2 m spacing. The study considered the use of one block (three plots) as control instead of two blocks (six plots) in order to minimize the number of control plots and thus limiting the total number of experimental plots to fifteen (15).

Figure 2: Study site showing the various plots

Preparation of plots for cultivation of rice

After construction of the experimental plots, when the refuge ponds were excavated, 4.5 kg of manure (cow dung) was applied to each plot, and

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they were plowed to mix and turn over the soil. Manure was applied to enhance the soil fertility. Harrowing was done to break the clods of soil into smaller masses and later puddle and level them before transplanting the rice seedlings. In addition, rubber pipes with a diameter of two inches (2″) were connected to each plot as inflow and outflow to regulate the water level.

Procurement and cultivation of fish and paddy rice

The two rice varieties used in this work were obtained from the seed laboratory of the Rice Research Department of the Central Agricultural Research Institute (CARI), Suakoko, Bong County, Liberia. After the seeds were procured, they were grown on a dry bed nursery closer to the experimental site. Both Nerica L19 and Suakoko8 rice seedlings were grown for twenty-one (21) days. Before transplanting the seedlings, the water level in each experimental plot was increased to approximately 2.5 cm. Transplanting the seedlings were carried out in rows of 20 x 20 cm. All these activities were carried out manually.

Collection and Conditioning of fingerlings

The fingerlings used for this work were purchased from the Light for Liberia hatchery on Kokoyah Road in Gbarnga, Liberia. At the hatchery, the fingerlings were weighed, counted and placed in clean water to be collected the next day. Before being transported to the experimental site, they were placed in a polyethylene bag with water of pH of 7.1 and at a temperature of 29.0 °C, oxygen was added to the polyethylene, the opening was sealed, and the bags were placed in a bag given cooler. Transport to the research site took place at 8:00 a.m. when the weather was not so harsh.

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Stocking of fingerlings into experimental ponds / paddy field

Fingerlings were conditioned for two days in concrete ponds to enable them to acclimatize to the new environment. Upon arrival, the polythene bags which contained the fingerlings were carefully lowered into the ponds and allowed to remain for about 10 minutes (Figure 3). This was to ensure that the fingerlings do not experience temperature shock. They were then stocked at a rate of four fingerlings / m^2.

Figure 3: Fingerlings in polythene bags placed in ponds for acclimatization

Preparation of Local feed

Locally available feed ingredients such as *Ipomoea aquatica* and snail (*Achatina fulica*) were used as protein source and cassava flour (*Manihot esculenta*) as a carbohydrate source in the feed. *Ipomoea aquatica* were harvested from nearby swamps and washed well with clean water cut and sun dried, and later grinds into powder for feed formulation.

Local feed was prepared from *Achatina fulica*, commonly known as “city girl” in Liberia, collected from swamps, landfills and dilapidated gardens and washed twice to remove impurities. They were then boiled for an hour to allow the meat to cook. The meat was then removed from the shell and dried over the fire. The dried snail meat was ground into powder and mixed with

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cassava powder and *Ipomoea aquatica* powder to prepare local feed. *Achatina fulica* or city girl snail is a pest to many farmers in Liberia and due to its unfavorable habitat and dark color of flesh; it is not eaten in Liberia. The Pearson square method was used for feed formulation. This simple technique has been used to balance rations for many years. It is of greatest value when only two ingredients are to be mixed. In the square method, the number in the middle of the square is more important; it indicates an animal's nutrient requirements for a specific nutrient (Wagner et al., 2012). The proportions of snail powder (protein content) to *Ipomoea aquatica* powder (minerals and vitamin content) and cassava flour (carbohydrate content) was in a ratio of 4:2:1.

The level of crude protein in the industrial and local feeds was forty percent (40%) crude protein and thirty percent (30%) crude protein respectively. The industrial feed (Ranaan) was purchased from Ghana and transported to Liberia for the research.

Figure 4: Local feed ingredients (A) *Achatina fulica* and (B) *Ipomoea aquatica*

Feeding of Fish

The fish were fed twice a day at 10% body weight for the first four months (June to September) of the study and 3% body weight in the fifth

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month (October) which was the last phase of the work. The feeding schedules for the fish were 10:00 am and 2:00 pm. Water quality parameters were firstly recorded before feeding was done every day.

Morphometric data of fish

At the end of each month, five fish were collected / caught from each experimental plot and placed in a basin containing water from the said pond for sampling. Data collected for each fish was primarily total length (TL), which was measured in (cm) using the fish measuring board (Figure 4). This measurement was taken from the tip of the fish's mouth to the end of each fish's tail. The body weight (BW) of each fish was measured in (g) using an electronic scale. The fish were then placed back into their respective ponds after weighing.

Figure 5: Morphometric data of fish (A) Fish length data and (B) Fish monthly weight gain data

Water Quality Assessments

Physicochemical parameters such as pH, dissolved oxygen (mg/L) and temperature (°C) were recorded in the morning (9:00 am) three times per week for the fifteen (15) experimental plots during the research. The OxyGuard®water meter (Polaris C v1.04), was used to record the water quality parameters such as dissolved oxygen and temperature. The device was submerged into the water and the results displayed on the screen after reading,

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was recorded into a field diary and later imputed into excel for further analysis. The pH meter (Device: Hl98103) was used to collect the water pH value.

A B

Figure 6: Determination of water quality (A) Use of oxyguard to record dissolved oxygen and temperature (B) Use of electronic pH meter to record water pH.

Rice growth

Of the sixty-four (64) rice plants planted per plot, fifteen were randomly selected and assessed. During the first phase June-July, data was collected on rice height and number of shoots (tillers) per plant and this activity was halted during the rice booting stage. According to Nordstrom and Glass (2002), the booting stage is broadly defined as the period characterized by swelling of the flag leaf sheath caused by enlargement of the panicle as the leaf sheath grows up. Stress at this stage can reduce rice grain yield. Data on plant height was obtained using a tape ruler. It was determined from the base to the tip of the uppermost spikelet of the plant and reported in centimeters (cm) (Figure 7 (A); the number of tillers per plant was also recorded following Rothuis et al. (1998). A day after harvesting of rice, fifteen (15) plants were cut from each plot, totaling forty-five plants (45) per treatment. These plants

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were cut from the base, properly wrapped around and placed on the scale to obtain the plant wet biomass (*Figure 7* (B). Thereafter, they were dried in the sun and later reweighed to get the plant dry biomass data. Before performing the ANOVA, a test for Homogeneity of variance, and normality test was conducted. Data was subjected to a one-way ANOVA test to determine if there was significant difference in plant height, number of tillers, wet and dry biomass between treatments. The Tukey HSD posthoc analysis result was also displayed to show significant different in the various treatments.

A B

Figure 7: Measurement of plant growth indices; (a) height and (b) wet biomass

Fish growth data

Fish growth data was analyzed per treatment. The average monthly weight gain per treatment was tabulated along with the standard deviation and standard error **(***Figure 10*).

Thereafter, results from the monthly weights gained were placed in Microsoft excel to derive the graph for growth. A one-way ANOVA test was ran to determine if there was significant difference in treatments. The Tukey HSD posthoc analysis result was also displayed to show if there were significant different in the various treatments.

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Survival

The percent survival of fish was calculated per treatment. There were sixty (60) fish initially stocked per treatment. At the end of the work (fifth month), the fish harvested per treatment was counted to know how many of the initial stock made it to the final stage. The total survival per treatment was then used to calculate for the percent survival per treatment using the equation:

Percentage survival (% SR) = $\frac{Fh}{Fi} \times 100$

where Fh refers to final fish harvested and Fi is the initial fish stocked respectively (Limbu et al., 2016).

Condition index

To calculate the condition index of the fish per treatment during the culture period, the average monthly total length (TL) and the average monthly body weight of the fish during the culture period was used for the analysis. The formula employed was:

$$k = \frac{BW}{TL^3} \times 100$$

where BW is the body weight (g) and TL is total length (cm) (Limbu et al., 2016).

Rice yield data

The final data, namely plant grain weight per plot for the two rice varieties was recorded as rice yield at the time of rice harvest. The harvesting was done with a small kitchen knife of blade four inches (4”) long and handle four inches (4”). The panicle harvested from each plant was placed in a small polyethylene bag. The grains were further removed manually from the panicle of each plant. After sieving, the filled grains were placed in the polyethylene

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bag and weighed using the electronic balance to determine the grain weight. The average mean yield per treatment was tabulated in Microsoft Excel along with the standard deviation and standard error. One-way ANOVA test was performed to determine the significant difference between treatments and the Tukey HSD posthoc analysis result was displayed in table.

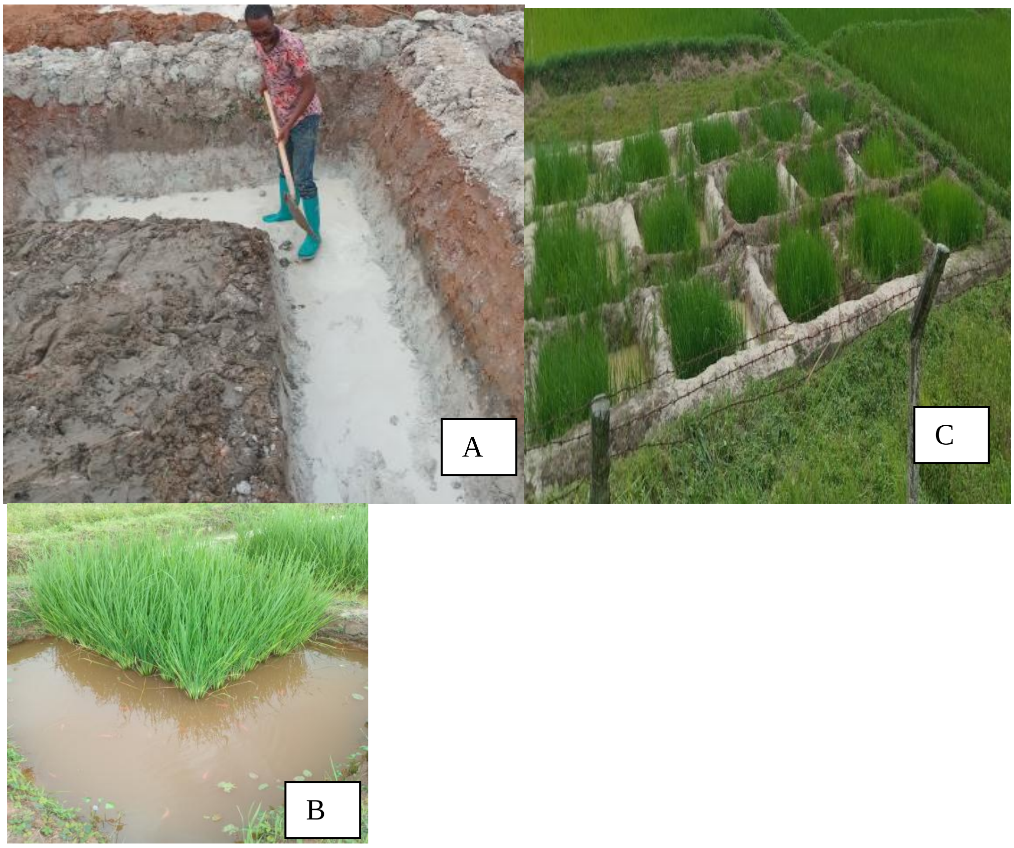

Figure 8: Field lay out (A) Pond construction diagram, (C), Research field diagram and (B) View of how each plot was designed

Physico-chemical parameters of plots

The OxyGuard probe (Polaris C v1.04) was used to record the dissolved oxygen content and temperature of the water. Three replicates of each of these measurements were taken three times weekly at 10:00am.The Hl98103 pH meter was used to obtain the pH of the water.

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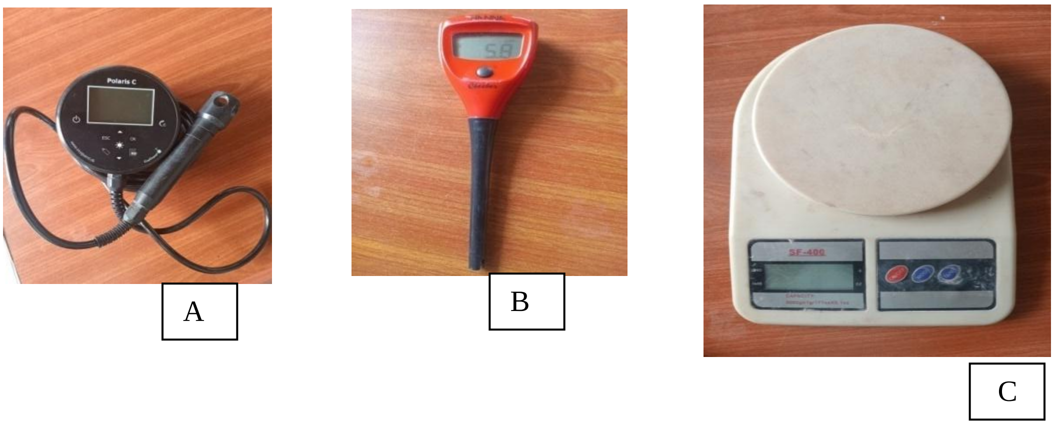

Figure 9: Data collection instruments: (a) OxyGuard probe (Polaris C v1.04), (b) Hl98103 pH meter and (c) electronic scale

Profitability measurement

To study the economic performance of rice sole culture, fish sole culture and the rice-fish culture systems, total cost, fixed cost, total variable cost, profit, gross margin, gross profit margin, benefit cost, contributing per unit, and break-even were calculated based on the local market price of different inputs, products, and labor wages. Profit was calculated by subtracting total revenue from total cost (TR-TC) and benefit cost ratio was calculated by dividing the total revenue by cost (TR/Cost).

Analyses of Data

The body weight (BW), total length (TL), Condition Factor (K) of the fish and the percent survival were used as parameters to monitor fish growth. In addition, plant height (PH), number of tillers and the final yield were used as parameters for plant growth and yield. The average pH, temperature and dissolved oxygen (DO) were used to account for the physicochemical parameters of the cultured water. To perform the ANOVA, a test for Homogeneity of variance, and normality of data test was conducted using Shapiro-wilk test.

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Table 1: Shapiro-Wilk W test for normal data

Variable	Obs	w	v	z	**Prob>z**
r	75	**0.86192**	**8.990**	**4.794**	**0.00000**

A one-way analysis of variance (ANOVA) was performed to determine whether there were any significant differences between the means calculated for treatments: S8R, N19L, S8L, N19R and S8 using the Minitab 16 Statistical Package at $P< 0.05$ Change in body weight was considered as a function of growth. The individual weights, total lengths (TL) of fish and the plant height (PH), numbers of tillers and yield sampled from each plot were recorded. The calculated means were then imported into the Minitab 16 software with their respective standard errors (SE) and standard deviation and the posthoc analysis was displayed using the Tukey HSD. The percent survival and condition factor among fish fed with the two treatment diets were ascertained using Microsoft Excel.

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CHAPTER FOUR

RESULTS

Introduction

This chapter presents the results of the study. The results include growth, survival and condition factor of fish (*O. niloticus*) fed with the two regimes of feed. Data on dissolved oxygen (DO), pH, temperature of the cultured water, growth, numbers of tillers and yield of the two varieties of rice (Suakoko8 and Nerica L19), as well as the profitability of the rice-fish integrated system are also presented. Results are presented in text, tables and graphs showing differences in treatments where the data was supportive.

Growth of all-male Nile tilapia

The growth of the Nile tilapia in the various treatments is shown in Figure 9. There was a gradual increase in mean body weight from the initial weight of 5 g to a maximum mean weight of 103.88 g. From June to October, the growth of fish in the SR8 treatment increased from 15.907 ± 2.669 g to 103.467 ± 3.332 g. Treatment S8L in June had a mean weight of 16 ± 2.50 g; this increased to 30.66 ± 3.786 g in July and 47.4 ± 10.190 g in August. From that point, it obtained an increase of 67.33 ± 9.614 in September and 78.93 ± 5.428 in October. Whereas treatment N19L obtained an increased from 12.2 ± 2.078 g in June to 98.133 g at the end of the experiment which was in October. Starting from June, N19R had 17.4 ± 2.55 g, in July it obtained 34.133 ± 2.99 g. From that point, it increased up to 73.6 ± 7.790 g and in October, it got 93.933 ± 6.997 g. Treatment S8 had the lowest increase in mean body weight among the treatments. It started from 11.667 ± 1.949 g in June 21 ± 2.043 in July, 22.73 ± 2.034 in August and 37.2 ± 3.043 in October.

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An analysis of variance for the mean weight of the five treatments indicated a significance difference in weight ($P< 0.05$) [Test: ANOVA; n=75; df = (4, 70); F=19.6; *P*=0.000] as shown in Appendix 2. The ANOVA result was validated using the Bartlett's test for equal variances and the Shapiro Wilk normality test. As shown in Appendix 1. A further posthoc analysis of the difference in mean weight revealed that S8R, N19L and N19R performed significantly better that S8L and S8 [Post-hoc Summary: S8R: 103.47^{A}, N19L: 98.13^{AB}, N19R: 93.93^{AB}, S8L: 78.93^{B}, S8: 37.20^{C}] as shown in Appendix 3.

A two-sample t-test indicated that there was no significance difference in the weight gained of fish feed with Ranaan and those fed with the local feed p>0.05 [Test:T-Value = 1.48 P-Value = 0.144: DF = 51] as shown in Appendix 4.

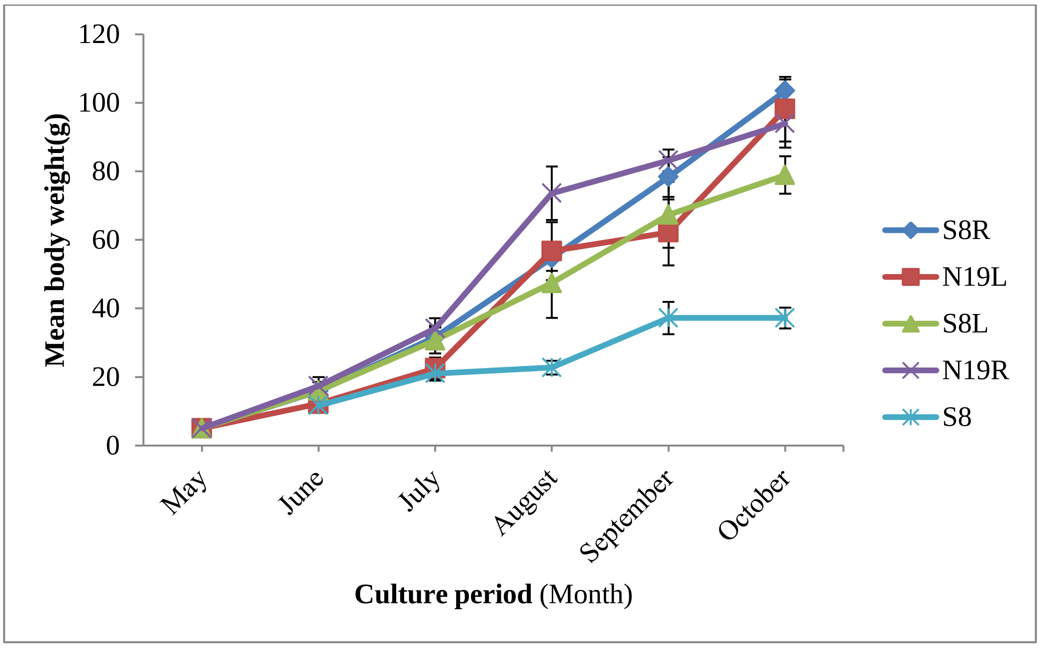

Figure 10: Growth in mean body weight (g) of Nile tilapia (*O. niloticus*) in the five treatments for the culture period.

Physico-chemical parameters of water

Changes in pH, temperature and dissolved oxygen of the culture water during the study period are shown in Figures 11, 12 and 13 respectively.

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Generally, there was a gradual reduction in mean monthly pH from June to a minimum in September 2023; thereafter, there was a considerable increase in pH to a maximum in October. Water samples from treatment S8R had the highest mean pH during the culture period (*Figure 11*).

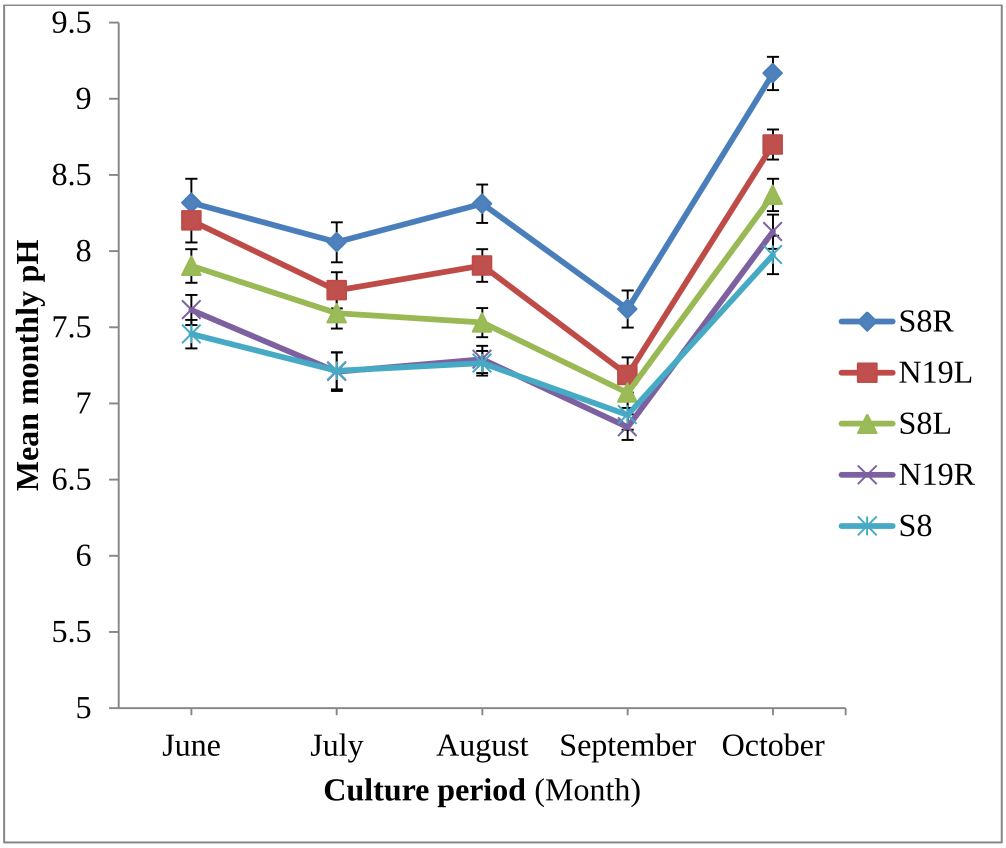

Figure 11: Mean monthly pH of culture water for the five treatments during the culture period

During the culture period, there was a gradual increase in mean monthly temperature of the water used in culture for all the treatment from June to the end of the culture period. The highest monthly water temperature values were recorded for treatment S8R throughout the culture period. The least monthly water temperature of (26.891 ± 0.147) was recorded in treatment (N19R) in June and the highest temperature (28.602 ± 0.178) was recorded in treatment S8R in October as shown in Figure 12.

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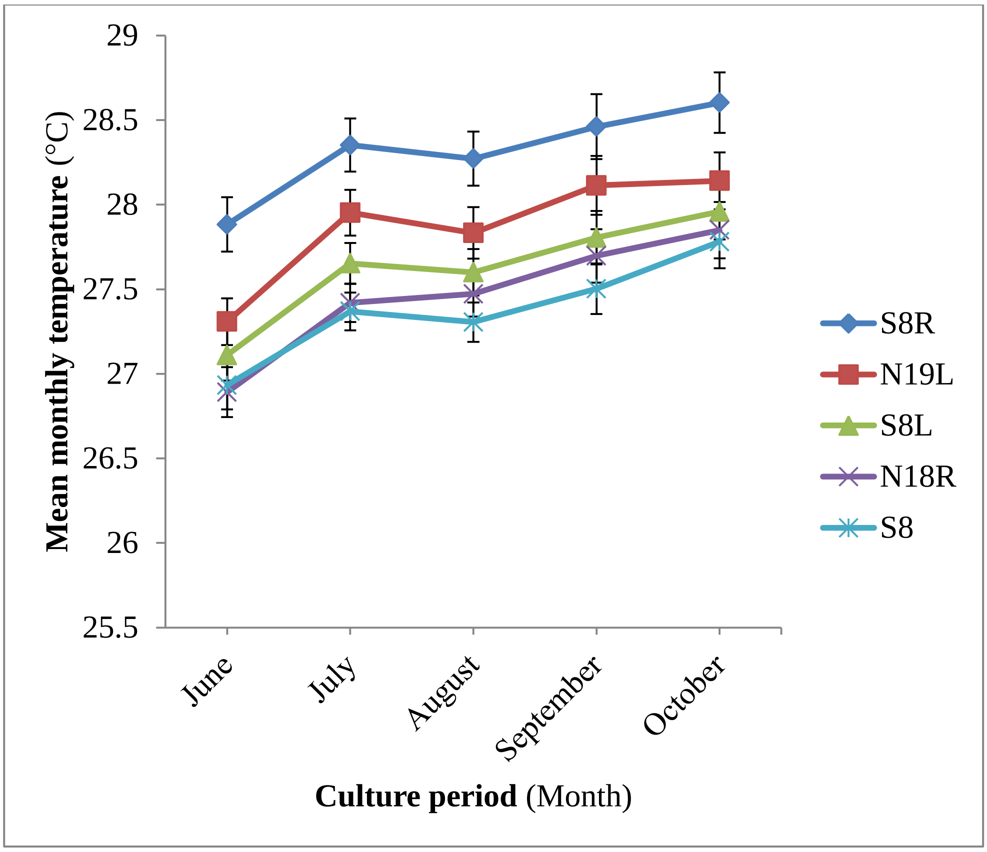

Figure 12: Mean monthly temperature of water for the five treatments during the culture period.

The highest mean monthly dissolved oxygen value of 5.252 ± 0.268 mg/L was recorded for S8R in June (Figure 13). It decreased to 4.179 ± 0.213 mg/L in July and later rose in August to 4.684 ± 0.348 mg/L. June and August marked the point where the mean monthly dissolved oxygen was high for N19L. Generally, there was a reduction in dissolved oxygen from the start of the culture trial to the end of the period. The lowest mean dissolved oxygen values were recorded in July 3.896 ± 0.193 mg/L and October 3.653 ± 0.211 mg/L. In July, September and October, the mean dissolved oxygen was low for S8L. Increase in mean dissolved oxygen were recorded in June and August across all treatments. N19R experienced increased trends in mean dissolved oxygen for July, 4.013 ± 0.168; August, 4.293 ± 0.219 mg/L and October was

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3.956 ± 0.222 mg/L. Low mean dissolved oxygen for this treatment was recorded in June and September. The mean dissolved oxygen concentration for treatment S8 was high in June and August with values of 3.948 ± 0.240 mg/L and 4.268 mg/L. July had a mean value of 3.817 ± 0.156 mg/L, September 3.158 ± 0.181mg/L, while October was 3.503 ± 0.193 mg/L.

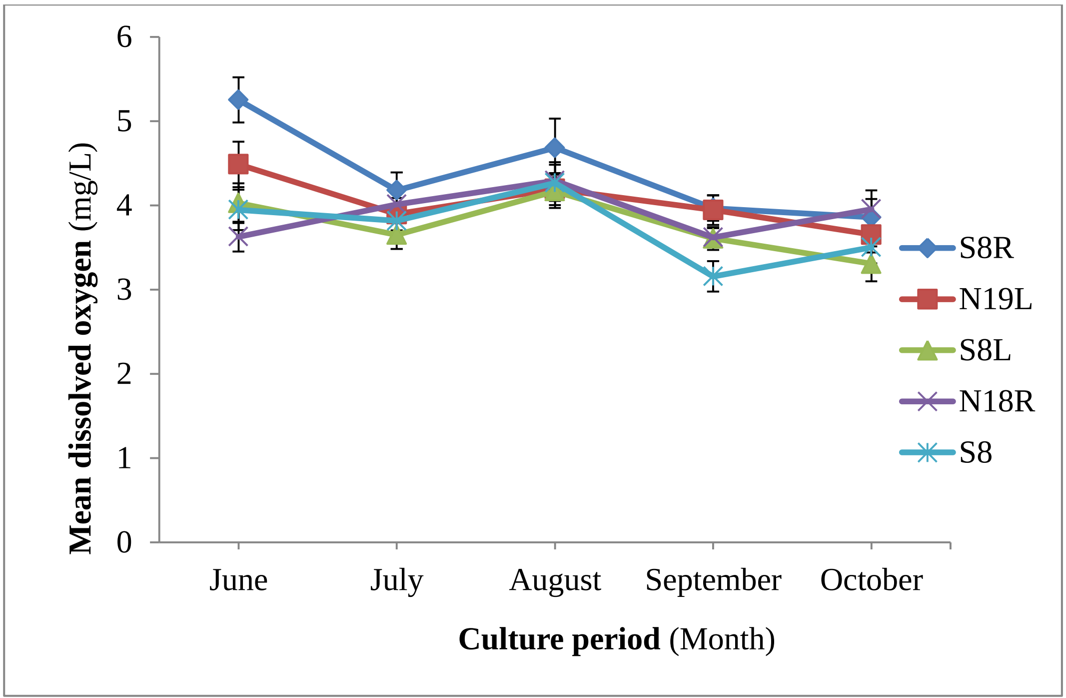

Figure 13: Mean monthly dissolved oxygen concentration in water during the culture period

Condition Index

The mean monthly condition factor of the fish (*Oreochromis niloticus)* for the various treatments during the culture period is shown in Figure 14. Apart from treatment N19L, where an increase in condition factor was observed, marginal fluctuations in the condition factor was recorded for the other treatments. During the last culture period of October, a mean condition factor of 1.89 ± 0.035 was obtained for S8R, 3.67 ± 0.71 and for N19L, 1.75 ± 0.038 for S8L, 1.84 ± 0.028 for N19R, and 1.73 ± 0.032 for S8. Treatment two (N19L) displayed the significantly highest condition factor during the culture

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period. Treatments three (S8L) and five (S8) showed similar trends. The highest mean condition factor values for treatment four (N19R) were recorded in June and July.

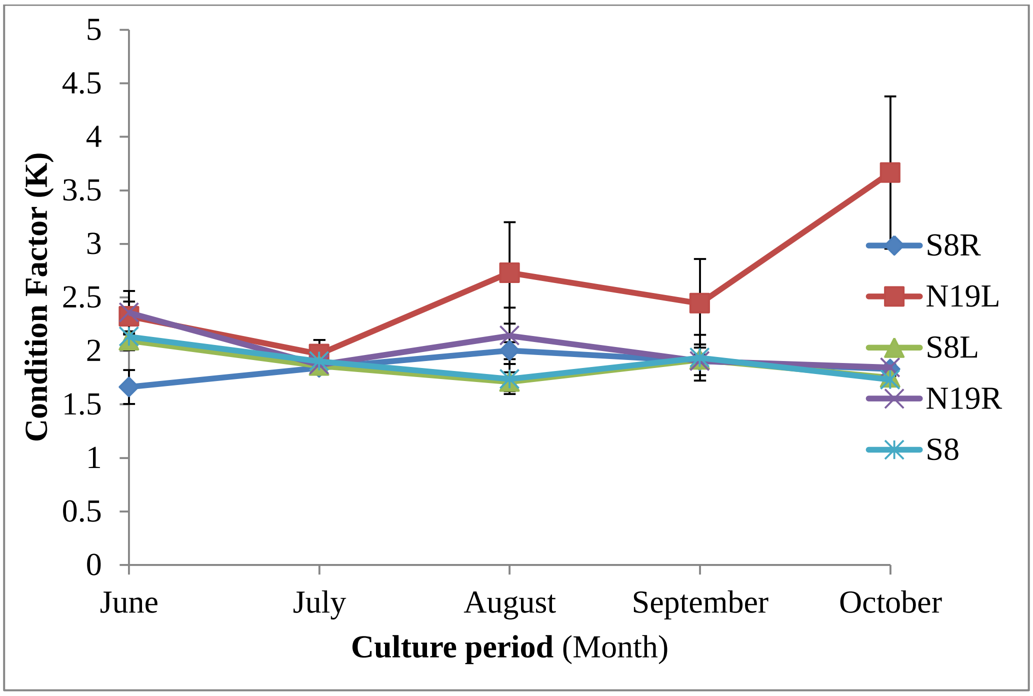

Figure 14: Mean monthly fish condition factor for each of the five treatments during the culture period

Survival of *O. niloticus*

Table 2 displays the percentage survival of fish per treatment at the end of the culture period. The percent (%) survival for treatment S8L was the highest (93.33%) among all the treatments. Next to that were treatments S8R and N19R which both obtained 88.33%. The least percent survival was obtained in S8, which had an overall survival of 68.33%.

Table 2: Percentage survival of fish per treatment for the culture period

Treatments	Initial fish stock	Total fish harvested	% Survival
S8R	60	53	88.33%
N19L	60	43	71.67%
S8L	60	56	93.33%
N19R	60	53	88.33%
S8	60	41	68.33%

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Yield and Biomass of Rice cultivars

The yield of rice per treatment and the dry and wet biomass of the rice per treatment for the culture period are shown in Table 4. The highest wet and dry plant biomass was obtained for treatment S8R during the culture period. Treatments N19L and N19R had the highest rice yield during the culture period, while the lowest rice yield was obtained in S8 (control), which was 5.667 ± 0.239. A one-way analysis of variance for the rice yield indicated a significant difference among the five treatments ($p < 0.05$) [Test: ANOVA; n=75; df = (4, 220); F=29.45; *P*=0.000] as shown in Appendix 5. Tukey's HSD analysis indicated that N19L and N19R produced the highest yield while S8 and S8L had the least yield (Appendix 6). In addition, the outcome of the one-way ANOVA indicates that for rice wet biomass, there were significant differences between treatments ($p< 0.05$) [Test: ANOVA; n=75; df = (4, 220); F=45.04; *P*=0.000] as shown in Appendix 7. The post-hoc analysis however shows that wet biomass of rice in treatment S8R was significantly higher than those of S8L and N19L, N19R, S8 (Appendix 8). The one-way ANOVA indicated that for rice dry biomass, there were significantly different between treatments at $p< 0.05$ [Test: ANOVA; n=75; df = (4, 220); F=43.96; *P*=0.000] as on Appendix 9. The post-hoc analysis however showed that the rice in treatment S8R performed better than the other treatments.

Table 3: Summary data of yield (kg) for various treatments

S8R	S8L	S8	N19L	N19R
9.956^{A}	8.289^{B}	6.311^{C}	4.889^{CD}	3.822^{D}

as illustrated in Appendix 10.

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Table 4: Rice Yield, Wet and Dry Biomass (g) under the five different cultivation treatments

Treatment	Yield (g)	Wet weight of rice biomass (g)	Dry weight of rice biomass (g)
S8R	7.778 ± 0.240	35.156 ± 0.451	9.956 ± 0.269
N19L	9.200 ± 0.467	18.356 ± 0.374	1.802 ± 0.219
S8L	6.200 ± 0.255	27.267 ± 0.463	6.733 ± 0.245
N19R	9.022 ± 0.378	19.867 ± 0.322	3.822 ± 0.193
S8	5.667 ± 0.239	18.000 ± 0.366	6.311 ± 0.235

Plant height and number of tillers in response to treatment

Table 5 presents the mean plant height measure in (cm) (standard deviation) and the mean number of tillers obtained in each treatment for the months of June and July. Treatment S8R had the highest mean plant height for June and July and had the highest mean number of tillers for that period. The highest plant height of 115.178 ± 1.586 cm was recorded for treatment N19L in July and its highest mean number of tillers (10.511 ± 0.689) was obtained in July. For the remaining three treatments (S8L, N19R and S8), their highest mean plant height and highest mean tiller numbers was recorded in July. An analysis of variance for the mean height for the five treatments indicated a significance difference in height ($P< 0.05$) [Test: ANOVA; n=75; df = (4, 220); F= 9.05; *P*=0.000] as shown in Appendix 11. A further post-hoc analysis of the difference in height shows that S8R was significantly different from S8 [Summary: S8R: 123.29^{A}, S8L: 120.27^{AB}, N19L: 115.18^{BC}, N19R: 113.47^{BC}, S8: 109.87^{C}] as shown in Appendix 12. There was also a significant difference in mean number of tillers ($P< 0.05$) [Test: ANOVA; n=75; df = (4, 220); F=

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29.24; *P*=0.000] as shown in Appendix 13. The Tukey post-hoc analysis for numbers of tillers indicated that S8, S8R and S8L perform better than N19L and N19R [Summary: S8: 13.644^{A}, S8L:13.600^{A}, S8R: 12.911^{A}, N19L: 10.511^{B}, N19R: 6.200^{C}] as shown in Appendix 14.

Table 5: Mean plant height (cm) and number of tillers per treatment for June and July for the five treatments

Treatments	Plant Height(cm) for June	Plant Height (cm) for July	# of tillers for June	# of tillers for July
S8R	75.867± 0.566	123.289 ± 1.745	9.889 ± 0.435	12.911± 0.758
N19L	69.467 ±0.736	115.178 ± 1.586	7.556 ± 0.448	10.511 ± 0.689
S8L	68.911±0.701	120.267 ± 2.838	6.578 ± 0.454	13.6 ± 0.545
N19R	68.822 ±0.678	113.467 ± 1.151	4.244 ± 0.183	6.2 ± 0.333
S8	64.733 ±0.469	109.867 ± 0.984	5.467 ± 0.161	13.644 ± 0.5023

Profitability analysis

The profitability assessment of fish monoculture (ha) demonstrated that treatments S8 and S8L yielded the least profit margin. While the highest profit yield was recorded for treatment N19R, follow by S8R and N19L respectively as shown in Table 6. In this study, profitability was measured in United States Dollar using local market values.

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Table 6: Profitability ($) of fish monoculture culture (ha)

	S8R	N19L	S8L	N19R	S8
QTY*Price (TR)	11036.67	8628.15	7790.74	9924.44	2859.63
TC(FC+TVC)	8325.56	8325.56	8325.56	8325.56	8325.56
Profit ($) (TR-TC)	2711.11	302.59	-534.82	1598.89	-5465.93
Profit/4	677.78	75.64815	-133.70	399.72	-1366.48
Gross Margin(pro/TR)	272.94	38.97	-76.28	179.01	-2123.79
Gross Profit Margin(GM/100)	27293.98	3896.71	-7627.5	17900.68	-212379
Benefit Cost(TR/cost)	1472.93	1151.49	1039.74	1324.49	381.64
Contributing margin per unit	-500	-500	-500	-500	-500
Break-even(Fc÷Cm)	-106.17	-106.17	-106.17	-106.17	-106.17

As shown in Table 7, for rice monoculture, the highest profit was obtained in N19R ($7,606.94) (ha) followed by N19L ($ 5,647.22) per (ha), S8L ($ 2,648.61) per (ha) and S8R ($ 2,363.89) per (ha). The least was recorded in S8 ($ 1,527.78) per (ha) which is the control plot.

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Table 7: Profitability of rice monoculture culture (ha)

	S8R	N19L	S8L	N19R	S8
QTY*Price (TR)	4641.67	7925	4926.39	9884.72	3805.56
TC(FC+TVC)	2277.78	2277.78	2277.78	2277.78	2277.78
Profit (TR-TC) ($)	2363.89	5647.22	2648.61	7606.94	1527.78
Profit/4	581.42	1402.25	652.59	1892.18	372.39
Gross Margin(pro/TR)	556.71	786.40	588.75	850.78	434.91
Gross Profit Margin(GM/100)	5.57	7.86	5.89	8.51	4.349
Benefit/Cost(TR/cost)	2226.86	3802.05	2363.46	4742.24	1825.73
Contributing margin per unit	-888.89	-888.89	-888.89	-888.89	-888.89
Break-even(Fc÷Cm)	-47.78	-47.78	-47.78	-47.78	-47.78

On the overall for the rice-fish integrated system, S8R obtained the profit margin of ($ 5075), N19L ($ 5949.82), S8L ($ 2113.79), N19R ($ 9205.83) and S8 ($ -3938.15) per (ha) of cultivation. The highest profit margin was obtained from N19R (Table 8).

Table 8: Profitability of rice-fish integrated culture (ha) for the five treatments

	S8R	N19L	S8L	N19R	S8
QTY*Price (TR)	15678.33	16553.15	12717.13	19809.17	6665.19
TC(FC+TVC)	10603.33	10603.33	10603.33	10603.33	10603.33
Profit (TR-TC) ($)	5075.00	5949.82	2113.79	9205.83	-3938.15
Profit/4	1259.19	1477.89	518.89	2291.90	-994.09
Gross Margin(profit/TR)	829.65	825.37	512.48	1029.78	1029.78
Gross Profit Margin(GM/100)	27299.55	3904.58	-7621.61	17909.19	-212375
Benefit/Cost(TR/cost)	3699.79	4953.55	3403.19	6066.73	2207.37
Contributing margin per unit	-1388.89	-1388.89	-1388.89	-1388.89	-1388.89
Break-even(Fc÷Cm)	-153.95	-153.95	-153.95	-153.95	-153.95

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CHAPTER FIVE

DISCUSSION

Introduction

The profitability of integrated aquaculture was assessed using a rice-cum-fish culture system using two cultivars of rice and sex-reversed tilapia (all male). The one-way analysis of variance (ANOVA) of the final weight gain on the growth performance of tilapia in the rice-fish cum showed that there were significant different between treatments. In this study, the final weight gained between fish fed with commercial feed and those with locally formulated feed showed no significant difference. Manuel et al., (2020) reported that tilapia, fed with different proportions of water spinach showed outstanding performance in their study. Also, a study indicated that the inclusion of snail meal as protein source in the diet of sex-reversed tilapia resulted in improved growth (Chimsung & Tantikitti, 2014). However, there was a significant difference between treatment five (S8), which was the control plot that had zeroed feeding, and the rest of the other treatments. This could be due to inadequate nutrition, as the fish had to depend on the primary productivity of the water. Notwithstanding, this study indicated that feeding plays a crucial role in the growth of fish in an integrated rice-fish cum system (Figure 9).

Survival and condition factor of tilapia

The percent survival of the experimental fish varies from one treatment to another. The highest percentage survival was recorded in treatment three (93.33%). The lowest survival percentage was recorded in treatment five, S8, (68.33%), which was the control plot. This lower percentage survival of

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treatment five (S8) could be attributed to the statement of Alfred (2021). In this study, the decrease in number of fish stocked per treatment was not due to poor water quality or disease outbreak; but might be due to leeches and birds attacking the fish. In open ponds, the ability of a fish to escape predators is key in ensuring their survival. The presence of leeches in the pond may also account for the mortality among the fish. Leech infestation has also been identified as a common ectoparasite of tilapia (Van Muiswinkel, 2011).

Condition factors have been used as a measurement of health in studies on fishing biology, including growth and feeding intensity (Froese, 2006). The condition factors can also be used to assess a species’ level of feeding activity as to whether it is making good use of its food source (Lizama et al., 2002). According to Ayode (2011), condition factors of fish above 1.0 suggest good health condition which is desirable in fish farming. The mean condition factors (K) for the cultured fish in this study were 1.829, 3.67, 1.75, 1.844, and 1.73 for the five treatments. The condition factor values of *O. niloticus* fed with the two diets in all the treatments were greater than one. This indicated good health condition during the experiment, and it is indicative of an isometric growth, which is desirable for fish farming. This result is similar to that of other researchers (Ighwela & Ahmed, 2011; Anani & Nunoo, 2016).

Water quality of treatments

The physical, chemical, biological, and aesthetic aspects of water that affect its usefulness is known as water quality. Water quality variables can be defined as any feature of water in production systems that affects aquaculture species' survival, reproduction, growth, and output; impacts management choices; adversely affects the environment, or lowers the quality and safety of

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the produce (Boyd & Tucker, 1998). In this study, the pH, Temperature and Dissolved Oxygen measured were within appreciable range for survival of Nile tilapia. The lowest pH recorded was in September in treatment four (N19R) 6.8 ± 0.093 and the highest was in October in treatment one (S8R) 9.1 ± 0.093. Tilapia can survive at a pH of 5 to 10, but they thrive best at a pH of 6 to 9 (Idam & Elsheakh, 2022). There was a slight decrease in pH for all treatments during the month of September, which might have been because of the heavy downpour of rain during that period. The pH values observed in this study are similar to the report of (Lloyd, 1992) who found that the recommended pH for tilapia aquaculture is 6.8-9.5. Additionally, the lowest mean water temperature was recorded in treatment four (N19R) in June 26.89 ± 0.147 °C with the highest in October in treatment one (S8R) 28.6 ± 0.178 °C. At this point, the rainy season in Liberia was over and the appearance of the sun began to warm the environment, causing the temperature of the cultured water to rise. The temperature values observed in this study are within the optimal range for the growth of tilapia. According to Stander (2000), tilapia is a warm-water fish with optimal temperatures in the range of 24–32 °C. At temperatures below 20 °C the growth rate decreases. The least Dissolved Oxygen was recorded in September in treatment five (S8), 3.157 ± 0.180 mg/L and the highest was 5.25 ± 0.267 mg/L in June in treatment one (S8L). There was a slight decrease in dissolved oxygen for the months of July and September across all the treatments when the rainy season was at its peak. At this point, much of the culture water in the experimental plots was cloudy. Based on research results on the influence of turbidity changes on the solubility of oxygen in water, it is shown that the cloudier the water, the less

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oxygen is dissolved in the water (Lusiana et al., 2020). Therefore, the slight decrease in dissolved oxygen in July and September throughout the treatment could be due to turbidity. Although this situation does not affect rice production, it negatively affects fish survival. Wang et al. (2022) reported that increased turbidity affects various animal traits (such as risk-taking and foraging ability), disrupts predator-prey interactions, and ultimately influences the entire food web. In some fish, visual impairment caused by haze results in reduced food intake (Figueiredo et al. 2020), altered diet and food selection (Ajemian et al. 2015), and less efficient schooling behavior (Borner et al. 2015).

Yield of rice under different treatments

The finding indicates that treatments that had Nerica L19 recorded the highest mean yield of rice N19L (9.200 ± 0.467), N19R (9.022 ± 0.378). The lowest mean yield was recorded in the control treatment S8 (5.667 ± 0.239). Results from this study showed that Nerica L19 has high performance in terms of yield and this is consistent with Matsunami et al. (2009). The highest mean wet biomass were recorded in S8R (35.156 ± 0.451) and S8L (27.267 ± 0.463); these are treatments that contain Suakoko 8 rice variety. The lowest mean dry biomass were in N19L (1.802 ± 0.219) and N19R (3.822 ± 0.193). This study highlights that integrating fish with rice without feeding or fertilizing the system, results in poor growth of fish and low yield of rice. This can also have a trigger downstream effect on its profitability.

The highest mean of plant heights were recorded in S8R (123.289 ± 1.745), S8L (120.267 ± 2.838) and the highest number of tillers were in S8R (12.911 ± 0.758), S8L (13.6 ± 0.545) and S8 (13.644 ± 0.5023). The lowest

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number of tillers were recorded in the Nerica variety. These results indicate that the Suakoko 8 rice (S8, S8R and S8L) variety had high tillering ability compared to the Nerica L19, and it grows taller than the Nerica L19 (N19L and N19R). However, though Suakoko 8 rice variety had high tillering ability and grows taller than Nerica L19, in terms of yield, Nerica L19 had high performance. This study also find out that Nerica L19 had high resistance for wind compared to the Suakoko 8 rice variety. During the study, it was observed that in every wind situation, the experimental plots with the Suakoko 8 rice variety were affected.

Profitability of rice-fish culture

For the fish sole culture, the highest profit gained was under S8R ($ 2,711.11) N19R ($ 1,598.89) followed by N19L ($ 302.59). Treatment S8L and S8 obtained negative values, which shows that it resulted in loss because the total cost (TC) of production was higher than the total revenue (TR), gained. As such, it indicates that there should be an increment in price to have a breakeven point.

For the rice sole culture, the highest profit was obtained in N19R ($ 7,606.94) followed by N19L ($ 5,946.82), S8L ($ 2,648.61), S8R ($ 2,363.89) and S8 ($ -3,938.15). Treatment S8L value shows that production was low and as such, total cost (TC) was higher than total revenue (TR). Therefore, to breakeven to have a positive output, there should be an increment in price or production level should increase. This reveals that rice sole culture is more profitable than fish sole culture.

Findings from this work highlight the various profit obtained from each treatment under the rice-fish integrated system: S8R ($ 5,075), N19L ($

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5,946.82), S8L ($ 2,113.79), N19R (9,205.83) and S8 ($ -3,938.93). The highest profitability was recorded for treatment N19R, followed by N19L, S8R and S8L. Overall, S8 treatment (control) resulted in loss in production. From the data presented, this study could state the rice-fish integration is more profitable than fish or rice sole culture in terms of net profit return. This statement strongly agreed with those of Jyoti et al. (2020) and Ahmed et al. (2011).

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CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This chapter presents the study's summary, conclusions, and recommendations. Based on the objectives, the study's summary and conclusion were developed. In accordance with the objectives, the chapter also offered recommendations based on the conclusions.

The overarching objective of this research is to assess the yield of two rice cultivars (Suakoko 8 and Nerica L19) and growth of monosexual tilapia (*Oreochromis niloticus*) in an integrated rice-fish farming system. This work was initiated in May of 2023 and ended October of 2023. Two rice varieties and monosexual tilapia (*Oreochromis niloticus*) were used for this work. There were five treatments in total in fifteen (15) experimental plots with two levels of feeds, locally formulated and Ranaan feed.

The study's recorded water quality indicators fell within a significant range that allowed the farmed fish to develop and survive. The average fish output in treatment one was the highest, while the control treatment had the lowest. The rice variety, Nerica L19, produced the best rice yields and the lowest rice dry biomass when applied to treatments. Treatments that had the Suakoko 8 rice variety recorded the highest mean wet and dry biomasses of rice. Suakoko8 grows higher and has more tillers than Nerica L19; however, treatments one and three produced the maximum number of tillers and the highest plant height. Treatment three (3) also had the highest percentage of fish survival (S8L).

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Conclusions

Rice-fish culture resulted in higher net return and benefit cost ratio (BCR) compared to rice or fish sole culture. The use of local feed resulted in growth of fish which was not significantly different from that of Raanan feed. The physicochemical parameters observed in this study were within the range that supports growth and survival of the cultured fish *O. niloticus*.

Recommendations

1. Further study should be carried out during the dry season to have a fair understanding of the rice-fish integrated farming system in the two seasons.
2. Other Studies should be carried out using different planting distances and stocking densities to evaluate the best option for the rice-fish integrated farming system.
3. Studies should be done on other local rice varieties with this culturing method to evaluate their proficiency.
4. Based on the profitability analysis, the Liberian government should put more attention to this sector to decongest it from a subsistence approach to a more industrial scale and see it as a mean of creating job and raising revenue for the country.
5. Further study should be done on how to get rid of Leech in the rice-fish integrated system in Liberia.

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APPENDICES

APPENDIX A: Summary of One-way ANOVA for fish (*O. niloticus*) growth

Appendix 1: Shapiro-Wilk W test for normal data

Variable	Obs	w	v	z	**Prob>z**
r	75	**0.86192**	**8.990**	**4.794**	**0.00000**

Appendix 2: Results of one-way analysis of variance for final body weight (BW) of fish for the different treatments

Source	DF	SS	MS	F	P
Factor	4	43191	10798	19.16	0.000
Error	70	39440	563		
Total	74	82631			

S = 23.74 R-Sq = 52.27% R-Sq (adj) = 49.54%

Appendix 3: Tukey post-hoc analysis for fish body weight

Treatments	N	Mean
S8R	15	103.47^{A}
N19L	15	98.13^{AB}
N19R	15	93.93^{AB}
S8L	15	78.93^{B}
S8	15	37.20^{C}

Means that do not share a letter are significantly different.

Appendix 4: Two-Sample T-Test and CI: R, L for fish fed with Ranaan and Local feed

	N	Mean	StDev	SE Mean
R	30	98.7	21.4	3.9
L	30	88.5	30.9	5.6

Two-sample T for R vs L

Difference = mu (R) - mu (L)
Estimate for difference: 10.17
95% CI for difference: (-3.61, 23.94)
T-Test of difference = 0 (vs not =): T-Value = 1.48 P-Value = 0.144: DF = 51

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APPENDIX B: Summary of One-way ANOVA for rice growth and yield

Appendix 5: Results of one-way analysis of variance for rice yield of the different treatments

Source	DF	SS	MS	F	P
Factor	4	535.62	133.90	29.45	0.000
Error	220	1000.18	4.55		
Total	224	1535.80			

S = 2.132 R-Sq = 34.88% R-Sq (adj) = 33.69%

Appendix 6: Tukey post-hoc analysis for rice yield

Treatments	N	Mean
N19R	45	9.267^{A}
N19L	45	9.267^{A}
S8R	45	7.822^{B}
S8L	45	6.000^{C}
S8	45	5.667^{C}

Means that do not share a letter are significantly different.

Appendix 7: Results of one-way analysis of variance for the Plant wet biomass of the different treatments

Source	DF	SS	MS	F	P
Factor	4	9886.2	2471.6	45.04	0.000
Error	220	12072.2	54.9		
Total	224	21958.5			

S = 7.408 R-Sq = 45.02% R-Sq (adj) = 44.02%

Appendix 8: Tukey post-hoc analysis for plant wet biomass

Treatments	N	Mean
S8R	45	35.156^{A}
S8L	45	27.267^{B}
N19R	45	19.867^{C}
N19L	45	18.356^{C}
S8	45	18.000^{C}

Means that do not share a letter are significantly different.

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Appendix 9: Results of one-way analysis of variance for the Plant dry biomass of the different treatments

Source	DF	SS	MS	F	P
Factor	4	1117.14	279.28	43.96	0.000
Error	220	1397.82	6.35		
Total	224	2514.96			

S = 2.521 R-Sq = 44.42% R-Sq (adj) = 43.41%

Appendix 10: Tukey post-hoc analysis for plant dry biomass

Treatments	N	Mean
S8R	45	9.956^{A}
S8L	45	8.289^{B}
S8	45	6.311^{C}
N19L	45	4.889^{CD}
N19R	45	3.822^{D}

Means that do not share a letter are significantly different.

Appendix 11: Results of one-way analysis of variance for the Plant height of the different treatments

Source	DF	SS	MS	F	P
Factor	4	5184	1296	9.05	0.000
Error	220	31493	143		
Total	224	36677			

S = 11.96 R-Sq = 14.13% R-Sq (adj) = 12.57%

Appendix 12: Tukey post-hoc analysis for plant height

Treatments	N	Mean
S8R	45	123.29^{A}
S8L	45	120.27^{AB}
N19L	45	115.18^{BC}
N19R	45	113.47^{BC}
S8	45	109.87^{C}

Means that do not share a letter are significantly different

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Appendix 13: Results of one-way analysis of variance for the number of tillers of the different treatments

Source	DF	SS	MS	F	P
Factor	4	1799.4	449.9	29.24	0.00
Error	220	3385.2	15.4		
Total	224	5184.6			

S = 3.923 R-Sq = 34.71% R-Sq (adj) = 33.52%

Appendix 14: Tukey post-hoc analysis for numbers of tillers

Treatments	N	Mean
S8	45	13.644^{A}
S8L	45	13.600^{A}
S8R	45	12.911^{A}
N19L	45	10.511^{B}
N19R	45	6.200^{C}

Means that do not share a letter are significantly different.

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APPENDIX C Profitability of rice with fish culture

APPENDIX 15: Experimental values for fish sole culture

	Fish				
	S8R	N19L	S8L	N19R	S8
QTY (kg)	1.419	1.109333	1.001667	1.276	0.367667
Price (USD5)	7	7	7	7	7
QTY*Price(TR)	9.933	7.765333	7.011667	8.932	2.573667
Land (Fixed Cost)	0.043	0.043	0.043	0.043	0.043
Labor	1.75	1.75	1.75	1.75	1.75
Fingerling	2.8	2.8	2.8	2.8	2.8
feed	2.6	2.6	2.6	2.6	2.6
manure	0.3	0.3	0.3	0.3	0.3
TVC	7.45	7.45	7.45	7.45	7.45
TC(FC+TVC)	7.493	7.493	7.493	7.493	7.493
Profit(TR-TC)	2.44	0.272333	-0.48133	1.439	-4.91933
Profit/4	0.61	0.068083	-0.12033	0.35975	-1.22983
Gross Margin	0.245646	0.03507	-0.06865	0.161106	-1.91141
Gross Profit Margin	24.56458	3.50704	-6.86475	16.11061	-191.141
Benefit/Cost	1.325637	1.036345	0.935762	1.192046	0.343476
Contributing margin per unit	-0.45	-0.45	-0.45	-0.45	-0.45
Breakeven point	-0.09556	-0.09556	-0.09556	-0.09556	-0.09556

APPENDIX 16: Experimental values for rice sole culture

	Rice				
	S8R	N19L	S8L	N19R	S8
QTY (kg)	3.342	5.706	3.547	7.117	2.74
Price (USD5)	1.25	1.25	1.25	1.25	1.25
QTY*Price(TR)	4.1775	7.1325	4.43375	8.89625	3.425
Land (Fixed Cost)	0.0344	0.0344	0.0344	0.0344	0.0344
Labor	1.75	1.75	1.75	1.75	1.75
Fingerling	0	0	0	0	0
feed	0	0	0	0	0
manure	0.3	0.3	0.3	0.3	0.3
TVC	2.05	2.05	2.05	2.05	2.05
TC(FC+TVC)	2.05	2.05	2.05	2.05	2.05
Profit(TR-TC)	2.1275	5.0825	2.38375	6.84625	1.375
Profit/4	0.523275	1.262025	0.587338	1.702963	0.33515
Gross Margin	0.501041	0.70776	0.529879	0.765699	0.391416
Gross Profit Margin	0.00501	0.007078	0.005299	0.007657	0.003914
Benefit/Cost	2.004174	3.421848	2.127111	4.268015	1.643159
Contributing margin per unit	-0.8	-0.8	-0.8	-0.8	-0.8
Breakeven point	-0.043	-0.043	-0.043	-0.043	-0.043

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APPENDIX 17: Experimental values for rice- fish integrated culture

	Both				
	S8R	N19L	S8L	N19R	S8
QTY (kg)	4.761	6.815333	4.548667	8.393	3.107667
Price (USD5)	5.25	5.25	5.25	5.25	5.25
QTY*Price(TR)	9.8535	11.56983	8.440417	14.00025	4.895667
Land (Fixed Cost)	0.0774	0.0774	0.0774	0.0774	0.0774
Labor	3.5	3.5	3.5	3.5	3.5
Fingerling	2.8	2.8	2.8	2.8	2.8
feed	2.6	2.6	2.6	2.6	2.6
manure	0.6	0.6	0.6	0.6	0.6
TVC	9.5	9.5	9.5	9.5	9.5
TC(FC+TVC)	9.543	9.543	9.543	9.543	9.543
Profit(TR-TC)	0.3105	2.026833	-1.10258	4.45725	-4.64733
Profit/4	0.069025	0.498108	-0.28425	1.105713	-1.17043
Gross Margin	0.180921	0.019133	-0.34025	0.297635	-3.70355
Gross Profit Margin	-32.007	-68.8556	-87.008	-46.7988	-409.493
Benefit/Cost	2.761681	4.014045	2.661832	4.949184	1.839431
Contributing margin per unit	-1.25	-1.25	-1.25	-1.25	-1.25
Breakeven point	-0.13856	-0.13856	-0.13856	-0.13856	-0.13856

APPENDIX 18: Extrapolated experimental values for Fish sole culture

	Fish per ha				
	S8R	N19L	S8L	N19R	S8
QTY (kg)	1576.66667	1232.593	1112.963	1417.778	408.5185
Price (USD5)	7	7	7	7	7
QTY*Price(TR)	11036.6667	8628.148	7790.741	9924.444	2859.63
Land (Fixed Cost)	47.7777778	47.77778	47.77778	47.77778	47.77778
Labor	1944.44444	1944.444	1944.444	1944.444	1944.444
Fingerling	3111.11111	3111.111	3111.111	3111.111	3111.111
feed	2888.88889	2888.889	2888.889	2888.889	2888.889
manure	333.333333	333.3333	333.3333	333.3333	333.3333
TVC	8277.77778	8277.778	8277.778	8277.778	8277.778
TC(FC+TVC)	8325.55556	8325.556	8325.556	8325.556	8325.556
Profit(TR-TC)	2711.11111	302.5926	-534.815	1598.889	-5465.93
Profit/4	677.777778	75.64815	-133.704	399.7222	-1366.48

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Gross Margin	272.939808	38.96711	-76.275	179.0068	-2123.79
Gross Profit Margin	27293.9808	3896.711	-7627.5	17900.68	-212379
Benefit/Cost	1472.93029	1151.494	1039.736	1324.495	381.6401
Contributing margin per unit	-500	-500	-500	-500	-500
Breakeven point	-106.17284	-106.173	-106.173	-106.173	-106.173

APPENDIX 19: Extrapolated experimental values for rice sole culture

	Rice/ha				
	S8R	N19L	S8L	N19R	S8
QTY (kg)	3713.333	6340	3941.111	7907.778	3044.444
Price (USD5)	1.25	1.25	1.25	1.25	1.25
QTY*Price(TR)	4641.667	7925	4926.389	9884.722	3805.556
Land (Fixed Cost)	38.22222	38.22222	38.22222	38.22222	38.22222
Labor	1944.444	1944.444	1944.444	1944.444	1944.444
Fingerling	0	0	0	0	0
feed	0	0	0	0	0
manure	333.3333	333.3333	333.3333	333.3333	333.3333
TVC	2277.778	2277.778	2277.778	2277.778	2277.778
TC(FC+TVC)	2277.778	2277.778	2277.778	2277.778	2277.778
Profit(TR-TC)	2363.889	5647.222	2648.611	7606.944	1527.778
Profit/4	581.4167	1402.25	652.5972	1892.181	372.3889
Gross Margin	556.7125	786.4003	588.7542	850.7767	434.9067
Gross Profit Margin	5.567125	7.864003	5.887542	8.507767	4.349067
Benefit/Cost	2226.86	3802.053	2363.457	4742.239	1825.732
Contributing margin per unit	-888.889	-888.889	-888.889	-888.889	-888.889
Breakeven point	-47.7778	-47.7778	-47.7778	-47.7778	-47.7778

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APPENDIX 20: Extrapolated experimental values for rice-fish integrated culture

	Integrated				
	S8R	N19L	S8L	N19R	S8
QTY (kg)	5290	7572.59	5054.07	9325.56	3452.96
Price (USD5)	8.25	8.25	8.25	8.25	8.25
QTY*Price(TR)	15678.33	16553.14815	12717.13	19809.17	6665.19
Land (Fixed Cost)	86	86	86	86	86
Labor	3888.89	3888.89	3888.89	3888.89	3888.89
Fingerling	3111.11	3111.11	3111.11	3111.11	3111.11
feed	2888.89	2888.89	2888.89	2888.89	2888.89
manure	666.67	666.67	666.67	666.67	666.67
TVC	10555.56	10555.56	10555.56	10555.56	10555.56
TC(FC+TVC)	10603.33	10603.33	10603.33	10603.33	10603.33
Profit(TR-TC) ($)	5075	5949.82	2113.79	9205.83	-3938.15
Profit/4	1259.19	1477.89	518.89	2291.90	-994.09
Gross Margin	829.65	825.37	512.48	1029.78	-1688.88
Gross Profit Margin	27299.548	3904.57	-7621.61	17909.19	-212374
Benefit/Cost	3699.79	4953.55	3403.19	6066.73	2207.37
Contributing margin per unit	-1388.88	-1388.88	-1388.88	-1388.88	-1388.88
Breakeven point	-153.95	-153.95	-153.95	-153.95	-153.95

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APPENDIX D: FISH GROWTH RAW DATA

Treatments	BODY WEIGHT (BW) IN (g) FOR THE MONTH OF JUNE				
S8R	9	10.6	10	10	7
	40	19	15	23	13
	34	13	24	7	4
N19L	23	22	9	15	28
	8	4	11	7	24
	6	8	7	6	5
S8L	9	25	7	5	11
	26	15	11	9	5
	29	36	19	10	23
N19R	24	16	12	7	10
	37	27	11	30	14
	9	31	5	12	16
S8	14	5	3	6	4
	12	13	12	11	20
	23	28	4	15	5

Treatments	TOTAL LENGTH (TL) IN (cm) FOR THE MONTH OF JUNE				
S8R	11.2	8.6	8.5	10	10.8
	12.5	9.7	9.8	10	8.9
	11.5	8	10.2	8	7
N19L	9	9.5	7.3	9	10.5
	7.2	6	8.2	7	10.5
	6	7	8	6.5	5.2
S8L	7	11	7	6	8
	12	9	8	7.5	6
	11.3	11.8	10	8	10.1
N19R	10.3	9	8	6	7
	12.5	12.4	8	11	9
	8.5	11.5	6	8	7
S8	8.5	5.3	5.3	6	6.2
	8.5	8.5	8	8	9.5
	10.5	10.6	6.5	9.5	7

Treatments	BODY WEIGHT (BW) IN (g) FOR THE MONTH OF JULY				
S8R	45	20	13	15	19
	57	35	21	47	25
	37	35	24	44	37
N19L	14	37	22	29	24
	43	17	12	13	22
	19	9	49	15	13
S8L	22	20	31	24	15
	38	34	19	15	17
	48	44	63	22	48
N19R	50	20	26	16	12
	46	38	47	30	45

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	38	42	33	37	32
S8	14	17	12	11	13
	31	36	20	24	24
	21	21	35	16	20

Treatments	TOTAL LENGTH (TL) IN (cm) FOR THE MONTH OF JULY				
S8R	14.5	10	9	10	10.5
	14.5	12.5	11	14	10.3
	12	12	11	12.7	12.5
N19L	9.5	10	10.5	12	10.5
	13	10	9	9	10
	10	8	14	9	9
S8L	9.5	10.5	12.3	11	9.5
	12.5	12.5	10.4	9.5	9.8
	13	14	14.5	10	15
N19R	13.5	10.5	11.5	9.5	8.5
	14	13	13.5	11.5	13
	12.5	13.2	12	12.5	12
S8	9	10	9	8	10
	11.5	12	10.5	10.8	11
	10.5	10	12	9	9.8

Treatments	BODY WEIGHT (BW) IN (g) FOR THE MONTH OF AUGUST				
S8R	67	39	28	31	38
	73	68	57	59	71
	61	62	53	54	59
N19L	57	57	55	40	39
	64	42	57	30	39
	130	130	64	27	20
S8L	180	59	30	22	24
	52	43	43	34	32
	61	61	26	22	22
N19R	88	172	69	68	33
	87	67	67	69	54
	71	70	72	60	57
S8	34	29	20	16	14
	36	26	27	24	21
	19	13	8	26	28

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Treatments	TOTAL LENGTH (TL) IN (cm) FOR THE MONTH OF AUGUST				
S8R	15.5	13	11.5	11.5	12.5
	16	15.3	12.5	14	16
	15	14.8	13	14	14.2
N19L	14	14	11.5	12.4	12.6
	15	13.2	14	11.5	12.5
	12	12.5	15	11.5	11
S8L	19	14.5	12.3	11.5	12.5
	14.5	14.5	13	12.5	12
	15.5	15.5	11.5	10.5	12
N19R	16.5	14.4	14.5	15.5	13.2
	16	16	15.2	15.2	14.3
	15	15.5	16	14.5	15
S8	12.3	12	10.9	10	95
	12.7	11.5	11.6	11	10.5
	10.4	8.5	7	10.2	11.2

Treatments	BODY WEIGHT (BW) IN (g) FOR THE MONTH OF SEPTRMBER				
S8R	102	91	39	58	54
	91	71	111	111	98
	91	63	66	63	66
N19L	72	72	56	61	45
	42	52	49	38	56
	149	147	38	27	29
S8L	192	51	60	50	58
	78	68	64	47	39
	90	69	42	43	59
N19R	100	103	95	92	89
	84	82	85	68	73
	80	75	92	68	62
S8	70	41	42	84	19
	17	32	29	31	29
	30	41	30	22	41

Treatments	TOTAL LENGTH (TL) IN (cm) FOR THE MONTH OF SEPTEMBER				
S8R	17	17.6	12.9	14.5	14.4
	17.5	15.5	18	17.9	17.5
	16.4	15	15.2	14.5	14.5
N19L	15.5	16.3	14	15	13.4
	13.5	14	13.5	12.7	14.5
	13.5	13	13	11.7	11.5
S8L	22	14	14.5	15	15
	16	15.5	15.5	13.8	13
	16.8	16	13.5	13.5	11.5
N19R	16.5	18	17.5	16.5	15.5
	15.6	16.2	16.6	15.3	16
	16.5	16.5	16.5	16.5	15.5
S8	15.5	13	13.5	12	10.5
	11.2	12	12.2	12.4	11.5
	11.5	13.5	12	11	13

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Treatments	BODY WEIGHT (BW) IN (g) FOR THE MONTH OF OCTOBER				
S8R	113	101	98	116	97
	112	119	126	101	118
	93	86	96	85	91
N19L	94	83	77	86	75
	84	74	87	90	67
	185	185	102	101	82
S8L	78	72	69	70	66
	81	72	72	69	65
	96	73	76	75	150
N19R	99	83	102	80	70
	88	86	98	75	89
	186	97	93	84	79
S8	73	38	45	33	24
	39	39	39	37	28
	33	31	22	35	42

Treatments	TOTAL LENGTH (TL) IN (cm) FOR THE MONTH OF OCTOBER				
S8R	18.4	18	18.3	19	18
	18.5	18.5	18.5	18	18.2
	16.5	16.5	17	16.5	17.2
N19L	17	16.4	16	16.5	16
	16.5	16.5	16.5	17	14.5
	12.8	12.8	11.4	11.4	12
S8L	17.6	16	16	15.5	15.5
	16.5	16.5	16.7	15.7	15
	17.2	16	16.5	15.6	20.5
N19R	18	16	17.5	16	16
	16.8	17	17.5	16	17
	22.5	17	17	16.5	16
S8	16	13	14	12.5	12
	13	13	13	13	12
	12	12	10.5	12.5	13.5

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APPENDIX E: CONDITION INDEX RAW DATA

CONDITION FACTOR(K) FOR JUNE

Treatments	k	K2	K3	K4	K5	AVG	SD	SE
S8R	0.6406	1.6665	1.6283	1	0.5557	1.6619	0.6134	0.1584
	2.048	2.0818	1.5937	2.3	1.8441			
	2.2355	2.5391	2.2616	1.3672	1.1662			
N19L	3.1550	2.5659	2.3135	2.0576	2.4187	2.3222	0.5342	0.1379
	2.1433	1.8519	1.9950	2.0408	2.0732			
	2.7777	2.3324	1.3672	2.1848	3.556			
S8L	2.6239	1.8783	2.0408	2.3148	2.1484	2.0968	0.2503	0.0646
	1.5046	2.0576	2.1484	2.1333	2.3148			
	2.0098	2.1911	1.9	1.9531	2.2323			
N19R	2.1963	2.1948	2.3438	3.2407	2.9155	2.3568	0.7889	0.2037
	1.8944	1.4161	2.1484	2.2539	1.9204			
	1.4655	2.0383	2.3148	2.3438	4.6647			
S8	2.2797	3.3585	2.0151	2.7778	1.6784	2.1338	0.4932	0.1274
	1.9539	2.1168	2.3438	2.1484	2.3327			
	1.9868	2.3509	1.4565	1.7495	1.4577			

CONDITION FACTOR(K) FOR JULY

Treatments	k	K2	K3	K4	K5	AVG	SD	SE
S8R	1.4761	2	1.7833	1.5	1.6413	1.8435	0.2434	0.0628
	1.8697	1.792	1.5778	1.7128	2.2878			
	2.1412	2.0255	1.8032	2.1480	1.8944			
N19L	1.6329	3.7	1.9004	1.6782	2.0732	1.9704	0.5070	0.1309
	1.9572	1.7	1.6461	1.7833	2.2			
	1.9	1.7578	1.7857	2.0576	1.7833			
S8L	2.5659	1.7277	1.6659	1.8032	1.7495	1.8614	0.2874	0.0742
	1.9456	1.7408	1.6891	1.7495	1.8062			
	2.1848	1.6035	2.0665	2.2	1.4222			
N19R	2.0322	1.7277	1.7095	1.8662	1.954	1.8703	0.1167	0.0301
	1.6764	1.7296	1.9103	1.9725	2.0482			
	1.9456	1.8261	1.9097	1.8944	1.8519			
S8	1.9204	1.7	1.6461	2.148	1.3	1.9021	0.2419	0.0625
	2.0383	2.0833	1.7277	1.9052	1.8032			
	1.8141	2.1	2.0255	2.1948	2.1249			

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CONDITION FACTOR(K) FOR AUGUST

Treatments	k	K2	K3	K4	K5	AVG	SD	SE
S8R	1.7992	1.7751	1.8410	2.0383	1.9456	2.0029	0.3088	0.0797
	1.7822	1.8986	2.9184	2.1501	1.7334			
	1.8074	1.9125	2.4124	1.9679	2.0606			
N19L	2.0773	2.07726	3.6163	2.0979	1.9496	2.7294	1.8361	0.4741
	1.8963	1.8261	2.07726	1.9725	1.9968			
	7.5231	6.656	1.8963	1.7753	1.5026			
S8L	2.6243	1.9353	1.6122	1.4465	1.2288	1.7115	0.3388	0.0875
	1.7057	1.4105	1.9572	1.7408	1.8519			
	1.6381	1.6381	1.7095	1.9004	1.2731			
N19R	1.9589	5.7602	2.2633	1.8261	1.4348	2.1414	1.0220	0.2639
	2.1240	1.6357	1.9078	1.9648	1.8467			
	2.1037	1.8798	1.7578	1.9681	1.6889			
S8	1.8271	1.6782	1.5444	1.6	0.0016	1.7364	0.5455	0.1408
	1.7575	1.7095	1.7298	1.8032	1.8141			
	1.6891	2.1168	2.3324	2.4500	1.9929			

CONDITION FACTOR(K) FOR SEPTEMBER

Treatments	k	K2	K3	K4	K5	AVG	SD	SE
S8R	2.0761	1.6692	1.8168	1.9025	1.8084	1.9057	0.1395	0.0360
	1.6979	1.9066	1.9033	1.9354	1.8286			
	2.0631	1.8667	1.8794	2.0665	2.1649			
N19L	1.9335	1.6625	2.0408	1.8074	1.8702	2.4446	1.6033	0.4139
	1.7071	1.8950	1.9916	1.8551	1.8369			
	6.0559	6.6909	1.7296	1.6858	1.9068			
S8L	1.8032	1.8586	1.9681	1.4815	1.7186	1.9173	0.5549	0.1433
	1.9043	1.8261	1.7186	1.7884	1.7752			
	1.8981	1.6846	1.7071	1.7477	3.8793			
N19R	2.2261	1.7661	1.7726	2.0480	2.3899	1.9040	0.2405	0.0621
	2.2126	1.9287	1.8582	1.8986	1.7822			
	1.7809	1.6696	2.0480	1.5138	1.6649			
S8	1.8798	1.8662	1.7071	4.8611	1.6413	1.9361	0.8302	0.2143
	1.2100	1.8519	1.5971	1.6259	1.9068			
	1.9725	1.6664	1.7361	1.6529	1.8662			

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CONDITION FACTOR(K) FOR OCTOBER

Treatments	k	K2	K3	K4	K5	AVG	SD	SE
S8R	1.8139	1.7318	1.5991	1.6912	1.6632	1.8297	0.1346	0.0348
	1.7689	1.8795	1.9900	1.7318	1.9573			
	2.0703	1.9145	1.9539	1.8922	1.7884			
N19L	1.9133	1.8817	1.8799	1.9145	1.8311	3.6662	2.7556	0.7115
	1.8699	1.6473	1.9367	1.8319	2.1977			
	8.8215	8.8215	6.8847	6.8172	4.7454			
S8L	1.4307	1.7578	1.6846	1.8798	1.7723	1.7508	0.1454	0.0375
	1.8032	1.6028	1.5459	1.7829	1.9259			
	1.8866	1.7822	1.6918	1.9755	1.7411			
N19R	1.6975	2.0264	1.9032	1.9531	1.7089	1.8444	0.11034	0.0285
	1.8559	1.7505	1.8286	1.8311	1.8115			
	1.6329	1.9744	1.8929	1.8699	1.9287			
S8	1.7822	1.7296	1.6399	1.6896	1.3889	1.7309	0.1250	0.0323
	1.7751	1.7751	1.7751	1.6841	1.6204			
	1.9097	1.7939	1.9004	1.792	1.7071			

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APPENDIX F: RICE GROWTH RAW DATA

JUNE DATA ON RICE GROWTH (Treatment one S8R)

S8R P.Height	S8R P.Height	S8R P.Height	S8R # of tillers	S8R # of tillers	S8R # of tillers
85	82	72	13	14	9
78	73	73	10	9	5
73	82	76	7	12	13
71	76	67	12	10	6
78	77	75	7	10	6
72	82	76	16	14	11
74	81	74	10	7	7
75	77	74	8	8	11
75	78	73	6	6	13
80	74	78	7	14	8
72	84	76	11	9	8
76	79	78	5	13	16
75	72	76	9	8	11
73	80	69	8	11	13
74	74	75	11	13	10

JUNE DATA ON RICE GROWTH (Treatment two N19L)

N19L P.Height	N19L P.Height	N19L P.Height	N19L # of tillers	N19L # of tillers	N19L # of tillers
75	81	66	10	10	6
70	78	68	9	9	5
66	78	64	6	11	4
75	71	68	11	5	6
74	64	64	7	4	4
74	68	68	13	6	4
77	65	70	12	7	7
73	70	66	10	10	6
69	70	61	9	10	4
70	60	64	11	5	5
76	67	73	17	6	4
73	66	65	13	6	6
74	69	67	9	9	4
74	60	70	9	5	5
68	72	65	8	7	6

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JUNE DATA ON RICE GROWTH (Treatment three S8L)

S8L P.Height	S8L P.Height	S8L P.Height	S8L # of tillers	S8L # of tillers	S8L # of tillers
62	62	70	13	5	3
60	70	75	5	5	3
64	68	69	9	4	3
65	78	76	8	9	3
66	73	78	13	8	4
67	72	71	12	10	4
64	71	68	9	8	4
65	72	73	14	8	4
64	63	69	5	6	4
65	66	74	12	4	4
67	72	74	8	6	6
62	70	70	6	5	4
64	71	72	10	6	4
63	78	72	8	6	3
65	72	69	9	8	4

JUNE DATA ON RICE GROWTH (Treatment Four N19R)

N19R P.Height	N19R P.Height	N19R P.Height	N19R # of tillers	N19R # of tillers	N19R # of tillers
70	73	67	3	6	3
75	69	63	3	4	3
69	62	60	3	5	3
76	60	65	3	9	5
78	63	67	4	4	4
71	67	66	4	5	4
68	70	58	4	4	3
73	69	65	4	6	4
74	70	72	6	6	3
70	74	62	4	5	3
72	76	68	4	6	4
72	71	67	3	5	3
69	69	69	4	6	4
74	71	65	4	5	3
72	70	66	4	5	4

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JUNE DATA ON RICE GROWTH (Treatment Five S8)

S8 P.Height	S8 P.Height	S8 P.Height	S8 # of tillers	S8 # of tillers	S8 # of tillers
66	62	66	6	6	5
60	63	71	6	7	6
62	63	69	4	7	6
66	71	67	5	6	4
65	64	70	5	6	4
68	67	67	5	5	5
64	63	70	6	4	5
64	63	68	5	8	6
59	60	70	5	5	5
61	62	67	4	5	6
64	67	62	5	8	6
60	62	66	4	5	4
66	66	64	4	6	8
60	62	63	5	7	5
64	65	64	5	6	6

JULY DATA ON RICE GROWTH (Treatment ONE S8R)

S8R P.Height	S8R P.Height	S8R P.Height	S8R # of tillers	S8R # of tillers	S8R # of tillers
108	127	101	8	21	12
122	130	125	5	16	13
101	120	134	10	19	9
124	130	126	10	10	10
115	130	142	8	18	12
110	129	141	11	7	11
106	118	133	8	10	14
108	130	129	10	22	11
122	114	141	10	19	9
126	112	138	13	18	8
97	118	130	12	13	23
115	130	128	8	8	28
108	152	120	7	13	22
129	130	128	18	10	14
122	122	127	11	17	15

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JULY DATA ON RICE GROWTH (Treatment TWO N19L)

N19L P.Height	N19L P.Height	N19L P.Height	N19L # of tillers	N19L # of tillers	N19L # of tillers
110	107	110	12	12	9
126	108	110	13	5	11
118	115	100	9	8	11
123	112	110	10	7	11
129	108	110	12	12	7
127	120	122	11	10	8
135	93	100	14	5	7
127	108	108	11	11	9
120	110	110	9	7	5
128	103	116	8	12	7
128	96	123	23	10	7
104	113	123	28	5	7
130	115	118	22	14	7
140	118	117	14	12	7
127	98	110	15	11	8

JULY DATA ON RICE GROWTH (Treatment THREE S8L)

S8L P.Height	S8L P.Height	S8L P.Height	S8L # of tillers	S8L # of tillers	S8L # of tillers
119	100	112	20	15	11
107	104	112	16	13	12
118	122	117	12	14	13
112	118	90	9	9	15
123	130	105	17	14	17
118	123	120	15	11	10
126	123	124	20	12	13
122	130	107	11	9	11
130	129	119	10	15	15
107	123	130	17	15	7
126	124	106	21	20	15
122	231	118	17	7	11
122	126	115	14	10	9
120	126	117	17	11	22
116	108	115	14	12	14

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JULY DATA ON RICE GROWTH (Treatment FOUR N19R)

N19R P.Height	N19R P.Height	N19R P.Height	N19R # of tillers	N19R # of tillers	N19R # of tillers
100	112	109	4	10	9
122	93	112	6	9	3
115	117	120	5	14	6
120	116	112	2	8	5
116	103	113	5	9	7
122	104	117	6	6	6
120	110	124	6	7	5
127	108	99	7	9	6
124	119	119	7	7	6
124	108	117	4	11	5
118	102	117	6	4	5
109	107	112	7	6	4
112	112	120	4	4	5
107	102	108	4	5	4
121	115	122	7	6	8

JULY DATA ON RICE GROWTH (Treatment FIVE S8)

S8 P.Height	S8 P.Height	S8 P.Height	S8 # of tillers	S8 # of tillers	S8 # of tillers
111	100	99	13	15	8
117	101	101	18	16	20
119	106	108	18	12	13
112	108	114	12	15	12
97	100	114	11	13	10
117	101	113	13	6	8
116	105	94	10	14	11
117	113	105	18	17	9
117	106	108	13	15	19
120	109	112	17	16	11
119	114	111	19	9	9
106	118	114	13	17	16
116	116	106	15	15	12
118	108	109	17	18	11
109	112	108	13	14	13

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PLANT WET BIOMASS (RICE)															
S8R	24	49	42	50	52	32	39	29	32	34	32	32	31	37	16
	52	21	31	31	52	34	38	29	32	44	23	41	37	42	22
	31	27	33	42	36	41	53	34	38	24	26	46	23	31	37
N19L	21	21	27	26	14	18	33	20	27	22	23	19	25	16	23
	17	10	14	19	14	13	13	15	36	24	21	16	16	24	23
	12	25	18	20	8	17	14	13	15	17	17	12	15	7	6
S8L	51	37	33	39	29	32	38	34	42	34	20	48	38	25	30
	16	29	37	32	27	37	27	38	27	27	26	39	18	23	23
	23	13	21	22	17	17	14	16	16	23	14	19	23	21	12
N19R	20	26	23	32	25	27	21	23	18	25	28	24	18	22	14
	23	14	16	21	21	23	11	24	16	16	18	21	18	22	14
	21	25	18	20	15	12	18	20	19	22	22	19	14	13	12
S8	20	19	16	18	22	12	26	20	17	10	12	11	14	26	14
	15	19	13	9	17	12	16	22	25	16	25	11	14	26	14
	16	18	10	16	15	32	24	30	9	18	32	25	20	19	15

PLANR DRY BIOMASS (RICE)															
S8R	9	9	10	8	7	6	10	9	6	8	7	7	7	8	8
	7	5	9	6	7	8	7	8	11	9	6	4	6	9	9
	6	9	7	7	9	8	7	7	9	6	12	9	9	9	8
N19L	6	12	10	9	8	5	7	5	12	11	12	11	9	10	8
	13	7	17	6	12	10	6	6	6	8	11	10	6	6	8
	19	7	8	10	12	5	10	14	11	8	10	12	6	9	9
S8L	7	8	7	5	7	9	6	6	6	6	3	6	5	4	4
	9	7	10	6	7	7	7	7	7	7	6	6	6	5	9
	6	6	6	3	4	5	5	6	4	7	6	4	4	4	5
N19R	7	9	7	10	11	10	9	8	10	8	7	7	7	9	15
	11	12	9	13	10	9	11	9	6	6	9	8	6	6	6
	11	8	6	11	9	12	10	15	14	10	7	13	11	7	8
S8	6	7	4	5	4	6	5	7	7	7	7	7	5	5	10
	8	6	4	7	5	4	5	5	6	4	6	7	5	3	3
	8	7	5	6	5	3	5	4	4	7	8	6	7	4	6

RICE YIELD DATA FOR THE TWO VARIETIES															
S8R	9	9	10	8	7	6	10	9	6	8	7	7	7	8	8
	7	5	9	6	7	8	7	8	11	9	6	4	6	9	9
	6	9	7	7	9	8	7	7	9	6	12	9	9	9	8
N19L	6	12	10	9	8	5	7	5	12	11	12	11	9	10	8
	13	7	17	6	12	10	6	6	6	8	11	10	6	6	8
	19	7	8	10	12	5	10	14	11	8	10	12	6	9	9

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S8L	7	8	7	5	7	9	6	6	6	6	3	6	5	4	4
	9	7	10	6	7	7	7	7	7	7	6	6	6	5	9
	6	6	6	3	4	5	5	6	4	7	6	4	4	4	5
N19R	7	9	7	10	11	10	9	8	10	8	7	7	7	9	15
	11	12	9	13	10	9	11	9	6	6	9	8	6	6	6
	11	8	6	11	9	12	10	15	14	10	7	13	11	7	8
S8	6	7	4	5	4	6	5	7	7	7	7	7	5	5	10
	8	6	4	7	5	4	5	5	6	4	6	7	5	3	3
	8	7	5	6	5	3	5	4	4	7	8	6	7	4	6

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APPENDIX G: PHYSICOCHEMICAL PARAMETERS RAW DATA

JUNE pH VALUES FOR ALL TREATMENT

S8R	10.8	6.5	8.4	8.4	7.6	8.6	8.4	8.8	8.5	9.2	8.3	8.1
	10.5	6.5	8	8.1	8	8.5	8.3	8.6	8.3	9.1	8.1	7.8
	10.3	6.5	8	8	7.8	8.3	8	8.4	8.1	8.9	8	7.7
N19L	10	7.1	8.1	8.1	8	8.4	8.1	8.4	8.2	8.9	8.1	7.8
	10	6	8.3	8.3	8.2	8.4	8.3	8.4	8.3	9	8.2	8
	9.5	6.5	8.1	8	7.9	7.9	8.2	8.1	8.1	8.6	7.9	7.8
S8L	9.4	7.5	8	7.9	7.9	7.9	8	7.8	7.9	8.4	7.8	7.6
	9	7.3	7.8	7.6	7.7	7.8	7.8	7.6	7.7	8.1	7.6	7.5
	9.1	7.5	7.9	7.8	7.8	7.8	7.8	7.8	7.9	8.2	7.7	7.6
N19R	8.8	7.2	7.7	7.4	7.4	7.5	7.6	7.6	7.7	8	7.5	7.4
	8.6	7.3	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.8	7.3	7.4
	8.4	7.2	7.9	7.6	7.4	7.5	7.5	7.5	7.6	7.8	7.4	7.4
S8	8.4	7.2	7.6	7.4	7.3	7.3	7.5	7.4	7.4	7.7	7.3	7.3
	8.4	7.3	7.5	7.5	7.2	7.3	7.4	7.3	7.3	7.6	7.2	7.2
	8.4	7.4	7.5	7.4	7.3	7.3	7.4	7.3	7.4	7.6	7.2	7.2

JUNE TEMPERATURE VALUES FOR ALL TREATMENT

S8R	27.7	28	27.9	29.4	28	28.8	26	29.2	27.4	27	27.6	27.6
	27.6	27	27.4	28.4	28.4	27.7	26.1	27.9	27.3	26.9	27.3	27.3
	27.5	27	27	29.1	28.2	27.2	26	27.5	27.2	26.8	27.2	27.2
N19L	27	27	27	28.7	28.2	26.8	25.9	27.4	27.1	26.6	27.1	27.1
	27.8	27	27	28.5	28.2	26.5	25.1	27.2	27	26.6	27.1	27.1
	27	27.8	27	28.3	28.2	26.3	28.8	27	27	26.5	26.2	26.2
S8L	27.9	27.7	27	28.1	28.1	26	25.8	26.9	26.9	26.6	26.8	26.8
	28.1	27.6	26.9	28	28	25.9	25.8	26.5	26.9	26.5	26.7	26.7
	27.8	27.6	26.9	27.9	28.1	25.9	25.8	26.6	26.9	26.5	26.7	26.7
N19R	27	27.4	26.9	28	28	25.7	25	26.5	26.8	26.4	26.7	26.7
	27.8	27.3	26.9	27.9	28	25.8	25.7	26.5	26.9	26.3	26.7	26.7
	28	27.3	26.8	27.8	28	25.7	25.7	26.6	26.8	26.4	26.8	26.8
S8	28	27.3	26.8	27.8	28	25.6	27.7	26.4	26.8	26.4	26.8	26.8
	27	27.1	26.8	27.8	28	25.7	25.7	26.4	26.7	26.3	26.7	26.7
	29.9	27.4	26.9	27.8	28	26	25.7	26.4	26.7	23.3	26.8	26.8

JUNE DISSOLVED OXYGEN VALUES FOR ALL TREATMENT

S8R	2.5	5.3	3.24	3.35	5.63	6.59	5.76	3.31	10.24	10.4	6.29	8.39
	0.85	12	4.67	2.84	5.01	4.11	3.2	3.26	5.74	6.72	4.51	7.43
	0.43	9.9	6.79	3.94	3.66	3.99	3.35	3.82	4.61	5.86	4.8	6.59
N19L	2.14	12.3	6.52	3.7	3.91	3.31	3.1	3.78	3.85	4.18	3.84	7.48

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	1.26	9.2	5.58	5.01	3.56	2.55	2.18	3.1	3.39	3.36	3.71	7.3
	5.18	13.4	3.66	3.52	3.28	2.59	2.93	3.77	2.69	2.85	2.57	6.77
S8L	3.85	10.1	6.52	3.91	2.48	2.41	2.25	4.55	3.32	3.09	3.23	7.34
	3.41	6	6.94	3.37	2.45	2.59	2.2	3.31	3.15	3.06	3.13	9.4
	3.89	5.1	4.37	3.31	3.2	1.25	3.12	3.19	2.89	2.8	3.15	6.63
N19R	4.54	3.8	3.78	3.35	2.45	3.25	3.2	3.82	2.89	2.7	2.33	6.48
	3.86	4.4	3.58	4.56	3.4	3.64	3.29	3.89	2.73	2.51	3.23	5.11
	3.84	2.3	6.72	3.42	3.8	2.55	2.3	3.98	2.23	3.2	3.13	6.33
S8	3.57	2.2	4.51	4.01	3.5	3.2	2.8	3.98	2.37	2.36	3.48	6.32
	3.82	4.2	4.72	4.55	4.1	3.11	3.4	3.63	2.45	2.4	3.54	6.6
	5.4	13.7	4.56	3.18	1.48	4.48	1.62	3.99	2.5	2.45	3.57	6.37

JULY pH VALUES FOR ALL TREATMENT

S8R	8.9	7.9	8	7.3	7.4	8.5	8.3	8.4	8.7	7.5	8.7	9.2
	8.5	7.8	7.9	7.2	7.2	8.3	8	8.5	8.6	7.4	8.4	9.1
	8.1	7.5	7.3	6.8	7	8.3	7.9	8.4	8.5	7.4	8.2	9
N19L	8	8.3	7.3	6.9	7	8.3	7.8	8.2	8.4	7.4	8	8.8
	8.2	8.5	7.6	7.3	7.4	8.5	7.7	8.2	8.2	7.3	7.5	8.6
	7.6	8.1	7.3	7	6.9	7.9	7.5	7.9	8	7.5	7.8	8.3
S8L	7.4	8	7.1	6.9	7	8.1	7.5	7.8	7.9	7.6	7.3	8.1
	7.8	8	7.6	7.3	7.2	8.1	7.5	7.8	7.9	7.7	7.1	8
	7.7	7.1	7.4	7.2	6.9	8.1	7.4	7.8	7.8	7.8	7.6	7.8
N19R	7.8	7	7.4	7.1	7	8.1	7.4	7.6	7.6	7.8	7	7.7
	6.7	7	6.6	6.3	6.6	7.4	6.6	6.9	7	8.7	7.2	7.2
	6.7	6.8	6.5	6.3	6.5	7.9	7.2	7.2	7.5	8.6	7.1	7.5
S8	7	6.5	6.8	6.7	6.6	8	7.3	7.4	7.5	8.4	7	7.5
	7	6.8	6.8	6.7	6.5	8	7.3	7.3	7.4	8.3	7.1	7.5
	7	6.7	6.8	6.7	6.5	7.9	7.3	7.3	7.4	8.2	7	7.5

JULY TEMPERATURE VALUES FOR ALL TREATMENT

S8R	28.7	28.6	30.6	28.8	27.2	30.1	27.3	28.1	27.9	28.5	28.8	28.1
	28.6	28.5	29.9	28.7	27.1	29.5	26.9	28.1	27.8	28.2	28.6	27.8
	28.3	28.3	29.8	28.5	27.1	29.2	26.9	28.1	27.7	28.1	28.5	27.8
N19L	28.3	28.3	29.6	28.4	27	29	26.9	28	27.7	28	28.4	27.8
	28	27.9	29.2	28.1	27	28.7	26.9	28	27.6	27.8	28.2	27.7
	28	27.7	28.9	27.9	26.9	28.8	27	27.8	27.5	27.7	28	27.6
S8L	27.8	27.6	28.7	27.7	27	28.6	27	27.7	27.4	27.5	28.7	27.5
	27.7	27.4	28.5	27.6	27	28.6	26.9	27.8	27.3	27.4	27.7	27.5
	27.7	27.4	28.4	27.5	26.9	28.5	26.9	27.7	27.3	27.4	27.7	27.5
N19R	27.6	27.1	28.1	27.5	26.9	28.4	26.7	27.8	27.1	27.3	27.5	27.4
	27.6	27.1	28.1	27.4	26.7	28.2	26.9	27.6	27.2	27.2	27.4	27.2
	27.4	27.1	28.1	27.4	26.8	28.6	27	27.5	27.1	27.2	27.4	27.5
S8	27.4	27.1	27.9	27.4	26.8	28.6	26.7	27.4	27.1	27.1	27.3	27.5
	27.4	27	28.2	27.3	26.9	28.4	26.9	27.4	27.1	27.1	27.3	27.4
	27.5	27.1	28.1	27.4	26.9	28.2	26.9	27.4	27.3	27.1	27.3	27.4

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JULY DISSOLVED OXYGEN VALUES FOR ALL TREATMENT

S8R	3.39	5.2	2.94	2.98	5.06	1.48	4.92	3.54	2.54	3.31	5.81	6.03
	3.39	5.25	3.18	2.09	4.73	1.38	4.93	3.47	4.54	5.32	5.78	5.32
	3.41	5.82	3.29	2.05	4.63	1.46	5.2	3.38	3.46	5.6	6.73	8.86
N19L	3.41	5.82	3.16	2.25	4.84	1.47	4.07	3.33	3.49	5.91	6.04	5.19
	3.56	4.8	2.95	2.07	4.21	1.39	3.02	3.21	3.36	5.67	5.52	4.28
	3.23	4.68	3.37	2.99	4.43	1.48	3.08	3.21	4.37	6.69	4.89	4.81
S8L	3.24	4.51	3.26	2.84	4.5	1.49	4.97	3.11	5.28	4.82	4.55	4.77
	3.34	4.29	3.34	1.6	3.98	1.63	3.92	3.07	3.27	4.93	3.6	4.01
	3.5	4.52	3.42	2.88	3.89	1.63	4.06	3.07	4.22	4.85	3.26	3.8
N19R	3.33	4.27	3.24	5.84	3.59	2.17	4.04	3.97	5.43	3.3	3.13	3.79
	4.63	4.82	3.94	3.28	5.11	2.89	4.25	3.07	5.43	6.89	3.79	4.13
	5.11	5.17	4.22	3.38	4.57	2.53	3.07	3.99	3.14	4.14	2.59	4.23
S8	4.57	4.99	3.95	3.97	4.37	2.34	3.97	3.92	3.16	4.32	2.17	3.88
	4.55	4.75	4.1	3.91	3.85	2.27	3.05	3.89	3.21	4.53	2.33	3.64
	4.58	4.81	4.83	3.99	3.64	2.21	3.95	3.89	5.16	5.16	2.33	3.18

AUGUST pH VALUES FOR ALL TREATMENT

S8R	8.7	8.2	8.3	8.2	8.8	8.9	7.5	9.3	9.5	8.6	7.8	8.6
	8.4	7.9	8.7	8.3	8.5	9.1	7.4	8.7	9	8.5	7.3	8.4
	8.4	7.7	8.3	8	7.9	9.1	7.4	8.2	8.5	8	7.5	7.6
N19L	8.2	7.6	8.4	7.8	7.8	8.8	7.3	8	8.4	8	8.1	7.6
	8	7.6	8.1	7.6	7.7	8.6	8.6	7.8	8.2	7.8	8.6	7.5
	7.8	7.4	8	7.6	7.5	8.4	8.3	7.2	8	7.6	7.4	7.3
S8L	7.8	7.5	8	7.6	7.4	8.2	8.1	7.4	7.9	7.6	7.3	7.4
	7.5	7.4	7.9	7.4	7.3	8.1	6.9	7.3	7.8	7.4	6.9	7.3
	7.5	7.3	7.8	7.4	7.3	8	7.4	7.7	7.6	7.5	6.9	7.3
N19R	7.3	7.1	7.7	7.2	7.1	7.9	7.4	7.3	7.7	7.4	7.1	7.1
	7.1	6.8	7.4	7	7	7.3	7.8	6.9	7.4	7.2	7.2	7
	7.4	6.9	7.5	7.2	7	7.7	7.3	7.2	7.5	7.3	8	7
S8	7.2	7	7.5	7.2	7.1	7.7	7	7.1	7.5	7.3	7.6	7.2
	7.1	7	7.5	7.2	7	7.6	7.5	6.9	7.5	7.3	7.8	7.2
	7	7.1	7.5	7.1	7	7.5	7.4	7.1	7.4	7.2	7.2	7

AUGUST TEMPERATURE VALUES FOR ALL TREATMENT

S8R	27.7	28.8	27.9	27.2	28.5	28.5	28.2	29.6	28.4	29	28.1	30.5
	27.4	28.4	27.9	27.1	28.2	28.2	26.9	29.5	28	28.4	28.4	30.4
	27.2	27.9	27.9	27	28.1	28.5	26.9	29.4	27.8	28.1	27.8	30
N19L	27.2	27.8	27.9	27	27.9	27.3	26.9	29.2	27.8	28	27.8	29.9
	27.1	27.7	27.8	26.9	27.8	27.2	26.9	29.2	27.7	27.9	27.8	29.9
	27	27.6	27.6	26.7	27.3	27.4	28.5	29	27.6	27.8	27.5	29.4
S8L	27	27.5	27.6	26.7	27.3	27	28.6	28.8	27.5	27.6	27.3	29.1
	27	27.4	27.6	26.6	27.4	27.3	27.2	28.7	27.5	27.6	27.4	29
	27	27.4	27.6	26.6	27.5	27.4	27.4	28.7	27.4	27.6	27.3	29

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N19R	26.9	27.4	27.6	26.5	27.6	27	27.8	28.6	27.4	27.5	27.9	29
	26.7	27.2	27.4	26.3	27.2	27	27.3	28.5	27.3	27.4	27	28.8
	27.1	27.6	27.5	26.5	27.1	27.9	27.3	28.4	27.3	27.4	27	28.6
S8	27.3	27.7	27.5	26.4	27	27.1	27	28.4	27.4	27.4	27.1	28.1
	27.2	27.6	27.5	26.4	26.9	27	27	28.3	27.3	27.3	27	27.9
	27	27.5	27.5	26.4	27	27	27	28.2	27.3	27.3	27	28

AUGUST DISSOLVED OXYGEN VALUES FOR ALL TREATMENT

S8R	2.25	2.95	5.79	2.3	6.8	3.31	3.97	3.98	3.11	5.34	3.33	2.72
	4.41	2.91	5.63	1.08	8.3	5.32	3.89	2.1	3.97	3.94	3.32	2.66
	3.92	3.56	5.29	1.37	7.8	5.6	3.85	2.24	3.21	4.87	5.32	28.2
N19L	3.94	3.99	5.18	2.91	6.69	5.93	3.92	2.14	3.55	3.59	4.32	2.87
	4.39	4.1	4.82	2.94	5.43	5.74	3.93	2.33	3.57	3.47	4.39	2.27
	4.08	4.15	4.92	2.11	5.47	6.81	4.99	3.65	3.74	7.3	4.65	2.71
S8L	3.37	3.2	3.91	2.18	6.73	7.32	4.79	3.34	3.67	4.32	4.56	2.33
	3.5	3.11	3.77	2.52	6.7	4.82	4.07	3.2	3.68	6.87	5.82	2.28
	3.45	3.45	3.65	2.69	6.8	5.81	4.88	3.18	3.74	4.83	4.82	2.67
N19R	3.51	3.25	3.38	3.05	4.52	3.98	3.98	3.14	3.82	3.72	5.86	2.69
	3.39	3.15	3.52	2.58	9.3	7.32	3.11	3.59	4.57	5.74	6.15	3.69
	3.73	3.3	3.25	2.43	8.3	4.83	3.67	3.36	3.84	8.5	5.78	2.56
S8	4.15	3.81	3.05	2.2	8.7	6.81	4.1	3.42	4.16	8.3	4.74	2.49
	3.84	3.18	2.9	2.12	6.7	5.47	4.79	4.35	4.15	6.5	3.74	2.61
	3.24	3.31	2.71	2.35	5.16	6.31	3.69	4.22	4.01	5.16	4.82	2.38

SEPTEMBER pH VALUES FOR ALL TREATMENT

S8R	9	8	8.2	8.1	7.9	7.8	7.2	7.3	7.6	7.5	6.6	7.3
	8.9	8	7.9	8	8.2	7.4	7.3	7.5	7.3	7.5	7.6	7.4
	8.8	7.6	7.4	7.6	7.5	7.1	7	7.5	6.9	7.2	7.2	7
N19L	8.6	7.6	7.3	7.4	7.3	6.9	7	6.7	6.8	7	7.1	7
	8.4	7.4	7.2	7.3	8	6.9	7	6.8	6.8	6.9	6.9	6.8
	8.1	7.3	7	7.1	8	6.9	6.9	6.8	6.8	6.8	7	6.9
S8L	8	7.3	7.1	7.1	7.8	6.9	6.9	7.3	6.8	6.9	7	6.8
	7.9	7.2	7.1	7	7.7	6.9	7	7	6.8	6.8	6.9	6.8
	7.8	7.2	7.1	7	6.8	6.9	6.9	6.8	6.7	6.7	6.8	6.8
N19R	7.7	7	6.9	6.8	6.8	6.6	6.8	6.8	6.7	6.7	6.8	6.8
	7.1	6.9	6.8	6.7	6.8	6.4	6.8	7.4	6.5	6.6	6.7	6.7
	7.3	6.9	6.9	6.7	7	6.7	6.9	7.3	6.8	6.7	6.7	6.7
S8	7.9	7.1	7	6.9	7	6.7	7	6.9	6.9	6.7	6.7	6.8
	7.4	7.1	7.1	6.9	7.6	6.8	7	6.3	7	6.7	6.7	6.8
	7.3	6.9	6.8	6.7	7.9	6.6	6.9	6.5	6.7	6.6	6.7	6.7

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	SEPTEMBER TEMPERATURE VALUES FOR ALL TREATMENT											
S8R	27.9	28.1	30.4	31.1	27.2	28.6	26.7	27.3	27.9	28.8	29.9	30.7
	27.6	28	30.1	30.7	27.5	28	26.5	27.7	27.4	28.1	29.5	30.1
	27.3	27.9	29.9	30.6	27.8	27.9	26.4	27.5	27.2	27.7	28.9	29.7
N19L	27.5	28	27.9	30.5	27	28	26.6	27	27.3	27.5	28.7	29.5
	27.8	27.8	29.6	30.3	29.2	28	26.7	27	27.2	27.4	28.7	29.2
	27.7	27.6	29.2	30.2	29.6	27.9	26.7	27.4	27.1	27.2	28.2	28.9
S8L	27.2	27.4	28.8	29.7	28.2	27.8	26.7	27.8	27	27	28.1	28.7
	27.2	27.4	28.7	29.7	28.6	27.7	26.6	27.7	26.9	26.9	28.2	28.5
	27.1	27.4	28.6	29.8	26.9	27.7	26.6	27.8	26.9	26.8	28.5	28.4
N19R	27.1	27.4	28.7	29.7	27.1	27.8	26.7	27	27	26.8	28.5	28.5
	27.1	27.3	28.5	29.7	28.3	27.8	26.5	27	26.9	26.8	28.1	28.5
	27.1	27.2	28.4	29.7	27.1	27.8	26.7	27.4	27.1	26.8	28.5	28.5
S8	26.9	27.1	28.1	29.4	27.8	27.6	26.6	28	26.9	26.8	28.1	28.2
	26.9	27.4	28	29.4	26.9	27.5	26.4	27	26.9	26.7	28	28
	26.9	27.2	28.1	29.4	26.8	27.5	26.4	27.6	26.8	26.7	28.1	28

	SEPTEMBER DISSOLVED OXYGEN VALUES FOR ALL TREATMENT											
S8R	3.29	3.32	3.41	3.33	6.42	3.89	3.29	4.41	3.35	3.84	3.93	3.29
	3.32	3.62	3.87	3.86	5.8	3.98	3.86	4.82	3.62	3.97	3.88	3.25
	3.33	3.81	3.57	4.94	6.41	3.78	4.15	4.12	3.8	4.05	4.04	3.19
N19L	3.32	3.77	3.3	3.45	6.81	3.87	4.14	5.32	3.4	4.56	3.59	0.89
	3.37	3.84	3.06	3.15	7.81	3.33	3.95	5.41	3.76	4.57	3.53	3.18
	3.35	4.02	3.02	3.58	4.32	4.08	4.45	3.93	3.69	4.77	3.78	3.7
S8L	3.3	3.57	3.42	2.94	4.41	3.58	3.95	6.32	3.2	4.55	3.57	3.42
	3.31	3.37	3.39	2.58	3.87	3.05	3.65	4.31	3.38	4.39	3.56	3.43
	3.31	3.27	3.36	2.58	3.92	3.21	3.34	3.41	3.34	4.49	3.71	3.38
N19R	3.3	3.34	3.39	2.95	4	2.81	3.37	3.82	3.44	4.46	3.67	3.42
	3.51	3.69	4	3.42	3.89	4.31	3.67	3.45	3.73	4.53	4.17	3.57
	3.51	2.87	3.56	3.27	3.75	3.18	3.2	3.94	3.32	4.36	4.04	3.45
S8	3.51	2.98	3.15	2.84	4.32	2.32	0.98	3.82	3.34	4.39	4	1.26
	3.45	3.32	3.04	2.66	5.4	2.38	0.88	3.94	3.6	4.42	3.73	1.15
	3.45	3.23	3.1	2.91	5.32	2.56	0.99	4.32	3.46	4.41	3.8	1.25

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	OCTOBER pH VALUES FOR ALL TREATMENT											
S8R	9.3	9.5	9.3	8.8	9.3	8.2	9.6	9.1	9.6	9.2	8.9	8.6
	9.3	9.5	9.6	8.8	9.5	8.9	9.8	9.4	9.7	9.3	9.1	8.5
	9.2	9.2	9.3	8.6	9.4	9.3	9.5	9.1	9.4	9.1	8.8	8.3
N19L	9.1	9.1	9.1	8.5	8.3	9	9.3	8.8	9	8.9	8.6	8.2
	9.1	9	8.9	8.5	8.6	8.9	9.1	8.7	8.9	8.7	8.5	8.1
	9	8.8	8.8	8.3	7.9	8.8	8.9	8.4	8.7	8.5	8.3	7.9
S8L	8.9	8.8	8.9	8.3	7.4	8.7	8.7	8.4	8.6	8.5	8.4	7.9
	8.9	8.7	8.8	8.3	7.4	8.6	8.7	8.3	8.5	8.3	8.1	7.7
	8.8	8.7	8.7	8.3	7.7	8.3	8.5	8.2	8.3	8.2	8.1	7.7
N19R	8.8	8.7	8.7	8.3	7.7	8.2	8.6	8.2	8.2	8.2	8.1	7.7
	8.7	8.4	8.4	8.1	7.1	8.3	8.2	8	8.2	7.9	7.8	7.3
	8.7	8.5	8.5	8.2	6.8	8.3	8.4	8.2	7.9	7.9	8	7.4
S8	8.7	8.5	8.5	8.2	6.4	8.2	8.3	8.1	7.9	7.8	7.8	7.4
	8.7	8.4	8.4	8.2	6.9	8.2	8.3	8.1	7.8	7.8	7.8	7.3
	8.6	8.3	8.5	8.4	6.3	8.3	8.3	8.1	7.8	7.8	7.7	7.3

	OCTOBER TEMPERATURE VALUES FOR ALL TREATMENT											
S8R	29.2	28.8	29	28.2	27	28.9	30.1	29.4	28.5	28.5	32.1	28.4
	28.6	28.6	28.7	28	26.9	28.3	29.3	28.1	27.7	27.7	31.5	28.1
	28.4	28.6	28.5	27.8	26.9	28	29	28	27.7	27.7	31.3	28.2
N19L	28.3	28.4	28.4	27.7	26.9	27.8	28.9	28	27.6	27.6	31.2	28.2
	28.3	28.3	28.3	27.6	26.8	27.6	28.7	28	27.5	27.5	31.1	28.1
	28.2	28.2	28.2	27.5	26.8	27.4	28.5	27.8	27.4	27.4	30.9	28
S8L	28.1	28.2	28.1	27.5	26.9	27.4	28.5	27.8	27.3	27.3	30.7	28
	28.1	28.2	28.1	27.5	26.8	27.3	28.4	27.8	27.3	27.3	30.8	28
	28.1	28.1	28	27.4	26.8	27.3	28.3	27.8	27.3	27.3	30.8	27.9
N19R	28.1	28.1	28	27.4	26.8	27.2	28.3	27.7	27.2	27.2	30.7	27.8
	28.1	28.1	27.8	27.2	26.6	27.1	28.1	27.7	27.3	27.3	31.1	27.7
	28.1	28.2	27.9	27.3	26.8	27.2	28.2	27.7	27.2	27.2	30.5	27.7
S8	28.1	28.2	27.9	27.3	26.7	27.2	28.2	27.7	27.2	27.2	30.3	27.8
	28	28.1	27.8	27.2	26.7	27.1	28.1	27.7	27.2	27.2	30.4	27.8
	27.9	28.1	27.9	27.3	26.8	27.1	28.1	27.6	27.2	27.2	30	27.8

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	OCTOBER DISSOLVED OXYGEN VALUES FOR ALL TREATMENT											
S8R	3.58	5.86	4.32	4.56	7.45	2.66	2.26	2.15	2.81	3.1	3.76	2.18
	6.07	6.92	4.71	3.98	5.29	3.55	3.15	2.28	2.49	2.39	1.27	2.19
	7.45	7.56	4.65	5.61	3.14	3.41	3.29	1.81	2.32	2.5	5.45	2.71
N19L	6.47	5.09	4.47	3.51	2.65	3.36	3	1.89	2.66	2.21	4.57	2.33
	2.62	7.22	5.21	3.31	1.72	3.23	2.98	2.15	2.58	2.47	4.25	2.64
	7.55	7.53	4.95	4.33	3.81	4.42	2.91	1.63	2.98	2.58	3.98	2.25
S8L	3.67	8.9	4.79	3.79	1.78	3.42	3.86	1.68	2.5	2.36	3.45	2.39
	3.3	5.59	4.37	1.48	1.81	2.12	2.35	1.95	2.53	2.37	3.65	2
	6.52	5.92	4	3.4	3.04	3.06	4.06	2.06	2.68	2.48	3.42	2.31
N19R	3.84	5.24	4.41	4.55	3.43	4.23	3.05	2.03	2.91	2.46	3.87	2.15
	10.2	7.51	6.5	5.5	3.98	3.9	3.85	2.84	3.36	3.13	3.88	2.66
	8.45	4.42	3.34	3.94	3.29	2.98	3.63	2.27	2.78	3.03	2.45	2.34
S8	5.1	5.71	3.17	3.64	4.12	3.63	2.96	1.89	2.21	2.45	2.32	2.11
	6.27	5.78	4.92	3.8	3.72	2.72	3.81	2.11	2.48	2.76	1.86	2.25
	5.64	5.42	5.89	4.28	4.42	3.69	2.9	1.78	2.58	2.79	2.88	2.06

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