NUTRIENT BUDGETING IN RICE BASED FARMING SYSTEM

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Nutrient budgeting in rice based farming system"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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LISTOF ABBREVIATIONS

AICRP	All India Co-ordinated Research Project
ANOVA	Analysis of Variance
B	Boron
B: C ratio	Benefit cost ratio
BOD	Biological Oxygen Demand
Ca	Calcium
CD	Critical difference
cm	centimetre
DAS	days after sowing
Day^{-1}	per day
DAT	days after transplanting
DO	dissolved oxygen
$dS\ m^{-2}$	deci Siemens per square metre
et al.	and co-workers/co-authors
Fig.	Figure
g	gram
$g\ m^{-2}$	gram per square metre
ha	hectare
ha^{-1}	per hectare
$hill^{-1}$	per hill
ICAR	Indian Council of Agricultural Research
i.e.	that is
IFSRS	Integrated Farming System Research Station
kg	kilogram
$kg\ ha^{-1}$	kilogram per hectare

K	Potassium
KAU	Kerala Agricultural University
m	metre
m^{-2}	per square metre
Mg	Magnesium
MOP	Muriate of Potash
MSL	mean sea level
N	Nitrogen
P	Phosphorus
$Plant^{-1}$	per plant
$Panicle^{-1}$	per panicle
POP	Package of Practices
REY	Rice Equivalent Yield
RH	relative humidity
S	Sulphur
SEm	Standard Error mean
$Trench^{-1}$	per trench
t	tonnes
t ha^{-1}	tonnes per hectare
viz.	namely
via	through
Zn	Zinc

LIST OF SYMBOLS

%	per cent
^{0}C	Degree Celsius
₹	Rupees
@	at the rate of
&	and

Introduction

1. INTRODUCTION

Rice is synonymous with food throughout Asia and more than 90 percent of the world's rice is grown and consumed in Asia (Khush, 2005). It is the single largest food source for the poor and the source of one quarter of global per capita. The cultivation of almost 90 percent of the world's rice crops in irrigated, rainfed and deep-water systems equivalent to about 134 million hectares (Halwart and Bartley, 2007).

In Kerala, the major crop rice is an integral part of the wetland ecosystem with specific ecological functions. However, the recent years have witnessed the rapid decline in paddy area. Over the last three decades, area under rice in Kerala declined from 8.5 lakh ha to 1.99 lakh ha (FIB, 2017). Paddy fields have been reclaimed and used for non-agricultural purposes or for cultivation of other crops. A practical way to increase output, in terms of produce, income and sustainability, under different situations is diversification. Diversification makes the cropping systems more remunerative.

Rice-rice-fallow was identified as the major rice based cropping system in the southern districts of Kerala (John *et al*., 2014). The summer rice fallows are major avenues for the cultivation of other remunerative crops like pulses, vegetables, tuber crops and short duration fodder crops. Instead of keeping the field fallow during summer, going for a cropping system approach can increase cropping intensity, economic returns as well as create diversity in the field. The summer crops like legumes are also considered to contribute to the yield of succeeding rice crop.

Integrated farming system has been identified as the most efficient way for increasing self sufficiency of farm holdings, mainly through enhancing the resource use efficiency. It mainly focuses on vertical diversification consisting of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment. Integration of resources is made through a combination of land, water and animal resources of a farm through careful recycling of bio-resources (Dash *et al.*, 2015). A multi-enterprise farming system helps to optimise various agricultural components, enhance soil health, water and nutrient use efficiencies. Based on the principle of enhancing natural biological processes above and below the ground, the integrated system represents a winning combination that increases crop yields, soil biological activity and nutrient recycling (Mamun *et al.*, 2011). Judicious integration of rice enhances the income base of farmer as well as sustains rice production (Padmakumar, 2013).

Inclusion of animal components in the cropping systems can further improve the system productivity. Rice-fish integration is one such production system which provides additional food and income by diversifying farm activities and increasing the yield of both. Rice-fish farming is a sustainable livelihood form of agriculture originated along with paddy cultivation in South East Asia (Fernando, 1993). Integration of fish production with rice cultivation has the advantage of using limited natural resources, especially water and land, in an intensive and complementary manner (Berg, 2002). Though there is a scope for implementing integrated rice-fish farming in about 23 million hectares in India, the existing area under this system is below one million hectares (Brahmanand and Ghosh, 2014).

The introduction of fish into rice farming creates an integrated agro-ecological system and hence it has been listed by the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) as one of the Globally Important Ingenious Agricultural Heritage Systems (GIAHS) of the world.

Integrated farming systems with diversified crops and other enterprises improve whole farm productivity, enhance biological cycles and thus reduce the dependence on external inputs. In the present situation of rising costs of fertilizers and agro-chemicals, these systems have greater scope.

Reliable and quantitative information on the nutrient supplying ability of soils and response functions of different crops and cropping/farming systems are necessary for the judicious use of inherent and applied nutrients. Budgeting the nutrient cycling capacity, especially with regard to farming systems need to be explored so that the excessive use of synthetic fertilizers can be avoided.

In this context, the present study entitled "Nutrient budgeting in rice based farming system" was undertaken with the following objectives.

i. To study the effect of component crops on soil nutrient status.
ii. To characterise and study the effect of trench silt on the performance of rice.
iii. To work out the nutrient balance sheet of the rice based farming systems.

Review of Literature

2. REVIEW OF LITERATURE

Diversification is considered as a viable strategy to increase output, in terms of produce, income and sustainability, under different situations. Diversification through cropping system and farming system approach makes the agricultural production system more intensive and remunerative than monocropping systems. While, cropping system takes into account the crop components alone, farming system approach considers the array of complex interactions among all the inter-dependent components in a farm. The ever shrinking land holding size has made integration of enterprises a necessity. Further, integration also helps to reduce the risk involved in the production process.

Rice ranks first in terms of utilization of land, water, and other inputs (Rao, 2009).With the advent of modern production technologies, rice based farming systems could be intensified. However, this intensification is at the cost of resource utilization in larger quantities. Since these resources including soil nutrients are mostly non-renewable, resource recycling assumes paramount importance. Efficient management of resources and enhanced nutrient use efficiency are essential to economise input costs and improve factor productivity. The present study focused on studying the effect of rice based farming systems on the nutrient cycling in soil.

In this chapter, a detailed review on rice based farming systems and its effect on soil nutrients and nutrient recycling are presented. Studies on the effect of trench silt and fish integration in rice based farming systems are meagre. Hence, review on rice based farming systems with diversified components has also been included in this chapter.

2.1 NEED FOR DIVERSIFICATION IN RICE

Rice is synonymous with food for large number of people on earth. It is the single largest food source for the poor and the source of one quarter of global per capita. In India, rice is the staple food and is cultivated in an area of 43 million hectares (GOI, 2016). As far as Kerala is concerned, rice is the integral part of the wetland ecosystem with specific ecological functions. Even though rice is an integral part of agrarian economy, recent years have witnessed the rapid decline in paddy area. Over the last three decades, area under rice in Kerala declined from 8.5 lakh ha to 1.99 lakh ha (FIB, 2017).

The conventional system of rice monocropping is prevalent in our country. Intensive modern monoculture of rice has resulted in declined yield trends and the rice production system has become practically unsustainable (Pingali *et al.*, 1990). Intensive agricultural production practices based on increased use of pesticides and agrochemicals may reduce the natural productivity of the system as well as make the system more vulnerable to biotic and abiotic stresses. Monoculture of rice for longer periods resulted in reduced crop yield and system productivity (Yadav *et al.*, 1998). Depletion of soil nutrient status and multiple nutrient deficiencies arise due to these conventional production practices (Singh and Singh, 1995; Dwivedi *et al.*, 2001). Degradation of resources including soil and water, severity in pest and disease incidence are also consequences of monoculture. Thus, immediate attention is needed to sustain the agricultural production system, without deteriorating the natural resource base. Adoption of cropping and farming systems are helpful in achieving sustainability in the production system. The existing rice based cropping systems diversified with the inclusion of pulses, oilseeds and tuber crops is more beneficial than the conventional cereal – cereal system in addressing the problems associated with input scarcity, increasing economic and ecological sustainability (Kumpawat, 2001; Raskar and Bhoi, 2001).

2.3 DIVERSIFICATION IN RICE BASED CROPPING SYSTEMS

2.3.1 Effect of Cropping Systems on Yield and Productivity

The conventional system of cropping prevalent in our country is cereal – cereal sequential cropping. In Kerala also the predominant rice based system is rice – rice – fallow. Since land is a limiting factor, leaving a cropping season without cultivation make the system less remunerative. Maximization of productivity can be achieved through intensive and diversified cropping system approaches.

According to Umarani *et al.* (1992) the benefits derived from cropping systems including pulses and oilseed crops as components are more than the cereal-cereal systems. In the different rice based cropping systems studied, the grain yield of *Kharif* rice increased from 4.7 t ha^{-1} to 5.4 t ha^{-1} in rice – groundnut – cowpea system while a decline in grain yield was observed from 4.5 t ha^{-1} to 4.1 t ha^{-1} in rice – rice sequential cropping system (Prabhakaran and Janardhana, 1997). Bastia *et al.* (2008) reported among the different systems, maximum number of productive tillers (362 m^{-2}) and maximum number of grains $panicle^{-1}$ (112) were observed in rice when grown in rice-groundnut-green gram in cropping system.

Investigations carried out at Rice Research Station, Kayamkulam to identify the most suitable rice-based cropping system for *Onattukara* tract proved that rice-rice-groundnut was the most efficient cropping system followed by rice – rice – bhindi in terms of production efficiency and benefit : cost ratio (Pillai, 1998).

As reported by Yadav *et al.* (2000) the rice equivalent yield of cropping sequence, rice – potato – cowpea was 22.5 t ha^{-1} year and was observed to be remunerative. According to Anbumani *et al.* (2000), black gram as a fallow crop in rice based system produced more rice grain equivalent yield. Bationo *et al.* (2002)

observed that the yields of cereals succeeding cowpea could be double compared to continuous cereal cultivation.

A two year study conducted by Singh *et al.* (2007) on rice based farming systems showed rice – pea – okra system to be the most remunerative cropping sequence, with the highest rice grain-equivalent yield (170.98 q ha^{-1}) and net return (₹ 66,079 ha^{-1}).

The cropping sequences rice – garlic and rice – berseem fetched 24.52 per cent and 4.84 per cent more rice equivalent yield than the rice – wheat system (Maurya *et al.*, 2011). Among the different rice based systems tried, the highest total productivity (22.29 t ha^{-1}) was obtained under rice – potato – cowpea system. The rice equivalent yield from rice – rice – amaranthus, rice – rice – sweet potato, rice – rice – pumpkin and rice – rice – vegetable cowpea was 4.3, 2.9, 2.6 and 2.3 times higher than the rice- rice-fallow system of conventional cropping (John *et al.*, 2013). As reported by Prasad *et al.* (2013) the rice equivalent yield was significantly higher when green gram grown as a summer crop in the rice-wheat system compared to the rice-wheat system.

Study conducted at Cropping Systems Research Centre, Karamana during the five year period from 2003-'04 to 2007-'08 shows that there was 100 percent yield increase in rice – cucumber – okra system compared to the conventional rice – rice – fallow system (John *et al.*, 2013).

2.3.2 Effect of Diversification on Soil Properties

Ghosh and Singh (1994) observed higher yields in maize succeeding fodder cowpea and attributed this to the greater availability of N, symbiotically fixed by the legumes. In cropping systems with legume inclusion, there was carry-over of N through roots and stover to the subsequent non-leguminous crop (Van Kessel and

Hartley, 2000). A study conducted by Kumar *et al.* (2008) proved that, the integration of leguminous crops such as green gram and berseem with the conventional rice – wheat system improved organic carbon content and available NPK status of soil.

In rice based systems, when grain/fodder legume or sesbania was grown for green manuring purpose the soil organic matter found to increase (Singh *et al.*, 2011). The soil P status was also observed to increase when a summer crop was raised in rice based systems.

According to Sravan and Murthy (2014) the highest organic carbon, available N, P and K in soil was recorded when sunhemp was grown as a pre-*kharif* crop, and was on par with treatments including green gram and black gram as pre- *kharif* crops. The lowest was recorded in fallow.

2.4 RICE BASED INTEGRATED FARMING SYSTEMS

Integrated farming system is a production system which ensures the vertical integration of different farm enterprises. It is considered as a strategy to meet the food demand of coming years. To sustain and satisfy the basic needs of farm family including food, feed and fuel, an attention towards integrated farming system is very essential. As rice is the major food crop for large majority, rice based integrated farming system approach has a greater potential. Judicious integration of rice enhances the income base of farmer while sustaining rice production (Padmakumar, 2013).

Manjunath and Itnal (2003) reported that the highest system productivity (21,487 kg ha^{-1} $year^{-1}$) of rice equivalent yield was recorded with rice-brinjal system integrated with mushroom and poultry as compared to rice crop alone. The contribution of crops towards the system productivity ranged from 33 to 52 per cent, while the share of poultry and mushroom production was 28 to 39 per cent and 20 to 28 per cent, respectively.

According to Channabasavanna *et al.* (2009) integrated farming system comprising the components like cropping, vegetables, fishery, poultry and goat rearing recorded 32.3 percent higher profitability over the conventional rice-rice system. Das *et al.* (2013) observed an increase in system productivity (352 per cent) in diversified farming which included crop, fruit, livestock and fishery, than the system without integration.

2.4.1 Rice-Fish Integrated Farming System

Rice-fish integration is a production system which supplies additional food and income by diversifying farm activities, reducing the risk in farming and increasing the yield of both. Rice-fish farming is a sustainable livelihood form of agriculture originated along with low land rice cultivation in South-East Asian countries (Fernando, 1993). Integrated rice – fish farming utilizes the scarce resources *viz.,* land and water in an intensive and complementary manner (Berg, 2002). In the Asian context rice-fish integration is considered to be fundamental and nutritionally complete (Halwart and Gupta, 2004). Integrated rice-fish production can optimize resource utilization through the complementary use of land and water (Frei and Becker, 2005a).

Rice + fish + poultry farming system recorded the highest grain yield of rice (5.67 t ha^{-1} and 5.25 t ha^{-1} during first and second season, respectively (Murugan and Kathiresan, 2005). Rautaray *et al.* (2005) reported that rice fish system generated 2.8 fold more income compared to rice alone. According to Channabasavanna and Biradar (2007), the REY of rice – fish – poultry system was 133.31 per cent higher than the conventional rice – rice system.

Though there is a scope for employing integrated rice – fish farming in about 23 million hectares, the present area under this system in our country is less than one million hectares (Brahmanand and Ghosh, 2014).

2.4.1.1 Effect of Rice-Fish Integration on Crop Yield and Productivity

Hora and Pillay (1962) reported that integration of fish with rice improved the yield of rice by 15 per cent in the Indo-Pacific region. In rice- fish integrated system, rice equivalent yield can be increased up to 4.43 t ha^{-1} in a season without using any plant protection chemicals and the yield increase was 7.9 to 8.6 per cent as compared to monoculture of rice. The increase in yield was observed to be due to the good aeration due to frequent movement of fishes, which enhanced tillering and additional supply of nutrients from the left over fish feed and excreta (Mohanty *et al.,* 2004).

Rice-fish farming is considered to be a low risk production system because of the integration of low risk-enterprises like fish and vegetable cultivation (Behera *et al.*, 2008).

2.4.1.2 Effect of Rice Fish Integration on Soil Properties

Significant saving in fertilizer cost in rice production was observed in fields previously utilized for fish production (Sevilejja, 1992). Cagauan *et al.* (1993) found that a rice field with simultaneous culture of fish had a greater capacity to produce and save nitrogen compared to monoculture of rice. Fishes are capable of feeding the unwanted aquatic biomass and thus they reduce the photosynthetic activity and conserve nitrogen. Fishes maintain the low pH condition of water and in this way they reduce the volatilization loss of nitrogen as ammonia.

A study conducted in rice-fish system recorded the soil parameters such as soil pH (6.6-7), available N (7.9-10.7 mg $100g^{-1}$), P (0.29 - 0.67 mg $100g^{-1}$), organic carbon (0.16- 0.53 per cent) to be in optimum range (Mohanty *et al.*, 2004).

Integrating rice with fish improved the soil fertility by increasing the availability of nitrogen and phosphorus (Giap *et al.*, 2005; Dungan *et al.*, 2006).

Integrated rice-fish farming system is a low external input system where the requirements of fertilizers and chemicals can be reduced to 50 per cent and sometimes no pesticide application is required (Lu and Li, 2006). The integration of fish with rice crop helps to improve nitrogen availability to the rice crop. The supplementary feed provided to fish is excreted by them and the excreta containing mineralized form of nutrients can easily be taken up by the rice crop (Oehme *et al.*, 2007). In a study undertaken on the nutrient dynamics of rice based farming system it was observed that multilevel integration enhanced rice yield and reduced rice production cost by 10 per cent. The period from June-October was identified to be the most suitable season for rice on account of higher productivity environment (KAU, 2015).

2.4.1.3 Effect of Rice Fish Integration on Water Quality

A significant reduction in the afternoon floodwater pH was observed in an integrated rice- fish system especially with carp/ Tilapia (Frei and Becker, 2005b).In integrated rice-fish system the pH value of water shifted to slightly acidic condition towards the end of the culture (Desta *et al.*, 2014). Bihari *et al.* (2015) recorded higher dissolved oxygen content and electrical conductivity (0.15- 0.45 dS m^{-1}) and a near neutral pH in water from rice-fish system.

2.4.1.4 Effect of Sediments from Fish Pond or Trench Silt

The bottom soils of fish pond are considered to be rich in nutrients and it can be recycled as manure in crop production.Nutrient rich bottom silt and water of pond can be a good source of fertilizers for the crop land (FAO, 1992).

The accumulation of sediments reduces the volume of ponds and hence the space available for fishes. The regular feeding with fish feed materials in intensive aquaculture practices lead to accumulation of organic wastes and nutrients in the pond bottom sediments. Sediments from fish pond can serve as a soil conditioner to enhance the soil physical properties (Mizanur *et al.*, 2004).

Organic and inorganic manures and fish feed are the major external source of nutrients (Mizanur *et al.*, 2004). Only 30 per cent of the N and P present in fish feed utilized by fishes (Tucker, 1998), and the remaining get accumulated in the pond bottoms.

As reported by Wahab *et al.* (1984), the nutrients present in pond bottom sediments contained about 4.5 to 13.1 g kg^{-1} of organic matter, 900- 2000 mg kg^{-1} total N, 70-112 mg kg^{-1} available P, 24.2-47.8 mg kg^{-1} exchangeable Ca, 87.8-130.8 mg kg^{-1} K. Among the nutrients accumulated in sediments, about 81 per cent organic carbon, 29 per cent N and 51 per cent P could be utilized as manure (Nhan, 2007). Considerable quantity of silt could be obtained from ponds used for growing fresh water fish when de-silted once in every three year. The silt obtained from 800 m^2 pond area with high organic carbon content (1.20 per cent) is estimated to add 18.56 kg N, 6.21 kg P and 74.24 kg K which cost ₹950.The addition of pond silt and use of fish pond water for irrigation resulted in increased yield in rice and wheat by 3.48 q ha^{-1} and 2.41 q ha^{-1} respectively (Singh *et al.*, 2011).

The study conducted by Jeyamangalam *et al.* (2012) found that, the addition of tank silt @ 12.5 t ha^{-1} to groundnut crop resulted in reduction of EC of soil. The organic carbon status of soil was 34.79 per cent higher in plots when tank silt was applied in combination of tank silt + coir pith + FYM than the control plots. In treatments where tank silt was applied @ 17.5 t ha^{-1}, the available N content was 43.48 per cent higher than the control. Available P content in soil was 74.15 per cent higher than control when trench silt was applied in combination with coir pith and FYM. Available K status was 54.55 per cent more when tank silt was applied in combination with FYM.

2.4.1.5 Physical properties of trench silt

The pond bottom sediments had higher moisture percentage and possessed lower dry bulk density ranging from 0.25 g cm^{-3} to 0.30 g cm^{-3}(Munsiri *et al.*, 1995). They also observed higher silt and clay fractions in the pond bottom sediments. The texture of the soil in rice-fish system showed increase in silt fraction, organic carbon and organic matter. The composited soil samples in the field after four months of culture showed increase in the amount of silt, reduction in clay content and sand than initial contents (Desta *et al.*, 2014).

The pond bottom sediments tend to get softer due to accumulation of hydrated organic matter (Avnimelech *et al.*, 2001).The water holding capacity of the soil and the humus content remained very high during the fish growing period (Panicker and Sebastian, 2002).The fish sediments enhanced soil structure and soil fertility by improving soil aeration, water and nutrient holding capacities, root penetration by crops and this in turn helped to obtain higher crop growth and yield (Ihejirika *et al.*, 2012).

High organic matter content and higher levels of leachable nutrients were observed in the accumulated wastes of ponds (Smith and Briggs, 1998).The basic properties of aquatic sediments were water content, organic matter levels, dry bulk density and porosity. These properties affect the mechanical properties of the soil and microbial metabolic rates. Organic matter in the pond bottom soils had a very important role in determining water content, density and porosity of sediments (Avnimelech *et al.*, 2001). Increase in organic carbon content may be due to accumulation of uneaten feed and dead planktons (Jayanthi *et al.*, 2007).

Bioturbation by fish resulted in accelerated decomposition of organic matter thus leading to reduction in organic carbon content (Ritvo *et al*., 2004).

Studies conducted by Lal and Steward (1992) identified nutrient recycling as one of the most important measures for restoring soil fertility. In an integrated system, fish could contribute to 10-15 per cent increase in yield of rice mainly by preventing floodwater pH to rise over 8.5 and hence reduce volatilization loss of ammonia and the major agronomic benefit of integration was derived through the retrieval and maintenance of the soil productive capacity (Rota and Sperandini, 2010). Rice-fish co-culture lessened the environmental impact of agricultural chemicals and could be regarded as a source of free fertilizer since fish refuse served as fertilizer and the movement of fish loosened the soil promoting fertilizer decomposition and root development (FAO, 2012). The high level of nutrients facilitated increase in tillering and panicles and thus led to a higher productivity (Desta *et al*., 2014).

2.4.1.6 Microbial Properties of Trench Silt

In the fish growing water and sediments, a luxuriant growth of bacteria were observed, which play an important role in maintenance of water quality and organic matter decomposition. The bacterial flora may be released from the excreta of fish or its body part act as a link in the food chain as food for zooplankton and fishes, in addition to other functions like nitrogen fixation and phosphate solubilisation (Panicker and Sebastian, 2002). The presence of heterotrophic bacteria in significant quantity was noticed from the contact surface between water and soil (Zhou*et al*., 2009).

Bacteria of the genus *Pseudomonas* were found commonly occurring in both pond water and sediment (Fang *et al.,* 1994). The presence of aerobic and facultative anaerobes played a major role in the bio-resource recycling (Panicker and Sebastian, 2002).

2.4.1.7 Effect of Rice-Fish Integration on Pest and Disease Incidence

Fishes serve as biological control agents against rice pests and diseases (Lin, 1996). They feed on insect pests and weeds. Fishes can be considered as an effective Integrated Pest Management (IPM) tool and it make rice production more eco-friendly and economical as reported from Thailand, Vietnam and Bangladesh (Little *et al.*, 1996; Haroon and Pittman, 1997; Berg, 2001). According to Berg (2001) pesticide use was decreased by 65 per cent in rice-fish farms compared to other farms wherein it is increased by 40 per cent during three year period in Vietnam. Fish prey on plant hoppers, leaf hoppers and leaf rollers.

Rice-fish integrated systems possess an increase in the number of natural enemies such as spiders and parasitic wasps (Lu, 1986; Lu and Huang, 1988; Wang and Lei, 2000).

2.5 NUTRIENT BALANCE SHEET OF RICE BASED SYSTEMS

A study on effect of crop rotations indicated that there was a buildup of nitrogen content in soil when rice crop is followed by berseem, compared to the cereal – cereal rotation of rice followed by wheat (Deka and Singh, 1984). Nitrogen balance sheet worked by Mahapatra *et al.* (1985) showed that the nitrogen balance of the rice – rice system was negative even when both the crops were supplied with 100 per cent recommended dose.

Nitrogen balance was positive, when legumes like grain cowpea was accommodated in rice based cropping system (Singh *et al.*, 1996). The balance sheet of nitrogen in soil was positive in the cropping systems *viz.*, rice – rice – groundnut and rice – rice – cowpea (Pillai *et al.*, 2007).

A positive balance was obtained for N and P in rice – wheat – green gram and rice – potato – green gram cropping systems, whereas, the K balance sheet of the systems were found to be negative (Sharma and Sharma, 2002). The biological nitrogen fixing property of leguminous crops not only supplied nitrogen but also helped the plant by increasing the availability of other nutrients by enhancing biological properties of soil (Azam *et al.*, 2008). Even though cassava is a soil depleting crop, the nitrogen balance sheet of rice – cassava + groundnut – cowpea system observed to have a more positive balance after second year of cropping (Vipitha, 2016). Abundant supply of N through fertilizers may result in suppression of N fixation (Subasinghe *et al*, 2001).In rice – rice – amaranthus sequence, the buildup of available P at the end of the sequence over the initial status was observed to be high irrespective of nutrient sources and levels (Nishan, 2016).

Saha *et al*. (2014) reported that addition of organic manure (cowdung, daincha) resulted in an apparent positive balance of P, S and Zn and a negative balance of N and K.

The development and maintenance of sustainable agricultural systems which can maintain and sustain soil fertility and crop productivity is the need of the hour. Hence it is imperative that the present integrated farming systems be analyzed in terms of the efficacy of the components in enhancing the productivity of the system and their potential in recycling the bio-resources.

Materials and Methods

3. MATERIALS AND METHODS

An investigation entitled "Nutrient budgeting in rice based farming system" was undertaken with the objectives to study the effect of component crops on soil nutrient status, to characterize and study the effect of trench silt on the performance of rice and to work out the nutrient balance sheet of the rice based farming systems. The materials used and methods adopted for the experiment is detailed in this chapter.

3.1 EXPERIMENTAL SITE

The study was undertaken at the Integrated Farming Systems Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, as a part of an ongoing project under the All India Co-ordinated Research Project (AICRP) on Integrated Farming Systems (ICAR). The experimental site was geographically located at 8° 28' 25'' N latitude and 76° 57' 32'' E longitude, at an altitude of 5 m above mean sea level.

3.1.1 Soil

The ongoing experiment of which the present study formed a part comprised treatments with and without fish combinations. The experiment was started in 2011. Hence composite soil samples were collected from both with and without fish combinations at a depth of 15 cm before the commencement of the present study. The samples collected were analyzed for its mechanical composition and chemical properties (Tables 1a and 1b respectively). The soil properties were rated as per the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 2016).

The soil of the experimental site was clayey in texture, acidic in pH, low in available nitrogen, medium in available phosphorus and potassium status.

Table 1a.Mechanical composition of the soil of the experimental site

Sl. No.	Fractions	Content in soil (%)		Method adopted
		Without fish	With fish	
1	Coarse sand	30.80	29.70	International pipette method (Piper, 1950)
2	Fine sand	8.50	7.20	
3	Silt	20.00	19.50	
4	Clay	39.50	42.00	
Textural class		Clay	Clay	

Table 1b. Chemical properties of the soil of the experimental site

Sl No.	Parameters	Content		Rating		Method adopted
		Without fish	With fish	Without fish	With fish	
1	Soil reaction (pH)	4.96	5.33	Very strongly acidic	Strongly acidic	1:2.5 soil solution ratio using pH meter (Jackson, 1973)
2	Electrical conductivity ($dS\ m^{-1}$)	0.19	0.20	Normal	Normal	Electrical conductivity meter (Jackson, 1973)
3	Organic carbon (%)	2.17	1.58	High	High	Walkley and Black's rapid titration (Jackson, 1973)
4	Available N ($kg\ ha^{-1}$)	249.91	249.20	Low	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available P_2O_5 ($kg\ ha^{-1}$)	18.76	24.70	Medium	Medium	Bray colorimetric method (Jackson, 1973)
6	Available K_2O ($kg\ ha^{-1}$)	137.36	154.85	Medium	Medium	Ammonium acetate method (Jackson, 1973)

3.1.2 Climate and Season

The experiment was conducted in two seasons, *viz*., summer season 2015-'16 (February – May) followed by the *Virippu* season2016-'17 (June – October). A warm humid tropical climate prevails over the experimental site. The data on various weather parameters such as mean temperature, relative humidity (RH), rainfall and bright sunshine hours during the cropping period were collected from the Class B Agrometereology Observatory, IFSRS, Karamana. The maximum temperature during summer season varied from 30.31 °C to 33.60 °C and minimum temperature from 20.89 °C to 27.39 °C. During the *Virippu* season the maximum temperature varied between 29.79 °C and 31.71 °C while the minimum temperature varied between 23.49 °C and 25.29 °C. The weather data during the cropping period are presented in Appendix-Ia and Ib and graphically represented in Fig.1a and 1b.

3.1.3 Cropping History of the Field

The experiment was undertaken as a part of the ongoing AICRP on Integrated Farming Systems started in the year 2011-'12, at IFSRS, Karamana, Thiruvananthapuram, Kerala. Rice crop is raised during *Virippu* and *Mundakan* seasons and vegetables and fodder cowpea during the summer season. The performance of the crops are being assessed with and without fish integration.

3.2 MATERIALS

3.2.1 Crops and Fish

Rice crop was raised during *Virippu* season and amaranthus, culinary melon and fodder cowpea during summer season. All these crops were raised integrated with fish and without fish. The characteristics of crops and fish varieties used for study are presented in Table 2.

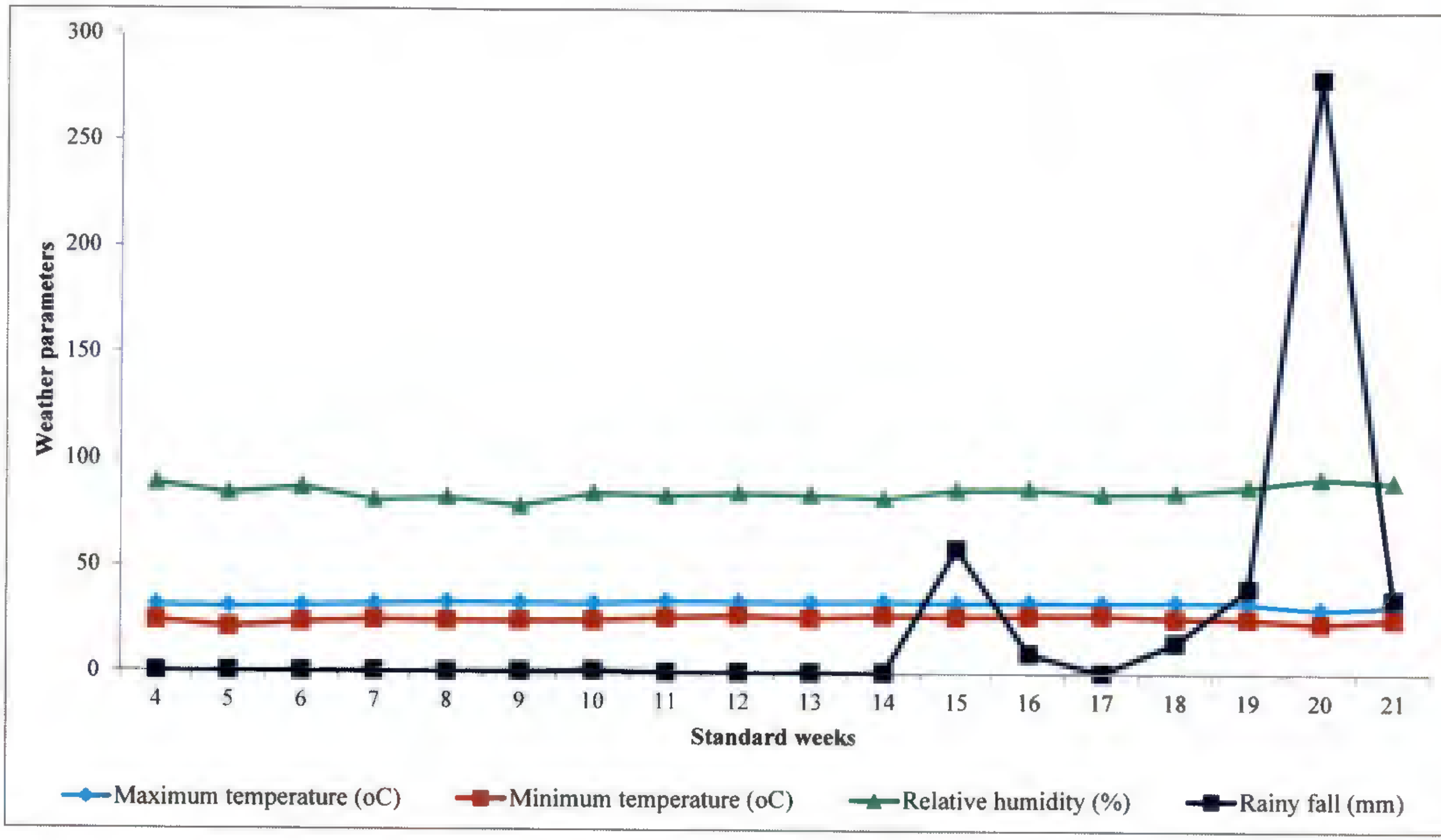

Fig. 1a. Weather data during summer crop period (February to May 2016)

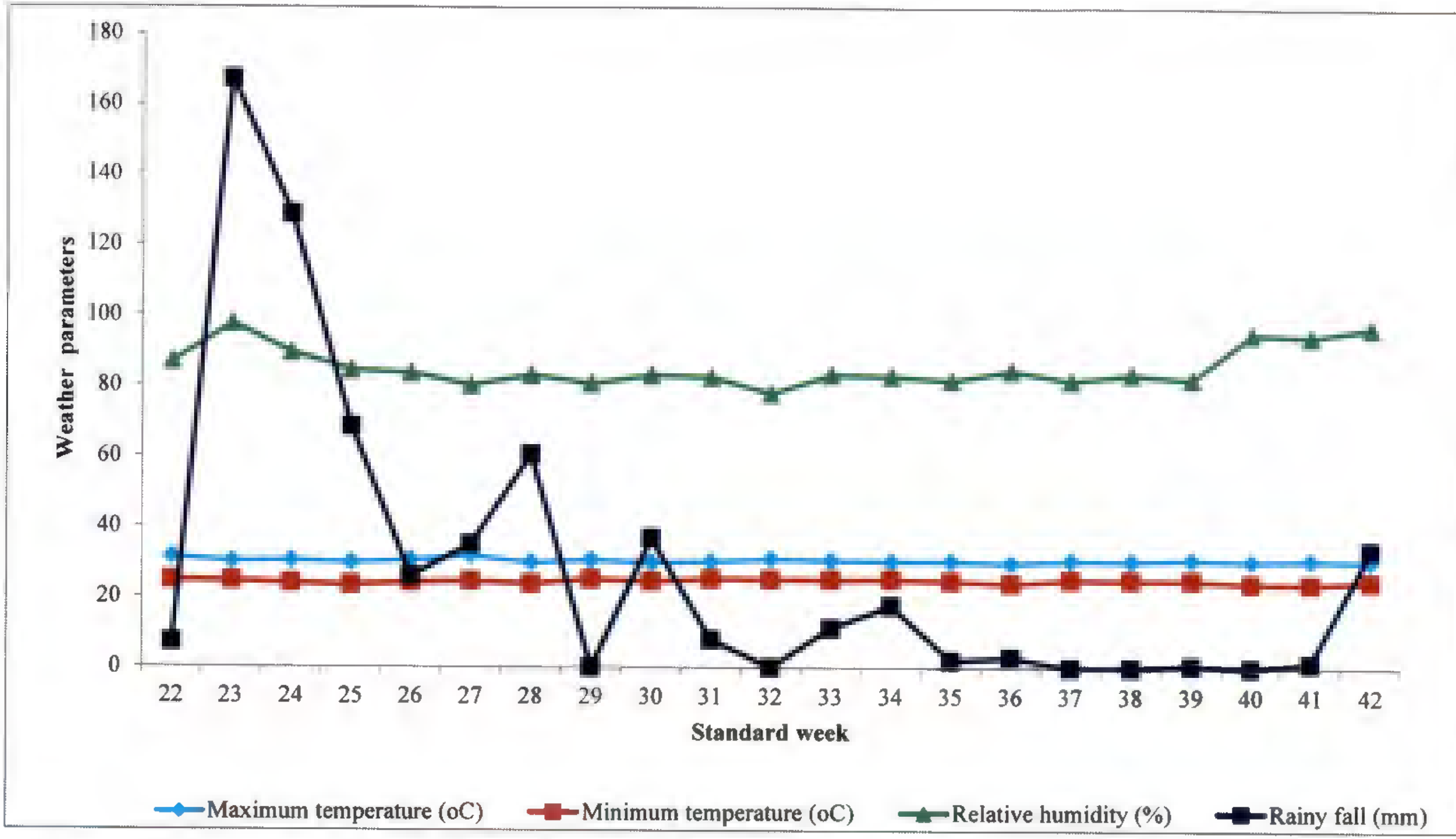

Fig. 1b. Weather data during *Virippu* crop period (June to October 2016)

Table 2. Important characters of crop and fish varieties chosen for study

Sl No.	Crop/Fish	Variety	Description	Source of seed
1	Rice	Uma (MO-16)	Medium duration (115-120 days); medium tillering; dwarf; non-lodging variety resistant to brown plant hopper and gall midge biotype-5; dormancy up to 3 weeks; released from Rice Research Station, Moncompu.	IFSRS, Karamana, Kerala Agricultural University
2	Amaranthus	Arun	High yielding dark red coloured; photo insensitive; developed through mass selection from 'Palapoor local'; released from Kerala Agricultural University.	Department of Olericulture, College of Agriculture, Vellayani.
3	Culinary melon	Vellayani local	Local collection from Vellayani area of Thiruvananthapuram district;70-75 days duration; medium sized, cylindrical shaped, creamy white coloured fruits with green stripes.	Department of Olericulture, College of Agriculture, Vellayani.
4	Fodder cowpea	Aiswarya	Single cut variety developed through hybridization and selection; 29.92 t ha^{-1} of green fodder yield; recommended for cultivation in uplands and homesteads of southern districts of Kerala.	AICRP on Fodder Crops,College of Agriculture, Vellayani
5	Fish	Catla	*Catla catla* ; Surface feeder	Department of Fisheries, Thiruvananthapuram
		Rohu	*Labio rohita*; Column feeder	

3.2.2 Manures and Fertilizers

Farmyard manure (FYM) containing 0.50 per cent N, 0.20 per cent $P_2O_5$and 0.40 per cent K_2O was used as organic manure. Urea (46 per cent N), Factamphos (20 per cent N, 20 per centP_2O_5, 15 per cent S), Rajphos (20 per cent P_2O_5) and Muriate of Potash (60 per cent K_2O) were used as the inorganic sources of N, P and K.

3.3 METHODS

3.3.1 Design and Layout

The experiment was laid out in Randomized Block Design. The experiment under the AICRP on Farming System comprised seven rice based farming systems(Rice – rice – fallow, Rice – rice – amaranthus, Rice – rice – culinary melon, Rice – rice – fodder cowpea, Rice + fish – rice + fish – amaranthus + fish, Rice + fish – rice + fish – culinary melon + fish, Rice + fish – rice + fish – fodder cowpea + fish),replicated thrice.

The treatment details for the two seasons are given below. The layout of the experiment is depicted in Fig. 2.

Summer season (2015-'16)

Design	:	Randomised Block Design
Treatments	:	7
Replication	:	3
Plot size	:	6 m x 6 m

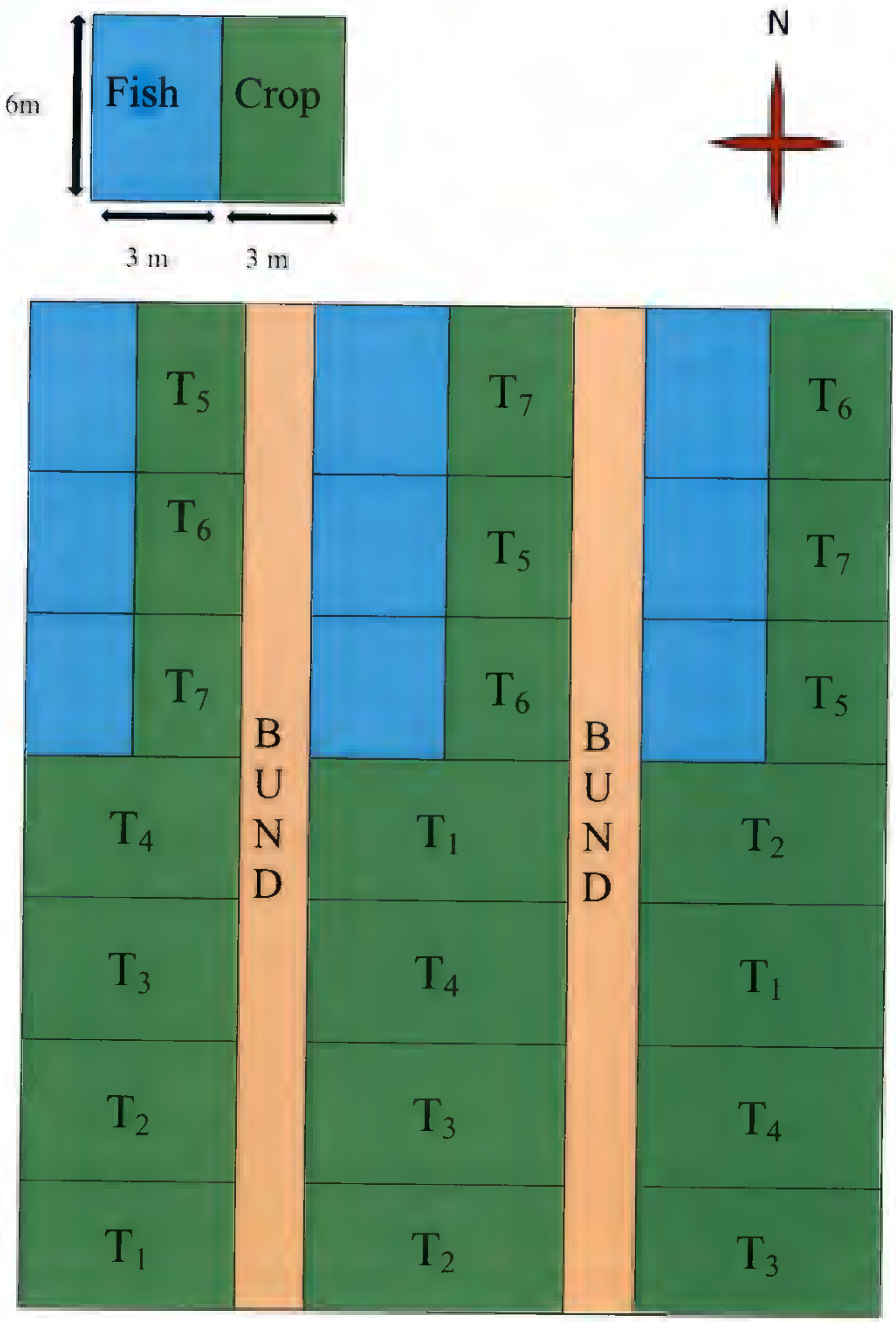

Fig. 2. Layout of the experimental field

Treatments

T_1	:	Fallow
T_2	:	Amaranthus
T_3	:	Culinary melon
T_4	:	Fodder cowpea
T_5	:	Amaranthus+fish
T_6	:	Culinary melon+fish
T_7	:	Fodder cowpea+fish

***Virippu* season (2016-'17)**

Design	:	Randomised Block Design
Treatments	:	7
Replication	:	3
Plot size	:	6 m x 6 m

Treatments

T_1	:	Rice	(succeeding fallow)
T_2	:	Rice	(succeeding amaranthus)
T_3	:	Rice	(succeeding culinary melon)
T_4	:	Rice	(succeeding fodder cowpea)
T_5	:	Rice + fish	(succeeding amaranthus + fish)
T_6	:	Rice + fish	(succeeding culinary melon + fish)
T_7	:	Rice + fish	(succeeding fodder cowpea + fish)

In treatments with fish integration, half of the plots were made into trenches of size 6m x 3m x 1 m.

3.3.2 Crop Management

All crop management practices were carried out as per the Package of Practices Recommendations of KAU (KAU, 2016). However, chemical plant protection measures were avoided since fish was a component of the systems.

3.3.2.1 Summer Crop

3.3.2.1.1 Land Preparation

After the harvest of *Mundakan* crop, weeds were removed and plots were laid out into raised beds and furrows. Raised beds of 3 m length, 1 m width and 30 cm height were prepared for the treatments integrated with fish and beds of 6 m length 1 m width and 30 cm height for treatments without fish. The beds were perfectly leveled and brought to a fine tilth.

3.3.2.1.2 Application of Manures and Fertilizers

Well decomposed farm yard manure was applied to all the plots (except to T_1– fallow) @ of 50t ha^{-1}, 25 t ha^{-1}and 10 t ha^{-1} for amaranthus, culinary melon and fodder cowpea respectively at the time of land preparation. Fertilizers were applied as per the Package of Practices Recommendation for the respective crops (KAU, 2016).

Fertilizers were applied @ 100:50:50 kg NPK ha^{-1} for amaranthus (half N, full P, full K as basal with Factamphos and Muriate of Potash, half N as top dressing at 20 days after sowing (DAS) with Urea). For culinary melon, fertilizers were applied @ 75: 25: 25 kg NPK ha^{-1}(half N, full P, full K as basal, half N as topdressing at 20 DAS). In the case of fodder cowpea, a fertilizer recommendation of 40:30:30 kg NPK ha^{-1}was followed and the entire dose of fertilizers was applied as basal. The fertilizers *viz.*, Urea, Rajphos and Muriate of Potash were used for culinary melon and fodder cowpea.

3.3.2.1.3. Sowing

Amaranthus seeds were line sown @ of 2 kg ha^{-1}at a spacing of 20 cm between lines. Culinary melon was sown in shallow pits of 60 cm diameter and 30 cm

Plate 1. General view of field during the summer season

depth taken at a spacing of 2.0 m x 1.5 m, @ 0.75 kg ha^{-1}. Fodder cowpea seeds were sown @ 30 kg ha^{-1}at a spacing of 30 cm x 15 cm.

3.3.2.1.4. Water Management

Irrigation was provided as and when required with water from the furrows and trenches.

3.3.2.1.5. Harvest of Crops

Amaranthus was harvested at 40 days after sowing (DAS) by uprooting the plants prior to bolting. Culinary melon fruits were harvested at green stage when they attained maximum size (40 DAS). Being a single cut variety, fodder cowpea was harvested when the plants just started flowering (45 DAS).

3.3.2.1.6. Desilting of Trenches

After summer crops, fish was harvested and the trenches were de-watered and desilted. The trench silt was added to the plots with fish integration, before raising the succeeding *Virippu* rice crop.

3.3.2.2 Virippu Crop

3.3.2.2.1 Nursery

Nursery area was ploughed and leveled and beds of 10 m length, 1 m width and 15 cm height were prepared with drainage channels between beds. Farmyard manure was incorporated at the rate of 1 kg m^{-2}. Pre-germinated seeds were sown on the beds @ 60 kg ha^{-1}.

3.3.2.2.2 Main Field

After harvesting the summer crops and fish, the raised beds were dismantled and plots were leveled. Bunds were strengthened and channels were cleaned. Water was pumped out and the trenches were desilted. The trench silt was added to the plots integrated with fish and incorporated. The plots were puddled and leveled.

Plate 2. Field after trench silt addition and incorporation

Plate 3. General view of field during the *Virippu* season

3.3.2.2.3 Application of Manures and Fertilizers

Farmyard manure was incorporated at the rate of 5 t ha^{-1} as basal dose, two weeks before transplanting. Chemical fertilizers @ 90:45:45 kg NPK ha^{-1} was applied in two split doses - half the recommended dose of N and K and full dose of P as basal and remaining half N and Kat panicle initiation stage.

3.3.2.2.4 Transplanting

Eighteen days old seedlings were transplanted @ 2-3 seedlings $hill^{-1}$ maintaining a spacing of 20cm x 15 cm.

3.3.2.2.5 Water Management

Water level was maintained at 2 cm at the time of transplanting and increased to 5 cm after one week of transplanting. Subsequently, a water level of 5 cm was maintained in the plots during the entire crop period with occasional drainage. The field was drained two weeks before harvest.

3.3.2.2.6 Harvest

The crop was harvested when the grains attained maturity, leaving two border rows on all sides. The net plot area was harvested, threshed, winnowed, and dried separately. The fresh weight and dry weight of grains and straw from individual plots were recorded.

3.3.3 Management of Fishes

Fishes were reared in trenches during the period from June to May (immediately after transplanting of *Virippu* rice up to harvest of summer crops). In treatments with fish integration, half of the plots were made into trenches of size 6m length, 3m width and 1 m depth. The excavated soil was added to the plots where rice was to be raised. After 3 to 4 days the trenches got filled with water and it was left as such for a week for the reddish coloured scum (due to reduced iron) to disappear naturally. The surface and sides of the trenches were covered with nets so

Plate 4. Fish fingerlings (one month old) ready for releasing to trenches

Plate 5. Harvested fish

as to protect the fishes from birds and to prevent escape of fingerlings in the event of floods due to heavy rainfall. One month old fish fingerlings (5 cm size) were released into the trenches @ one fingerling m^{-1}. Fingerlings were fed with fish feed comprising a mixture of powdered coconut oil cake and groundnut oil cake in 1:1 ratio. The fish were fed with the feed @ of 50 g $trench^{-1}$ day^{-1} (to 18 m^2 area), initially for two months. It was gradually increased to 75 g and by the fourth month to 100 g.

3.3.3.1 Harvest of Fish

Fish was harvested at the end of summer season. When the fishes attained eleven months of age the trenches were de-watered and the fish was harvested.

3.4 OBSERVATIONS ON CROPS/FISH

3.4.1 Rice

The observations on yield and yield attributes were taken at the time of harvest of the *Virippu* rice. Observations were recorded from ten randomly selected hills from the net plot area.

3.4.1.1 Productive Tillers m^{-2}

At the time of harvest the number of panicles or productive tillers were counted from the selected hills in the net plot area and was expressed as number of productive tillers m^{-2}.

3.4.1.2 Grain Weight $Panicle^{-1}$

Middle panicles from 10 selected hills were taken, spikelets were separated and weight of grains from each panicle was recorded in g.

3.4.1.2 Filled Grains $Panicle^{-1}$

Grains were separated from 10selected panicles in the net plot area and the number of filled grains was counted. The mean value was expressed as the number of filled grains per panicle.

3.4.1.3 Sterility Percentage

The total number of spikelets and number of chaffy or unfilled grains were counted and the sterility percentage was expressed using the formula,

$$\text{Sterility percentage} = \frac{\text{Number of unfilled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.4.1.4 *Grain Yield*

Grain harvested from the net plot areawas cleaned and dried to constant weight and grain weight was expressed in tha^{-1}.

3.4.1.5 Straw Yield

The straw obtained from each net plot area was dried to a constant weight under sun, weighed and expressed in tha^{-1}.

3.4.1.6 Grain : Straw Ratio

The ratio between dry weight of grain and dry weight of straw was calculated.

3.4.2 Amaranthus, Fodder cowpea, Culinary melon

3.4.2.1 Yield

The net plot harvested individually, cleaned and fresh weight was recorded in tha^{-1}.

3.4.2.2 Total Dry Matter Production

Unit weight of fresh crops and fruits were dried to constant weight under sun and in oven at 70±5 °Cand percentage of dry matter per unit fresh weight was calculated. Total drymatter production for each crop was obtained by multiplying this percentage dry weight with total fresh weight from each plot.

3.4.2.3 Rice Equivalent Yield

Economic yields of crops were converted and expressed in terms of rice equivalent yield using the following equation (Palaniappan, 1985).

$$\text{Rice equivalent yield (REY)} = \frac{\text{Economic yield of crop(s)} \times \text{Price of crop(s)}}{\text{Price of rice}}$$

3.4.5 Fish

3.4.5.1 Yield

At the end of the summer season, fishes were harvested from the trenches, weighed and the yield expressed in t ha^{-1}.

3.4.5.2 Rice Equivalent Yield

Yield of fish was expressed in terms of rice equivalent yield using the following equation.

$$\text{Rice equivalent yield (REY)} = \frac{\text{Fish yield} \times \text{Price of fish}}{\text{Price of rice}}$$

3.5 CHEMICAL ANALYSIS

3.5.1 Plant Analysis

Samples of grain and straw were taken for rice crop. Whole plant samples were taken for amaranthus and fodder cowpea. Whole plant samples and fruit samples were taken separately for culinary melon. Samples were collected from each net plot area, dried under shade and oven dried to constant weight. Later samples were separately ground and digested for nutrient analysis. Single acid digestion using concentrated sulphuric acid was followed for N, P, and K whereas diacid digestion using nitric acid and perchloric acid mixture (9:4 ratio) was followed for all other nutrients *viz.*, secondary and micronutrients (Jackson, 1973).

3.5.1.1Nutrient Content of Rice and Component Crops

Different nutrients were analyzed by the following methods mentioned in Table 3.

3.5.1.2 Nutrient Uptake by Rice and Component Crops

Nutrient uptake by crops was calculated as the product of nutrient contents of plant and the respective dry weights and expressed in kg ha^{-1}.

Table 3. Analytical methods adopted for plant analysis

Sl No.	Parameter	Method	Reference
1	Nitrogen	Micro-Kjeldahl method	Jackson (1973)
2	Phosphorus	Vanado molybdate yellow colour method	Piper (1947)
3	Potassium	Flame photometry	Jackson (1973)
4	Calcium	Versanate titration method	Hesse (1971)
5	Magnesium	Versanate titration method	Hesse (1971)
6	Sulphur	Turbidimetry	Chesnin and Yien (1950)
7	Zinc	Atomic absorption spectroscopy	Lindsay and Norvel (1978)
8	Boron	Azomethane–H colorimetric method	Wolf (1971)

3.5.2 Soil Analysis (Before and After Each Component Crop)

3.5.2.1 Soil Reaction

Soil reaction was measured using pH meter from soil: water suspension of 1:2.5 ratio (Jackson, 1973).

3.5.2.2 Electrical Conductivity

Electrical conductivity of soil was measured using electrical conductivity meter, using soil: water suspension of 1:2.5 ratio, and expressed in dS m^{-1} (Jackson, 1973).

3.5.2.3 Organic Carbon

Organic carbon content of the soil was determined by Walkley and Black's rapid titration method (Jackson, 1973).

3.5.2.4 Nutrient Status

Soil samples were collected from all plots before and after each crop season. Soils samples were also obtained just before the experiment to study the residual effect of previous *Mundakan* crop. The samples were dried in shade and sieved through 2mm sieve and used to determine the nutrient contents. The different methods used for estimation of nutrient status are described in Table 4.

Table 4. Analytical methods followed for soil analysis

Sl. No.	Parameters	Methods	References
1	Available nitrogen	Alkaline potassium permanganate method	Subbaiah and Asija (1956)
2	Available phosphorus	Bray No. 1 extraction and spectrophotometry	Jackson (1973)
3	Available potassium	Extraction using neutral normal ammonium acetate and flame photometry	Jackson (1973)
4	Exchangeable Calcium and Magnesium	Extraction using neutral normal ammonium acetate titration with EDTA (Versanate method)	Hesse (1971)
5	Available Sulphur	Extraction using 0.15% calcium chloride and turbidimetry	Chesnin and Yien (1950)
6	Zinc	Extraction using 0.5 N HCl and atomic absorption spectroscopy	Sims and Johnson (1991)
7	Boron	Hot water extraction and Azomethane-H colorimetry	Gupta (1967)

3.5.3 Water Analysis

At the end of summer season, water samples were collected from the trenches in polythene bottles and analysed by following the same procedures as for plant sample analysis (Table 3).

3.5.3.1 pH

pH of the water samples collected from the trenches was measured immediately after water collection using pH meter.

3.5.3.2 Electrical Conductivity

Electrical conductivity of water samples was determined using digital electrical conductivity meter and expressed in dS m^{-1}.

3.5.3.3 Nutrient Content (N, P, K, Ca, Mg, S, Zn, B)

Nutrient content of trench water was analyzed by adopting the same procedures for plant nutrient analysis.

3.5.3.4 Biological Oxygen Demand (BOD)

The BOD level of water was determined by comparing the dissolved oxygen (DO) level of water sample on the day of sample collection against the DO level of the sample after incubation in dark for five days.

3.5.4 Characterization of Trench Silt

Trenches were desilted after the harvest of summer crops and fishes. The trench silt collected was characterized in terms of quantity, physico-chemical and biological properties.

3.5.4.1 Quantity of Trench Silt Added

After harvest of fish the trenches were desilted. The trench silt was quantified using buckets of 10 kg capacity. Unit quantity of trench silt was air dried and dry weight was taken to quantify the trench silt on dry weight basis and expressed in t ha^{-1}.

3.5.4.2 Physical Properties of Trench Silt

3.5.4.2.1 Texture

Texture of trench silt was determined by international pipette method (Piper, 1950).

3.5.4.2.2 Bulk Density and Water Holding Capacity

Bulk density and water holding capacity of the trench silt was assessed using core sampler (Gupta and Dakshinamoorthy, 1980).

3.5.4.3 Chemical Properties of Trench Silt

Soil reaction (pH), electrical conductivity, organic carbon and nutrient status (available N, P and K, exchangeable Ca and Mg, available S, Zn and B) of trench silt were determined adopting the same analytical methods as for soil analysis (Table 4).

3.5.4.4 Total Microbial Count in Trench Silt

The count of bacteria, fungi and actinomycetes in the trench silt sample was determined and expressed as total microbial count, by serial dilution plate method (Timonin, 1940). The media used for enumeration of microrganisms are given in Appendix- II.

3.6 PEST AND DISEASE INCIDENCE

Pest and disease incidence was recorded at the peak growing season of each crop. Bacterial leaf blight of rice was scored in the 0-9 scale (Appendix-III) as per the standard evaluation system developed by the International Rice Research Institute (IRRI, 2002).

3.7 NUTRIENT BALANCE SHEET

Nutrient balance sheet of the soil was obtained by subtracting the computed balance of nutrients from actual balance. The computed balance was worked out by subtracting the total quantity of nutrients removed by the crops from that added by fertilizers and available nutrients in soil. The actual balance of nutrients was indicated by the available nutrient status of the soil. A positive balance indicated soil storage and negative balance depletion (Palaniappan, 1985).

3.8 STATISTICAL ANALYSIS

The data generated from the experiment was analysed by following the techniques of Analysis of Variance (ANOVA) for Randomized Block Design by Cochran and Cox (1965). Wherever significant differences among treatments were observed, CD values at 5 per cent level of significance were calculated for comparison of means. Student's T test was carried out for comparison of data on content and uptake of nutrients by summer crops integrated with fish and without fish (Gomez and Gomez, 1984).

Results

4. RESULTS

The present study entitled "Nutrient budgeting in rice based farming system" was undertaken with the objectivesto study the effect of component crops on soil nutrient status, to characterize and study the effect of trench silt on the performance of rice and to work out the nutrient balance sheet of the rice based farming systems. The data generated from the study were statistically analysed and the results are presented in this chapter.

4.1 OBSERVATIONS ON SUMMER CROPS (2015-'16)

The results on yield, rice equivalent yield and total drymatter production of summer crops integrated with fish represents the values for 0.5 ha since half the area of the field was converted into trenches and utilized for fish culture.

4.1.1 Yield

The results on the yield of summer crops, with and without fish integration are given in Table 5.

Among the sole crops, higher yield (23.70 t ha^{-1}) was recorded by fodder cowpea (T_4) followed by culinary melon (T_3) with yield of 10.9 t ha^{-1}. Among the crops integrated with fish, the treatment T_6 (culinary melon + fish) recorded higher yield (19.4 t per 0.5 ha). In the case of amaranthus and culinary melon the yield obtained from 0.5 ha along with fish integration was higher than the yields of the respective sole crops (T_5 yielded more than T_2 andT_6 more than T_3).

4.1.2 Rice Equivalent Yield (REY)

The results on REY of summer crops, with and without fish integration are presented in Table 5.

The treatments varied significantly in the REY, with culinary melon recording significantly higher REY both under sole crop (7.62 t ha^{-1}) and on integration with fish (13.57 t per 0.5 ha). The REY of amaranthus and culinary melon was significantly higher when they were raised along with fish compared to the sole crop.

4.1.3 Total Drymatter Production

The data on the total drymatter production of summer crops as influenced by the crop sequences are depicted in Table 5.

Total drymatter production followed the same trend as yield with the sole crop of fodder cowpea (T_4) recording higher drymatter production (2.37 t ha^{-1}), followed by culinary melon (1.20 t ha^{-1}) among the sole crops. Integration with fish resulted in higher total drymatter production (1.49 t per 0.5 ha) from culinary melon (T_6) followed by fodder cowpea (T_7). It was observed that fish integration increased the drymatter production of amaranthus and culinary melon. But fish integration could not bring about significant increase in the drymatter production of fodder cowpea.

4.1.4 Productivity of Summer Crops

The results on the productivity of summer crops are presented in Table 6.

Productivity was higher (38.78 t ha^{-1}) in T_6 (culinary melon + fish). Fish integration was observed to increase the productivity of amaranthus and culinary melon as compared to their respective sole crops. However, appreciable variation could not be observed between the productivity of sole crop and fish integrated fodder cowpea.

Table 5. Yield, Rice equivalent yield (REY) and total drymatter production of crops raised during summer

Treatments	Yield	Rice equivalent yield	Total drymatter production
T_1: Fallow* (R-R-Fallow)	0.00	0.00	0.00
T_2: Amaranthus* (R-R-Amaranthus)	5.79	4.63	0.58
T_3: Culinary melon* (R-R-Culinary melon)	10.88	7.62	1.20
T_4: Fodder cowpea* (R-R-F. Cowpea)	23.70	3.56	2.37
T_5: Amaranthus + fish** (R+F)-(R+F)-(Amaranthus+F)	8.94	7.16	0.89
T_6: Culinary melon+ fish** (R+F)-(R+F)-(Culinary melon+F)	19.39	13.57	1.49
T_7: Fodder cowpea + fish** (R+F)-(R+F)-(Fodder cowpea+F)	11.67	1.75	1.17
SEm (±)	-	1.31	-
CD (0.05)	-	2.925	-

R: Rice; F: Fish *Yield of crop from 1 ha **Yield of crop from 0.50 ha

Sale prices of commodities (2015- '16)

Rice: ₹ 22 kg^{-1}

Amaranthus: ₹ 20 kg^{-1}

Culinary melon: ₹ 15 kg^{-1}

Fodder cowpea: ₹ 7 kg^{-1}

Table 6. Productivity of summer crops, t ha^{-1}

Treatments	Productivity
T_1: Fallow (R-R-Fallow)	0.00
T_2: Amaranthus (R-R-Amaranthus)	5.79
T_3: Culinary melon (R-R-Culinary melon)	10.88
T_4: Fodder cowpea (R-R-F. Cowpea)	23.70
T_5: Amaranthus + fish (R+F)-(R+F)-(Amaranthus+F)	17.88
T_6: Culinary melon+ fish (R+F)-(R+F)-(Culinary melon+F)	38.78
T_7: Fodder cowpea + fish (R+F)-(R+F)-(Fodder cowpea+F)	23.34

R: Rice; F: Fish

4.2 CHARACTERISATON OF TRENCH SILT

After the harvest of summer crops and fish, the fish trenches were de-watered and desilted. This silt was characterized in terms of quantity, physico-chemical and biological properties.

4.2.1 Quantity of Trench Silt Added

A total quantity of 39.49 t of trench silt (fresh weight basis) could be collected from 0.5 ha of trench. On dry weight basis this amounted to 20.93 t of trench silt.

4.2.2 Physical Properties of Trench Silt

The data on physical properties of trench silt presented in Table 7 indicate that the trench silt was clayey in texture with low bulk density (0.78 Mg m^{-3}) and high water holding capacity (47.38 %).

4.2.3 Chemical Properties of Trench Silt

The data on chemical properties of trench silt are presented in Table 8.

Trench silt was strongly acidic in reaction (5.41) and normal in electrical conductivity (0.51 dS m^{-1}). It was rich in organic carbon (2.12 per cent), available N (709.33 mg kg^{-1}), available K (204.28 mg kg^{-1}), available S (33.99 mg kg^{-1}) and Zn (14.24 mg kg^{-1}).

4.2.4 Total Microbial Count in Trench Silt

The total microbial count of trench silt collected is presented in Table 9.

Among the microorganisms, bacterial population was the highest followed by fungi and actinomycetes.

Table 7. Physical properties of trench silt

Parameter	Value
Bulk density (Mg m^{-3})	0.78
Water holding capacity (%)	47.38
Sand (%)	32.67
Silt (%)	20.33
Clay (%)	45.20
Textural class	Clay

Table 8. Chemical properties of trench silt

Sl. No.	Parameters	Value
1	pH	5.41
2	Electrical conductivity(dS m^{-1})	0.51
3	Organic carbon (%)	2.12
4	Available nitrogen (mg kg^{-1})	709.33
5	Available phosphorus (mg kg^{-1})	7.53
6	Available potassium (mg kg^{-1})	204.28
7	Calcium (mg kg^{-1})	190.02
8	Magnesium (mg kg^{-1})	30.31
9	Available sulphur (mg kg^{-1})	33.99
10	Zinc (mg kg^{-1})	14.24
11	Boron (mg kg^{-1})	0.22

Table 9. Total microbial count in trench silt

Micro organism	Count (cfu g^{-1}soil)
Bacteria	$43x10^6$
Fungi	$125x10^2$
Actinomycetes	$12x10^3$

cfu- colony forming units

4.3 WATER ANALYSIS

Water sample collected from the trenches at the time of harvest of fish was analysed for its chemical properties. The results are presented in Table 10.

The trench water analysed to be near neutral in reaction with a pH of 7.18 and normal in electrical conductivity (1.30 dS m^{-1}). It was rich in nutrients such as N (10.26 mg L^{-1}), P (1.80 mg L^{-1}), K (17.28 mg L^{-1}) and S (9.26 mg L^{-1}). The biological oxygen demand (5.20 mg L^{-1}) was within the safe limits for the growth of aquatic organisms.

Table 10. Chemical properties of trench water

Sl No.	Parameter	Value
1	pH	7.18
2	EC (dS m^{-1})	1.30
3	Nitrogen (mg L^{-1})	10.26
4	Phosphorus (mg L^{-1})	1.80
5	Potassium (mg L^{-1})	17.28
6	Calcium (mg L^{-1})	3.22
7	Magnesium (mg L^{-1})	0.36
8	Sulphur (mg L^{-1})	9.26
9	Zinc (mg L^{-1})	0.05
10	Boron (mg L^{-1})	0.01
11	Biological oxygen demand (mg L^{-1})	5.20

4.4 OBSERVATION ON *VIRIPPU* RICE (2016 -'17)

The summer crops were followed by rice during the *Virippu* season. The results on effect of farming systems on *Virippu* rice are detailed below.

4.4.1 Productive Tillers m^{-2}

The data presented in Table 11shows that the number of productive tillers m^{-2} did not vary significantly among the different farming systems.

4.4.2 Grain Weight Panicle^{-1}

The data on grain weight panicle are presented in Table 11.

Grain weight panicle^{-1} was observed to differ significantly among the treatments. Rice + fish succeeding fodder cowpea + fish (T_7) recorded significantly higher grain weight panicle^{-1} (4.08 g) which was on a par with T_6 (rice + fish succeeding culinary melon + fish), T_5 (rice + fish succeeding amaranthus + fish) and T_1 (rice –rice – fallow). In general, fish integration resulted in higher grain weight panicle^{-1}.

4.4.3 Total Number of Grains Panicle^{-1}

The Table 12 presents the data on total number of grains panicle^{-1}.

There was significant difference among treatments in the total number of grains panicle^{-1}. The treatment wherein rice + fish succeeding fodder cowpea + fish (T_7) recorded significantly more number of grains panicle^{-1} (159.80). It was on a par with T_5 (153.30) and T_6 (148.35) in which rice + fish succeeding amaranthus + fish and culinary melon + fish combinations respectively.

4.1.4 Filled Grains Panicle^{-1}

The effect of treatments on filled grains panicle^{-1} are presented in Table 12.The treatments differed significantly in the number of filled grains panicle^{-1}.

Table 11. Effect of treatments on productive tillers m^{-2} and grain weight $panicle^{-1}$ in rice

Treatments	Productive tillers m^{-2}	Grain weight $panicle^{-1}$ (g)
T_1: Rice (R-R- Fallow)	426.62	3.61
T_2: Rice (R-R-Amaranthus)	442.17	3.33
T_3: Rice (R-R-Culinary melon)	452.17	3.22
T_4: Rice (R-R-Fodder Cowpea)	468.84	3.40
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	482.17	4.02
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	486.61	3.91
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	557.72	4.08
SEm (±)	39.64	0.246
CD (0.05)	-	0.532

R: Rice; F: Fish

Rice crop integrated with fish recorded significantly more number of filled grains panicle^{-1}, irrespective of the preceding summer crop components.

Among the treatments, rice + fish succeeding fodder cowpea + fish (T_7) had more number of filled grains panicle^{-1} (144.35) and was on a par with T_5 (137.84) and T_6 (137.67). Sole crop of rice succeeding fallow (T_1) recorded significantly lower number of filled grains panicle^{-1}and it remained at par with T_3, T_2 and T_4.

4.4.5 Sterility Percentage

The data on the effect of farming systems on sterility percentage of *Virippu* rice are presented in Table 12.

Sterility percentage of *Virippu* rice exhibited significant difference among the treatments. Significantly lower sterility percentage (5.69 per cent) was recorded in T_5 (rice + fish succeeding amaranthus + fish) and it was observed to be on a par with T_6. The highest percentage of chaffy grains (13.18 per cent) was observed in T_2 (rice succeeding amaranthus) which was at par with T_4, T_1 and T_3. On the whole, sterility percentage of *Virippu* rice integrated with fish was found to be lower compared to the sole crop of rice.

4.4.6 Grain Yield

The data on grain yield of *Virippu* rice as affected by the farming systems are presented in Table 13.

Grain yield varied significantly among the treatments. Grain yield was significantly higher (6.62 t ha^{-1}) in rice + fish succeeding fodder cowpea + fish (T_7). The treatments, T_5 (rice + fish succeeding amaranthus + fish) and T_6 (rice + fish succeeding culinary melon + fish)remained at par with T_7. Rice succeeding fallow (T_1) recorded significantly lower grain yield. There was a notable increase in the grain yield of *Virippu* rice when integrated with fish as compared to the sole crop.

Table 12. Effect of treatments on total number of grains panicle^{-1}, filled grains panicle^{-1} and sterility percentage in rice

Treatments	Total number of grains panicle^{-1}	Filled grains panicle^{-1}	Sterility percentage
T_1: Rice (R-R- Fallow)	126.35	112.02	12.77
T_2: Rice (R-R-Amaranthus)	135.00	117.73	13.18
T_3: Rice (R-R-Culinary melon)	129.56	114.07	11.93
T_4: Rice (R-R-Fodder Cowpea)	136.48	123.37	13.03
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	153.30	137.84	5.69
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	148.35	137.67	7.21
T_7: Rice+fish (R+F)-(R+F)-(Fodder cowpea+F)	159.80	144.35	7.86
SEm (±)	8.71	7.95	0.74
CD (0.05)	18.985	17.338	1.628

R: Rice; F: Fish

4.4.7 Straw Yield

The data on the effect of farming systems on straw yield of *Virippu* rice are presented in Table 13.

The straw yield was significantly higher (6.84 t ha^{-1}) in T_7 (rice + fish succeeding fodder cowpea + fish) and was on a par with T_5 (rice + fish succeeding amaranthus + fish). T_1 (rice succeeding fallow) recorded significantly lower straw yield.

4.4.8 Grain: Straw Ratio

The data pertaining to grain: straw ratio as influenced by farming systems presented in Table 13 indicate that there was no significant difference among the treatments in grain: straw ratio.

4.5 PLANT ANALYSIS

4.5.1 Nutrient Content and Uptake by Summer Crops

The data presented below represents a comparison made among the summer crops in nutrient content and uptake, with and without fish integration.

4.5.1.1 Nitrogen

The data on effect of farming systems on the N content and uptake by the summer crops are presented in Table 14.

Significant difference was not observed with respect to the N content of the summer crops due to fish integration. However, N uptake varied significantly between 'with fish' and 'without fish' treatments in amaranthus and culinary melon. Amaranthus and culinary melon recorded significantly higher N uptake on integration with fish. Fodder cowpea failed to record significant variation in N uptake.

Table 13. Effect of treatments on grain yield, straw yield and grain: straw ratio

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain: Straw ratio
T_1: Rice (R-R- Fallow)	4.89	5.19	0.94
T_2: Rice (R-R-Amaranthus)	5.37	5.86	0.92
T_3: Rice (R-R-Culinary melon)	5.31	5.76	0.93
T_4: Rice (R-R-Fodder Cowpea)	5.50	5.95	0.92
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	5.87	6.14	0.96
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	5.77	5.99	0.96
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	6.62	6.84	0.97
SEm (±)	0.44	0.36	0.106
CD (0.05)	0.960	0.770	-

R: Rice; F: Fish

Table 14. Effect of fish integration on nitrogen content and uptake by summer crops

Treatment	Amaranthus		Culinary melon		Fodder cowpea	
	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})
Without fish	3.53	20.42	2.78	27.28	3.22	76.46
With fish	3.75	66.53	2.61	67.67	3.34	77.87
t value	0.506	5.630	0.901	6.024	1.250	0.275

Table values @ 5 % (2.776) and 1 % (4.604)

4.5.1.2 Phosphorus

The data on P content and uptake by summer crops are presented in Table 15.

The content of P did not show significant variation in summer crops with fish integration. However, integrating summer crops with fish had significant effect on P uptake. Amaranthus and culinary melon recorded significantly higher P uptake on integration with fish. Uptake of P by fodder cowpea was not affected by the presence of fish.

4.5.1.3 Potassium

The data on content and uptake of K by the summer crops are presented in Table 16.

As in the case of N and P, significant difference could not be observed in K content of summer crops due to fish integration. While, fish integration resulted in significantly higher uptake of K in amaranthus and culinary melon, the effect was not significant in fodder cowpea.

4.5.1.4 Calcium

The content and uptake of Ca by the summer crops as affected by fish integration are presented in Table 17.

The effect of fish integration was not significant with respect to Ca content in amaranthus and culinary melon. The uptake of Ca by amaranthus also did not vary significantly. The uptake of Ca by culinary melon was significantly higher with fish integration. In the case of fodder cowpea, significantly higher Ca content and uptake was observed in the sole crop than fodder cowpea + fish.

Table 15. Effect of fish integration on phosphorus content and uptake by summer crops

Treatments	Amaranthus		Culinary melon		Fodder cowpea	
	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})
Without fish	0.38	2.13	0.34	3.18	0.34	8.11
With fish	0.35	6.15	0.43	9.58	0.34	8.06
t value	0.757	3.982	0.729	2.922	0.189	0.038

Table values @ 5 % (2.776) and 1 % (4.604)

Table 16. Effect of fish integration on potassium content and uptake by summer crops

Treatment	Amaranthus		Culinary melon		Fodder cowpea	
	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})
Without fish	7.71	45.40	8.97	59.54	3.45	81.56
With fish	8.46	151.44	7.60	138.10	3.21	75.39
t value	2.511	5.709	0.919	5.305	0.646	0.579

Table values @ 5 % (2.776) and 1 % (4.604)

Table 17. Effect of fish integration on calcium content and uptake by summer crops

Treatments	Amaranthus		Culinary melon		Fodder cowpea	
	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})
Without fish	0.41	2.07	0.41	5.47	0.81	19.06
With fish	0.32	5.73	0.63	13.25	0.53	12.16
t value	0.723	1.915	2.605	4.214	3.115	4.403

Table values @ 5 % (2.776) and 1 % (4.604)

4.5.1.5 Magnesium

The results on the effect of fish integration with respect to the content and uptake of Mg are presented in Table18.

The content and uptake of Mg followed the same trend as N, P and K. Fish integration proved to have had no significant influence on the Mg content of amaranthus, culinary melon and fodder cowpea.

While, Mg uptake of amaranthus and culinary melon was significantly higher with fish integration, the same remained unaffected in fodder cowpea.

4.5.1.6 Sulphur

The content and uptake of S by the summer crops as influenced by fish integration are presented in Table 19.

Sulphur content of the component crops was not affected by fish integration. However, the uptake of S by amaranthus and culinary melon was significantly higher with fish integration. In the case of fodder cowpea, integration with fish could not bring about significant difference in the uptake of S.

4.5.1.7 Zinc

The effect of fish integration on Zn content and uptake by summer crops are depicted in Table 20.

The content of Zn in amaranthus and culinary melon was not affected by fish integration. But, it was significantly higher in fodder cowpea integrated with fish. The uptake of Zn revealed a reverse picture. Zn uptake was significantly higher in amaranthus and culinary melon integrated with fish, while it was not significant in the case of fodder cowpea.

Table 18. Effect of fish integration on magnesium content and uptake by summer crops

Treatment	Amaranthus		Culinary melon		Fodder cowpea	
	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})
Without fish	0.03	0.17	0.02	0.25	0.04	0.98
With fish	0.03	0.54	0.02	0.76	0.05	1.25
t value	0.172	6.179	1.128	7.271	2.230	1.386

Table values @ 5 % (2.776) and 1 % (4.604)

Table 19. Effect of fish integration on sulphur content and uptake by summer crops

Treatment	Amaranthus		Culinary melon		Fodder cowpea	
	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})	Content (%)	Uptake (kg ha^{-1})
Without fish	0.39	2.31	0.48	4.84	0.37	8.87
With fish	0.40	7.09	0.45	11.45	0.37	8.57
t value	0.085	3.327	0.356	3.241	0.013	0.207

Table values @ 5 % (2.776) and 1 % (4.604)

Table 20. Effect of fish integration on zinc content and uptake by summer crops

Treatment	Amaranthus		Culinary melon		Fodder cowpea	
	Content (mg kg^{-1})	Uptake (kg ha^{-1})	Content (mg kg^{-1})	Uptake (kg ha^{-1})	Content (mg kg^{-1})	Uptake (kg ha^{-1})
Without fish	115.43	0.08	46.17	0.07	47.87	0.11
With fish	100.15	0.17	41.19	0.14	57.20	0.13
t value	0.928	3.702	1.122	2.899	2.930	2.014

Table values @ 5 % (2.776) and 1 % (4.604)

4.5.1.8 Boron

The effect of fish integration on B content and uptake of summer crops are presented in Table 21.

Integration of fish could not bring about significant difference in the content of B in all the three summer crops. But B uptake was observed to be significantly higher in amaranthus and culinary melon integrated with fish.

4.5.2 Nutrient Content and Uptake by *Virippu* Rice

4.5.2.1 Nitrogen

Results on the effect of treatments on N content and uptake by the *Virippu* rice are presented in Table 22.

Nitrogen content in grain and straw was not significant in different farming systems. Whereas total N uptake by the crop was significantly higher in rice + fish succeeding fodder cowpea + fish (T_7).

4.5.2.2 Phosphorus

The data on content and uptake of P by *Virippu* rice are presented in Table 23.

There was no significant difference among treatments in the content of P in rice grain and straw. But the uptake of P was significantly higher in rice + fish succeeding fodder cowpea + fish (T_7) and remained at par with T_6 (rice + fish succeeding culinary melon + fish) and T_5(rice + fish succeeding amaranthus + fish).

4.5.2.3 Potassium

The data on content and uptake of K by *Virippu* rice crop are presented in Table 24.

The content and uptake of K were not significantly influenced by the different farming systems.

Table 21. Effect of fish integration on boron content and uptake by summer crops

Treatment	Amaranthus		Culinary melon		Fodder cowpea	
	Content (mg kg^{-1})	Uptake (kg ha^{-1})	Content (mg kg^{-1})	Uptake (kg ha^{-1})	Content (mg kg^{-1})	Uptake (kg ha^{-1})
Without fish	10.30	0.01	10.15	0.01	12.79	0.03
With fish	10.90	0.02	10.22	0.04	10.17	0.03
t value	0.389	4.050	0.234	4.611	2.648	1.807

Table values @ 5 % (2.776) and 1 % (4.604)

Table 22. Effect of treatments in nitrogen content and uptake by rice grain and straw

Treatments	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	1.59	0.99	118.23
T_2: Rice (R-R-Amaranthus)	1.65	0.79	123.74
T_3: Rice (R-R-Culinary melon)	1.49	0.83	116.74
T_4: Rice (R-R-Fodder Cowpea)	1.60	0.87	129.16
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	1.60	0.84	134.41
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	1.54	0.96	134.58
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	1.60	0.99	160.09
SEm (±)	0.07	0.05	7.89
CD (0.05)	-	-	17.191

R: Rice; F: Fish

Table 23. Effect of treatments in phosphorus content and uptake by rice

Treatments	Phosphorus (%)		Phosphorus uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	0.14	0.11	12.04
T_2: Rice (R-R-Amaranthus)	0.16	0.11	13.90
T_3: Rice (R-R-Culinary melon)	0.16	0.12	13.62
T_4: Rice (R-R-Fodder Cowpea)	0.16	0.12	14.07
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	0.15	0.10	14.18
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	0.18	0.11	15.39
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	0.18	0.11	17.18
SEm (±)	0.05	0.03	1.39
CD (0.05)	-	-	3.023

R: Rice; F: Fish

Table 24. Effect of treatments in potassium content and uptake by rice

Treatments	Potassium (%)		Potassium uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	0.59	2.54	136.95
T_2: Rice (R-R-Amaranthus)	0.56	2.33	141.86
T_3: Rice (R-R-Culinary melon)	0.54	2.47	145.86
T_4: Rice (R-R-Fodder Cowpea)	0.57	2.57	157.42
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	0.59	2.46	158.87
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	0.62	2.36	151.45
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	0.59	2.44	177.26
SEm (±)	0.03	0.17	13.82
CD (0.05)	-	-	-

R: Rice; F: Fish

4.5.2.4 Calcium, Magnesium and Sulphur

The effect of different farming systems on the content and uptake of secondary nutrients *viz.*, Ca, Mg and S are presented in Tables 25, 26 and 27 respectively.

The content and uptake of secondary nutrients by the *Virippu* rice crop did not vary significantly among the different farming systems.

4.5.2.5 Zinc and Boron

The effect of treatments on the content and uptake of Zn and B by rice crop are presented in Table 28 and Table 29 respectively.

The effect of treatments was not significant with respect to the content and uptake of Zn and B by the rice crop.

4.6 SOIL CHEMICAL PROPERTIES

The soil chemical properties were analysed before and after each season and the results obtained are presented below.

4.6.1 Soil Reaction

The effect of treatments on soil reaction before and after each season is presented in Table 30.

There was significant difference among treatments in soil reaction before the summer crop. The treatment rice + fish - rice + fish - amaranthus + fish (T_5) recorded the highest soil pH (5.53) and was on par with rice + fish – rice + fish – fodder cowpea + fish (T_7). A reduction in soil pH was observed after summer crop in all the farming systems. Significant difference was observed in soil reaction among treatments after the summer season. Among the different farming systems, T_5 recorded higher soil pH (4.73) and was on a par with T_7 and T_6.

Table 25. Effect of treatments on calcium content and uptake by rice

Treatments	Calcium (%)		Calcium uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	0.29	0.28	26.22
T_2: Rice (R-R-Amaranthus)	0.35	0.28	32.08
T_3: Rice (R-R-Culinary melon)	0.34	0.23	29.39
T_4: Rice (R-R-Fodder Cowpea)	0.32	0.22	28.60
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	0.34	0.26	32.68
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	0.29	0.25	28.83
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	0.33	0.26	35.84
SEm (±)	0.07	0.07	3.27
CD (0.05)	-	-	-

Table 26. Effect of treatments on magnesium content and uptake by rice

Treatments	Magnesium (%)		Magnesium uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	0.18	0.13	14.17
T_2: Rice (R-R-Amaranthus)	0.23	0.12	17.51
T_3: Rice (R-R-Culinary melon)	0.20	0.13	16.53
T_4: Rice (R-R-Fodder Cowpea)	0.19	0.13	16.51
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	0.18	0.12	16.95
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	0.19	0.13	17.35
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	0.19	0.13	19.69
SEm (±)	0.07	0.04	1.47
CD (0.05)	-	-	-

Table 27. Effect of treatments on sulphur content and uptake by rice

Treatments	Sulphur (%)		Sulphur uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	0.11	0.08	9.31
T_2: Rice (R-R-Amaranthus)	0.11	0.09	10.43
T_3: Rice (R-R-Culinary melon)	0.13	0.09	10.99
T_4: Rice (R-R-Fodder Cowpea)	0.12	0.08	10.36
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	0.13	0.07	11.13
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	0.12	0.08	11.03
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	0.13	0.06	11.92
SEm (±)	0.04	2.51	0.88
CD (0.05)	-	-	-

Table 28. Effect of treatments in zinc content and uptake by rice

Treatments	Zinc (mg kg^{-1})		Zinc uptake (kg ha^{-1})
	Grain	Straw	
T_1: Rice (R-R- Fallow)	21.28	30.81	0.23
T_2: Rice (R-R-Amaranthus)	21.53	29.00	0.25
T_3: Rice (R-R-Culinary melon)	20.59	25.98	0.23
T_4: Rice (R-R-Fodder Cowpea)	20.73	26.05	0.24
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	20.43	30.66	0.27
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	20.77	27.57	0.26
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	20.01	28.97	0.30
SEm (±)	0.60	2.16	0.06
CD (0.05)	-	-	-

Table 29. Effect of treatments on boron content and uptake by rice

Treatments	Boron ($mg\ kg^{-1}$)		Boron uptake ($kg\ ha^{-1}$)
	Grain	Straw	
T_1: Rice (R-R- Fallow)	5.85	7.23	0.059
T_2: Rice (R-R-Amaranthus)	5.72	7.64	0.063
T_3: Rice (R-R-Culinary melon)	5.03	6.88	0.058
T_4: Rice (R-R-Fodder Cowpea)	6.74	7.28	0.073
T_5: Rice+fish (R+F)-(R+F)-(Amaranthus+F)	5.48	7.16	0.068
T_6: Rice+fish (R+F)-(R+F)- (Culinary melon+F)	5.29	7.26	0.069
T_7: Rice+fish (R+F)-(R+F)-(Fodder Cowpea+F)	5.33	6.99	0.071
SEm (±)	0.53	0.70	1.880
CD (0.05)	-	-	-

Soil pH increased after *Virippu* crop in all treatments. The data obtained indicated that the treatments differed significantly in soil reaction. Significantly higher soil pH was observed in T_5(5.16) and it was at par with T_7 and T_6.

In general, the treatments with fish integration and those without fish exhibited significant variation in soil reaction. The soil of the treatments with fish integration was observed to become less acidic compared to treatments without fish.

4.6.2 Electrical Conductivity

The Table 31 shows the effect of farming systems on electrical conductivity of soil.

The electrical conductivity (EC) of soil collected before the summer season exhibited significant variation in response to the treatments. Significantly higher EC value (0.22 dS m^{-1}) was observed in T_1 (rice – rice – fallow) and was on a par with T_6 (rice + fish – rice + fish – culinary melon + fish).

EC of soil increased after summer season. The treatments had significant effect on EC of soil and significantly higher EC was recorded from rice – rice – fallow (T_1), which remained at par with rice – rice – culinary melon (T_3).

A notable reduction could be observed in EC of soil after *Virippu* crop and the treatments varied significantly. Significantly higher EC value was observed in rice – rice – amaranthus (T_2) and was on par with rice – rice- culinary melon (T_3) and rice – rice – fallow (T_1).

EC was observed to be lower in treatments with fish integration as indicated by significantly lower EC in T_6 (rice + fish – rice + fish –culinary melon + fish) which was on a par with T_7 (rice + fish – rice + fish –fodder cowpea + fish) and T_5 (rice + fish – rice + fish– amaranthus + fish).

Table 30. Effect of treatments on soil reaction before summer, after summer and after *Virippu* seasons.

Treatments	Soil reaction (pH)		
	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	4.88	4.15	4.68
T_2: (R-R-Amaranthus)	4.95	4.36	4.80
T_3: (R-R-Culinary melon)	5.01	4.57	4.75
T_4: (R-R-Fodder Cowpea)	4.99	4.24	4.79
T_5: (R+F)-(R+F)-(Amaranthus+F)	5.53	4.73	5.16
T_6: (R+F)-(R+F)- (Culinary melon+F)	5.13	4.58	5.01
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	5.32	4.68	5.13
SEm (±)	0.12	0.13	0.14
CD (0.05)	0.264	0.305	0.338

R: Rice; F: Fish

Table 31. Effect of treatments on electrical conductivity of soil before summer, after summer and after *Virippu* rice, dS m^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	0.22	0.37	0.16
T_2: (R-R-Amaranthus)	0.18	0.33	0.18
T_3: (R-R-Culinary melon)	0.18	0.36	0.17
T_4: (R-R-Fodder Cowpea)	0.18	0.25	0.13
T_5: (R+F)-(R+F)-(Amaranthus+F)	0.18	0.26	0.11
T_6: (R+F)-(R+F)- (Culinary melon+F)	0.21	0.32	0.10
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	0.20	0.24	0.11
SEm (±)	0.03	0.04	0.03
CD (0.05)	0.010	0.021	0.021

R: Rice; F: Fish

4.6.3 Organic Carbon

The data on the effect of farming systems on organic carbon status of soil is presented in Table 32.

There was significant difference among treatments in soil organic carbon status, both before and after the summer crop. Significantly higher organic carbon content (2.54 per cent) was recorded with the farming system T_1 (rice – rice – fallow) before and after summer season. While, the treatment T_2 (rice – rice – amaranthus) remained at par with T_1 before summer season, it was observed to be at par with T_2 (rice – rice – amaranthus) and T_3 (rice – rice – culinary melon) after the summer season.

There was no significant effect for treatments in organic carbon status of soil after *Virippu* season.

4.6.4 Soil Nutrient Status before and after Each Season

4.6.4.1 Available Nitrogen

The data on available N status of soil before and after summer season and after *Virippu* season are presented in Table 33.

The different farming systems varied significantly in available N status for all the three seasons (after *Mundakan*, after summer and after *Virippu*).

Before summer crop (after *Mundakan*), significantly higher soil available N content (266.66 kg ha^{-1}) was observed in rice – rice – amaranthus (T_2) and was on par with T_3, T_4, T_5 and T_6. After summer season also significantly higher available N(286.53 kg ha^{-1}) was recorded in rice – rice – amaranthus (T_2). It was on a par with T_3, T_4 andT_5. Available N status after *Virippu* crop was significantly higher (246.22 kg ha^{-1}) for T_5 (rice + fish – rice + fish– amaranthus + fish) and was at par with T_2, T_6 and T_7.

4.6.4.2 Available Phosphorus

The data pertaining to available P status of soil before and after summer and after *Virippu* seasons are presented in Table 34.

Available P before summer season varied significantly among the treatments. Significantly higher (35.36 kg ha^{-1}) available P status was observed inT_5 (rice + fish – rice + fish– amaranthus + fish).

There observed significant difference among treatments in available P status after summer season. Significantly higher soil P status was recorded in T_5 (38.07 kg ha^{-1}) and it remained at par with T_2(rice – rice- amaranthus).

There was no significant difference among different farming systems in availability of P after *Virippu* season.

4.6.4.3 Available Potassium

The data presented in Table 35 represents the effect of treatments on available K content of soil.

The soil analysis before summer revealed the available K varied significantly among the treatments. The treatment T_5 (rice + fish – rice + fish – amaranthus + fish)recorded significantly higher (165.26 kg ha^{-1}) available K status and was on a par with T_2(rice – rice- amaranthus) and T_7(rice + fish – rice + fish –fodder cowpea + fish).

There was no significant difference among treatments in soil available K status both after summer and after *Virippu* season.

4.6.4.4. Exchangeable Calcium

The data presented in Table 36 shows that there was significant difference among treatments in exchangeable Ca status of soil before summer, after summer and after *Virippu* seasons.

Table 32. Effect of treatments on soil organic carbon status before summer, after summer and after *Virippu* rice, per cent

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	2.54	2.54	1.88
T_2: (R-R-Amaranthus)	2.21	2.21	1.68
T_3: (R-R-Culinary melon)	2.11	2.19	1.69
T_4: (R-R-Fodder Cowpea)	1.80	1.80	1.58
T_5: (R+F)-(R+F)-(Amaranthus+F)	1.72	1.72	1.61
T_6: (R+F)-(R+F)- (Culinary melon+F)	1.48	1.48	1.62
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	1.53	1.43	1.59
SEm (±)	0.17	0.19	0.15
CD (0.05)	0.361	0.409	-

R: Rice; F: Fish

Table 33. Effect of treatments on available nitrogen status of soil before summer, after summer and after *Virippu* seasons, kg ha^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	217.04	192.34	210.45
T_2: (R-R-Amaranthus)	266.66	286.53	244.26
T_3: (R-R-Culinary melon)	265.52	281.49	227.54
T_4: (R-R-Fodder Cowpea)	250.43	263.07	222.05
T_5: (R+F)-(R+F)-(Amaranthus+F)	256.19	280.86	246.22
T_6: (R+F)-(R+F)- (Culinary melon+F)	256.08	253.96	244.26
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	235.34	255.46	233.81
SEm (±)	11.55	13.15	6.27
CD (0.05)	25.161	28.648	13.662

R: Rice; F: Fish

Soil Ca content before summer crop was significantly higher (278.26 mg kg^{-1}) in T_5 (rice + fish – rice + fish – amaranthus + fish) and was on par with T_6(rice + fish –rice + fish –culinary melon + fish). Significantly higher Ca content (261.97 mg kg^{-1}) after summer crop was observed in T_5 and was on par with T_6, T_7, T_2 and T_3.

After *Virippu* crop significantly higher soil exchangeable Ca content (299.21 mg kg^{-1}) was observed in T_5 and it was on a par with T_6, T_7 and T_4.

A notable increase in exchangeable calcium status of soil was observed in treatments integrated with fish as compared to those without fish.

4.6.4.5 Exchangeable Magnesium

The Table 37 indicates that Mg content in soil varied significantly among different farming systems during all the three seasons.

Significantly higher Mg status was observed in T_5 (rice + fish – rice + fish – amaranthus + fish) before and after summer and after *Virippu* seasons (43.93 mg kg^{-1}, 31.73 mg kg^{-1}, 31.63 mg kg^{-1} respectively). Before summer season, it was at par with T_7 (rice + fish – rice + fish – fodder cowpea + fish). After summer crop, T_5 was on a par with T_7 and T6.

4.6.4.6 Available Sulphur

The data on effect of treatments on available S content of soil are presented in Table 38.

Available S status varied significantly among the treatments during all the three seasons. Significantly higher S content was recorded in T_5 (rice + fish – rice + fish – amaranthus + fish).The treatment T_5 remained at par with T_2 and T_7 before summer season, with T_2 after summer season and with T_2, T_3 and T_6 after *Virippu* season.

Table 34. Effect of treatments on available phosphorus content of soil before summer, after summer and after *Virippu* seasons, kg ha^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	13.02	14.74	11.29
T_2: (R-R-Amaranthus)	27.01	36.50	14.27
T_3: (R-R-Culinary melon)	19.58	25.18	12.52
T_4: (R-R-Fodder Cowpea)	15.44	19.70	11.33
T_5: (R+F)-(R+F)-(Amaranthus+F)	35.36	38.07	14.27
T_6: (R+F)-(R+F)- (Culinary melon+F)	23.31	28.13	13.38
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	18.44	22.86	11.30
SEm (±)	2.42	2.70	2.15
CD (0.05)	5.271	5.898	-

R: Rice; F: Fish

Table 35. Effect of treatments on available potassium content in soil before summer, after summer and after *Virippu* seasons, kg ha^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	122.91	122.69	126.26
T_2: (R-R-Amaranthus)	154.96	140.83	132.42
T_3: (R-R-Culinary melon)	147.26	129.12	140.77
T_4: (R-R-Fodder Cowpea)	124.31	127.16	141.10
T_5: (R+F)-(R+F)-(Amaranthus+F)	165.26	149.74	126.02
T_6: (R+F)-(R+F)- (Culinary melon+F)	144.56	127.90	141.44
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	154.75	133.70	128.08
SEm (±)	11.31	10.78	7.07
CD (0.05)	24.648	-	-

R: Rice; F: Fish

Table 36. Effect of treatments on exchangeable calcium status of soil before summer, after summer and after *Virippu* seasons, mg kg^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	192.07	196.35	214.90
T_2: (R-R-Amaranthus)	216.27	236.55	218.37
T_3: (R-R-Culinary melon)	206.81	226.35	203.74
T_4: (R-R-Fodder Cowpea)	196.07	211.37	246.43
T_5: (R+F)-(R+F)-(Amaranthus+F)	278.26	261.97	299.21
T_6: (R+F)-(R+F)- (Culinary melon+F)	272.94	259.93	294.22
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	234.44	247.59	267.59
SEm (±)	17.01	18.19	30.22
CD (0.05)	37.052	39.638	65.858

R: Rice; F: Fish

Table 37. Effect of treatments on exchangeable magnesium status of soil before summer, after summer and after *Virippu* season, mg kg^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	25.07	27.84	23.83
T_2: (R-R-Amaranthus)	26.45	27.35	26.34
T_3: (R-R-Culinary melon)	27.48	24.16	24.77
T_4: (R-R-Fodder Cowpea)	31.37	25.17	26.03
T_5: (R+F)-(R+F)-(Amaranthus+F)	43.93	31.73	31.63
T_6: (R+F)-(R+F)- (Culinary melon+F)	35.72	29.17	26.81
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	43.33	29.76	28.23
SEm (±)	1.57	1.40	1.32
CD (0.05)	3.416	3.047	2.889

R: Rice; F: Fish

4.6.4.7 Zinc

The data on Zn status of soil as affected by farming systems are presented in Table 39.

Soil Zn status varied significantly after each season. The treatment T_5 (rice + fish – rice + fish – amaranthus + fish) recorded significantly higher soil Zn status. It remained at par with T_2 both after summer and *Virippu* crops.

4.6.4.8 Boron

The data on the effect of treatments on B content of soil are presented in Table 40.

There was no significant difference in soil B status after *Mundakan* and summer seasons. Soil B status varied significantly after the *Virippu* rice. Significantly higher boron status was recorded from T_5 (rice + fish – rice + fish – amaranthus + fish) and it remained at par with T_6 (rice + fish – rice + fish – culinary melon + fish).

4.7PEST AND DISEASE INCIDENCE

4.7.1 Summer season

The incidence of pest and disease was not recorded during the summer crop period.

4.7.2 *Virippu* season

A mild incidence of bacterial leaf blight (score -1) was recorded in rice crop, uniformly over all plots, and the effect on crop yield was negligible.

Table 38. Effect of treatments on available sulphur status of soil before summer, after summer and after *Virippu* season, mg kg^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	11.73	10.48	7.49
T_2: (R-R-Amaranthus)	14.32	14.81	10.15
T_3: (R-R-Culinary melon)	12.08	12.93	9.43
T_4: (R-R-Fodder Cowpea)	12.46	10.20	7.93
T_5: (R+F)-(R+F)-(Amaranthus+F)	14.40	15.91	10.32
T_6: (R+F)-(R+F)- (Culinary melon+F)	12.51	10.94	8.72
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	13.81	11.31	7.63
SEm (±)	0.68	1.22	0.78
CD (0.05)	1.492	2.654	1.695

R: Rice; F: Fish

Table 39. Effect of treatments on zinc content of soil before summer, after summer and after *Virippu* seasons, mg kg^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	3.20	3.14	3.22
T_2: (R-R-Amaranthus)	3.43	5.07	5.03
T_3: (R-R-Culinary melon)	3.23	3.91	3.51
T_4: (R-R-Fodder Cowpea)	3.21	3.88	3.42
T_5: (R+F)-(R+F)-(Amaranthus+F)	3.86	5.24	5.05
T_6: (R+F)-(R+F)- (Culinary melon+F)	3.25	3.996	3.57
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	3.24	3.99	3.49
SEm (±)	0.09	0.25	0.23
CD (0.05)	0.225	0.535	0.507

R: Rice; F: Fish

Table 40. Effect of treatments on boron content of soil before summer, after summer and after *Virippu* seasons, mg kg^{-1}

Treatments	Before summer (after *Mundakan*)	After summer	After *Virippu*
T_1: (R-R- Fallow)	0.14	0.14	0.11
T_2: (R-R-Amaranthus)	0.11	0.16	0.12
T_3: (R-R-Culinary melon)	0.13	0.19	0.10
T_4: (R-R-Fodder Cowpea)	0.14	0.16	0.11
T_5: (R+F)-(R+F)-(Amaranthus+F)	0.16	0.17	0.14
T_6: (R+F)-(R+F)-(Culinary melon+F)	0.15	0.16	0.14
T_7: (R+F)-(R+F)-(Fodder Cowpea+F)	0.11	0.12	0.13
SEm (±)	0.06	0.07	0.03
CD (0.05)	-	-	0.019

R: Rice; F: Fish

4.8 NUTRIENT BALANCE SHEET

4.8.1. Nitrogen

The data on balance sheet of N after summer and *Virippu* season are presented in Table 41 and 42 respectively.

4.8.1.1 Summer season

The N balance of soil was positive for the systems T_4 (rice – rice – fodder cowpea) and T_7 (rice + fish – rice + fish – fodder cowpea + fish) after summer season (44.10 kg ha^{-1} and 52.99 kg ha^{-1} respectively). For all other systems the balance sheet was negative. Fish integration was observed to reduce the loss of N from the soil as indicated by lesser difference between the actual and computed balance of N (less negative) when compared to the respective sole crop treatments The N balance for T_5 (-83.79 kg ha^{-1}) and T_6 (-32.29 kg ha^{-1}) were higher than T_2 (-134.72 kg ha^{-1}) and T_3 (-54.24 kg ha^{-1}) respectively.

4.8.1.2 Virippu season

All farming systems except rice – rice – fallow (T_1) showed a negative balance (21.33 kg ha^{-1}) for N. Among the other systems, N loss was less (-5.89 kg ha^{-1}) in T_7 (rice + fish – rice + fish – fodder cowpea + fish) as compared to the other farming systems tested.

4.8.2 Phosphorus

The data on balance sheet of P after summer and *Virippu* season are presented in Table 43 and 44 respectively.

4.8.2.1 Summer season

The balance sheet for P was negative for all the systems except T_1. In rice – rice – fallow system (T_1) there was a net gain in the soil which amounts to 1.72 kg ha^{-1}.

4.8.2.2 Virippu season

The P balance sheet for all farming systems was negative irrespective of integration with fish.

4.8.3 Potassium

The data on balance sheet of K after summer and *Virippu* season are presented in Table 45 and 46 respectively.

4.8.3.1 Summer season

The balance sheet of K was negative for T_1 (-0.22 kg ha^{-1}), T_2 (-93.74 kg ha^{-1}) and T_3 (-21.09 kg ha^{-1}). However, a positive balance for K was observed for T_4 (49.42 kg ha^{-1}), T_5 (10.91 kg ha^{-1}), T_6 (58.94 kg ha^{-1}) and T_7 (19.36 kg ha^{-1}).

4.8.3.2 Virippu season

There was a net gain of K in soil after *Virippu* season in all the seven farming systems. Among them, T_4 (106.35 kg ha^{-1}) followed by T_7 (98.26 kg ha^{-1}) showed higher balance for K.

4.8.4 Calcium

The data on balance sheet of Ca after summer and *Virippu* season are presented in Table 47 and 48 respectively.

4.8.4.1 Summer season

After summer season, the balance sheet for Ca tended to be positive for the farming systems T_1 (rice – rice - fallow), T_4 (rice – rice – fodder cowpea) and T_7 (rice + fish – rice + fish – fodder cowpea + fish). For all the other four systems, the balance sheet was negative.

4.8.4.2 Virippu season

Generally a positive balance sheet could be obtained in all the farming systems, except for T_2 (rice – rice – amaranthus). The balance of Ca was higher in treatments integrated with fish.

4.8.5 Magnesium

The data on balance sheet of Mg after summer and *Virippu* season are presented in Table 49 and 50 respectively.

4.8.5.1 Summer season

The Mg balance proved to be positive only for T_1 (rice – rice –fallow). In the case of all the other farming systems it was negative.

4.8.5.2 Virippu season

The Mg balance sheet of soil after *Virippu* season was positive for all farming systems.

4.8.6 Sulphur

The data on balance sheet of S after summer and *Virippu* season are presented in Table 51 and 52 respectively.

4.8.6.1 Summer season

The balance sheet for S was negative in all the farming systems after summer season. The difference between actual balance and computed balance was more in treatments T_2 (rice – rice – amaranthus) and T_5 (rice + fish – rice + fish – amaranthus + fish) compared to the other systems. In T_1 (rice – rice – fallow) the difference was less. The effect of crop components on the balance sheet of S was almost similar irrespective of fish integration.

4.8.6.1 Virippu season

After the *Virippu* season balance sheet of S was negative for all the farming systems.

4.8.7 Zinc

The data on balance sheet of Zn after summer and *Virippu* season are presented in Table 53 and 54 respectively.

4.8.7.1 Summer season

All the farming systems recorded negative balance sheet for soil Zn. The difference between actual balance and computed balance was more in the farming systems, T2 (rice – rice – amaranthus) and T_5 (rice + fish – rice + fish – amaranthus + fish). But it was less in T_1 (rice – rice – fallow).

4.8.7.2 Virippu season

The soil Zn balance after *Virippu* rice was negative in all farming systems.

4.8.8 Boron

The data on balance sheet ofB after summer and *Virippu* season are presented in Table 55 and 56 respectively.

4.8.8.1 Summer season

The balance sheet of B was positive in farming systems T_3, T_4 and T_7, zero in T_1 and negative in T_2, T_5 and T_6.

4.8.8.2 Virippu season

The balance sheet of B was negative for all the farming systems.

Table 41. Balance sheet of nitrogen after summer season, kg ha^{-1}

Treatments	Nitrogen added				Crop uptake	Balance		
	Soil contribution (after *Mundakan*)	FYM	Fertilizer	Total input		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	217.03	0	0	217.03	0	217.03	192.34	-24.69
T_2: (R-R-Amaranthus)	266.65	125	50	441.65	20.41	421.24	286.52	-134.72
T_3: (R-R-Culinary melon)	265.51	62.5	35	363.01	27.28	335.73	281.49	-54.24
T_4: (R-R-Fodder Cowpea)	250.43	25	20	295.43	76.45	218.97	263.07	44.10
T_5: (R+F)-(R+F)-(Amaranthus+F)	256.19	125	50	431.19	66.53	364.66	280.86	-83.79
T_6: (R+F)-(R+F)-(Culinary melon+F)	256.09	62.5	35	353.58	67.66	285.92	253.62	-32.29
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	235.34	25	20	280.34	77.86	202.48	255.47	52.99

R: Rice; F: Fish

Table 42. Balance sheet for nitrogen after *Virippu* season, kg ha^{-1}

Treatments	Nitrogen added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total N		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	192.34	25	0	0	90	307.34	118.23	189.11	210.44	21.33
T_2: (R-R-Amaranthus)	286.52	25	0	0	90	401.52	123.73	277.79	244.26	-33.53
T_3: (R-R-Culinary melon)	281.49	25	0	15.04	90	411.53	116.74	294.79	227.53	-67.26
T_4: (R-R-Fodder Cowpea)	263.07	25	0	0	90	378.07	129.15	248.92	222.05	-26.87
T_5: (R+F)-(R+F)-(Amaranthus+F)	280.86	25	29.31	0	90	425.17	134.41	290.76	246.23	-44.53
T_6: (R+F)-(R+F)-(Culinary melon+F)	253.62	25	29.31	27.59	90	425.52	134.58	290.94	244.26	-46.68
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	255.47	25	29.31	0	90	399.78	160.08	239.69	233.80	-5.89

R: Rice; F: Fish

Table 43. Balance sheet for phosphorus after summer season, kg ha^{-1}

Treatments	Phosphorus added				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	13.02	0	0	13.02	0	13.02	14.74	1.72
T_2: (R-R-Amaranthus)	27.01	50	25	102.01	2.13	99.88	36.51	-63.37
T_3: (R-R-Culinary melon)	19.58	25	12.5	57.08	3.17	53.91	25.18	-28.72
T_4: (R-R-Fodder Cowpea)	15.43	10	15	40.43	8.11	32.33	19.71	-12.62
T_5: (R+F)-(R+F)-(Amaranthus+F)	35.36	50	25	110.36	6.14	104.22	38.06	-66.16
T_6: (R+F)-(R+F)-(Culinary melon+F)	23.32	25	12.5	60.82	9.58	51.24	28.12	-23.11
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	18.44	10	15	43.44	8.07	35.37	22.86	-12.51

R: Rice; F: Fish

Table 44. Balance sheet for phosphorus after *Virippu* season, kg ha^{-1}

Treatments	Phosphorus added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total P		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	14.74	10	0	0	45	69.74	12.04	57.70	11.29	-46.41
T_2: (R-R-Amaranthus)	36.51	10	0	0	45	91.51	13.90	77.61	14.28	-63.33
T_3: (R-R-Culinary melon)	25.19	10	0	1.53	45	81.72	13.63	68.09	12.52	-55.57
T_4: (R-R-Fodder Cowpea)	19.71	10	0	0	45	74.71	14.07	60.63	11.33	-49.30
T_5: (R+F)-(R+F)-(Amaranthus+F)	38.06	10	0.31	0	45	93.38	14.18	79.20	14.28	-64.92
T_6: (R+F)-(R+F)-(Culinary melon+F)	28.12	10	0.31	2.63	45	86.07	15.39	70.68	13.39	-57.29
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	22.86	10	0.31	0	45	78.18	17.77	60.41	11.30	-49.10

R: Rice; F: Fish

Table 45. Balance sheet for potassium after summer season, kg ha^{-1}

Treatments	Potassium added				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total K		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	122.91	0	0	122.91	0	122.91	122.69	-0.22
T_2: (R-R-Amaranthus)	154.97	100	25	279.97	45.40	234.57	140.83	-93.74
T_3: (R-R-Culinary melon)	147.26	50	12.5	209.76	59.55	150.21	129.12	-21.09
T_4: (R-R-Fodder Cowpea)	124.31	20	15	159.31	81.56	77.74	127.17	49.42
T_5: (R+F)-(R+F)-(Amaranthus+F)	165.27	100	25	290.27	151.44	138.83	149.74	10.91
T_6: (R+F)-(R+F)-(Culinary melon+F)	144.55	50	12.5	207.05	138.09	68.96	127.90	58.94
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	154.75	20	15	189.75	75.40	114.35	133.71	19.36

R: Rice; F: Fish

Table 46. Balance sheet for potassium after *Virippu* season, kg ha^{-1}

Treatments	Potassium added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total K		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	122.69	20	0	0	45	187.69	136.94	50.75	126.25	75.50
T_2: (R-R-Amaranthus)	140.83	20	0	0	45	205.83	141.87	63.96	132.41	68.45
T_3: (R-R-Culinary melon)	129.12	20	0	22.16	45	216.28	145.86	70.42	140.77	70.35
T_4: (R-R-Fodder Cowpea)	127.17	20	0	0	45	192.17	157.41	34.75	141.10	106.35
T_5: (R+F)-(R+F)-(Amaranthus+F)	149.74	20	8.37	0	45	223.12	158.88	64.24	126.02	61.77
T_6: (R+F)-(R+F)-(Culinary melon+F)	127.90	20	8.37	21.29	45	222.57	151.45	71.12	141.44	70.32
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	133.71	20	8.37	0	45	207.08	177.26	29.82	128.09	98.26

R: Rice; F: Fish

Table 47. Balance sheet for calcium after summer season, kg ha^{-1}

Treatments	Calcium added				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total Ca		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	430.23	0	0	430.23	0	430.23	442.80	12.57
T_2: (R-R-Amaranthus)	536.69	105	0	641.69	2.07	639.62	514.94	-124.68
T_3: (R-R-Culinary melon)	448.30	52.5	0	500.80	5.47	495.33	447.31	-48.02
T_4: (R-R-Fodder Cowpea)	334.67	21	0	355.67	19.06	336.61	473.47	136.86
T_5: (R+F)-(R+F)-(Amaranthus+F)	623.31	105	0	728.31	5.74	722.58	549.46	-173.11
T_6: (R+F)-(R+F)-(Culinary melon+F)	611.39	52.5	0	663.89	13.24	650.65	544.92	-105.74
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	409.42	21	0	430.42	12.17	418.25	524.71	106.46

R: Rice; F: Fish

Table 48. Balance sheet for calcium after *Virippu* season, kg ha^{-1}

Treatments	Calcium added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total Ca		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	442.80	21	0	0	0	463.80	26.22	437.58	481.37	43.79
T_2: (R-R-Amaranthus)	514.94	21	0	0	0	535.94	32.08	503.86	489.17	-14.69
T_3: (R-R-Culinary melon)	447.31	21	0	3.66	0	471.98	29.40	442.58	456.39	13.81
T_4: (R-R-Fodder Cowpea)	473.47	21	0	0	0	494.47	28.60	465.87	551.99	86.13
T_5: (R+F)-(R+F)-(Amaranthus+F)	549.46	21	7.96	0	0	578.42	65.35	513.07	670.25	157.17
T_6: (R+F)-(R+F)-(Culinary melon+F)	544.92	21	7.96	3.48	0	577.36	57.64	519.72	659.04	139.32
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	524.71	21	7.96	0	0	553.68	71.66	482.01	599.39	117.38

R: Rice; F: Fish

Table 49. Balance sheet for magnesium after summer season, kg ha^{-1}

Treatments	Magnesium added				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total Mg		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	56.15	0	0	56.15	0	56.15	62.37	6.22
T_2: (R-R-Amaranthus)	67.45	9.79	0	77.24	0.17	77.07	61.28	-15.79
T_3: (R-R-Culinary melon)	60.92	4.89	0	65.81	0.26	65.56	54.11	-11.45
T_4: (R-R-Fodder Cowpea)	66.52	1.96	0	68.48	0.98	67.50	56.39	-11.11
T_5: (R+F)-(R+F)-(Amaranthus+F)	98.39	9.79	0	108.18	0.53	107.64	71.09	-36.56
T_6: (R+F)-(R+F)-(Culinary melon+F)	80.01	4.89	0	84.91	0.77	84.14	65.36	-18.78
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	97.04	1.96	0	99.00	1.24	97.75	66.68	-31.07

R: Rice; F: Fish

Table 50. Balance sheet for magnesium after *Virippu* season, kg ha^{-1}

Treatments	Magnesium added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total Mg		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	62.37	1.96	0	0	0	64.33	14.17	50.15	53.38	3.23
T_2: (R-R-Amaranthus)	61.28	1.96	0	0	0	63.24	17.50	45.74	59.02	13.28
T_3: (R-R-Culinary melon)	54.11	1.96	0	0.17	0	56.24	16.53	39.70	55.47	15.76
T_4: (R-R-Fodder Cowpea)	56.39	1.96	0	0	0	58.35	16.52	41.83	58.31	16.47
T_5: (R+F)-(R+F)-(Amaranthus+F)	71.09	1.96	1.27	0	0	74.31	16.94	57.36	70.83	13.46
T_6: (R+F)-(R+F)-(Culinary melon+F)	65.36	1.96	1.27	0.38	0	68.97	17.35	51.62	60.07	8.45
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	66.68	1.96	1.27	0	0	69.91	19.70	50.20	63.23	13.02

R: Rice; F: Fish

Table 51. Balance sheet for sulphur after summer season, kg ha^{-1}

Treatments	Sulphur added (kg ha^{-1})				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total S		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	26.28	0	0	26.28	0	26.28	23.48	-2.80
T_2: (R-R-Amaranthus)	32.07	111.75	18.75	162.57	2.32	160.25	33.17	-127.08
T_3: (R-R-Culinary melon)	27.04	55.88	0	82.92	4.84	78.08	28.98	-49.11
T_4: (R-R-Fodder Cowpea)	27.90	22.35	0	50.25	8.87	41.38	22.84	-18.54
T_5: (R+F)-(R+F)-(Amaranthus+F)	32.24	111.75	18.75	162.74	7.10	155.64	35.65	-119.99
T_6: (R+F)-(R+F)-(Culinary melon+F)	28.04	55.88	0	83.92	11.45	72.47	24.53	-47.94
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	30.95	22.35	0	53.30	8.56	44.74	25.32	-19.42

R: Rice; F: Fish

Table 52. Balance sheet for sulphur after *Virippu* season, kg ha^{-1}

Treatments	Sulphur added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total S		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	23.48	22.35	0	0	0	45.83	9.31	36.52	7.49	-29.03
T_2: (R-R-Amaranthus)	33.17	22.35	0	0	0	55.52	10.43	45.09	10.15	-34.93
T_3: (R-R-Culinary melon)	28.98	22.35	0	2.60	0	53.92	10.99	42.93	9.44	-33.49
T_4: (R-R-Fodder Cowpea)	22.84	22.35	0	0	0	45.19	10.37	34.82	7.93	-26.89
T_5: (R+F)-(R+F)-(Amaranthus+F)	35.65	22.35	14.23	0	0	72.23	11.13	61.10	10.33	-50.78
T_6: (R+F)-(R+F)-(Culinary melon+F)	24.53	22.35	14.23	4.41	0	65.52	11.03	54.49	8.71	-45.77
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	25.32	22.35	14.23	0	0	61.90	11.92	49.98	7.63	-42.35

R: Rice; F: Fish

Table 53. Balance sheet for zinc after summer season, kg ha^{-1}

Treatments	Zinc added				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	3.20	0	0	3.20	0	3.20	3.14	-0.06
T_2: (R-R-Amaranthus)	3.43	6.28	0	9.70	0.07	9.63	5.07	-4.56
T_3: (R-R-Culinary melon)	3.22	3.14	0	6.36	0.07	6.29	3.92	-2.37
T_4: (R-R-Fodder Cowpea)	3.20	1.26	0	4.46	0.11	4.35	3.87	-0.47
T_5: (R+F)-(R+F)-(Amaranthus+F)	3.86	6.28	0	10.14	0.18	9.96	5.24	-4.72
T_6: (R+F)-(R+F)-(Culinary melon+F)	3.25	3.14	0	6.39	0.15	6.24	4.00	-2.25
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	3.24	1.26	0	4.49	0.13	4.36	3.99	-0.37

R: Rice; F: Fish

Table 54. Balance sheet for zinc after *Virippu*season, kg ha^{-1}

Treatments	Zinc added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total Zn		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	3.14	1.26	0	0	0	4.39	0.23	4.16	3.22	-0.94
T_2: (R-R-Amaranthus)	5.07	1.26	0	0	0	6.32	0.25	6.07	5.03	-1.04
T_3: (R-R-Culinary melon)	3.92	1.26	0	0.05	0	5.23	0.23	5.00	3.51	-1.49
T_4: (R-R-Fodder Cowpea)	3.87	1.26	0	0	0	5.13	0.24	4.89	3.43	-1.46
T_5: (R+F)-(R+F)-(Amaranthus+F)	5.24	1.26	0.60	0	0	7.09	0.28	6.82	5.05	-1.76
T_6: (R+F)-(R+F)-(Culinary melon+F)	4.00	1.26	0.60	0.08	0	5.93	0.25	5.67	3.57	-2.11
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	3.99	1.26	0.60	0	0	5.84	0.29	5.54	3.49	-2.06

R: Rice; F: Fish

Table 55. Balance sheet for boron after summer season, kg ha^{-1}

Treatments	Boron added				Crop uptake	Balance		
	Soil contribution	FYM	Fertilizer	Total		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	0.33	0	0	0.33	0	0.33	0.33	0.00
T_2: (R-R-Amaranthus)	0.24	0.23	0	0.47	0.01	0.46	0.37	-0.09
T_3: (R-R-Culinary melon)	0.30	0.11	0	0.41	0.16	0.25	0.43	0.18
T_4: (R-R-Fodder Cowpea)	0.30	0.05	0	0.34	0.03	0.31	0.37	0.06
T_5: (R+F)-(R+F)-(Amaranthus+F)	0.37	0.23	0	0.60	0.02	0.58	0.37	-0.21
T_6: (R+F)-(R+F)-(Culinary melon+F)	0.32	0.11	0	0.43	0.05	0.39	0.36	-0.03
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	0.25	0.05	0	0.29	0.02	0.27	0.28	0.01

R: Rice; F: Fish

Table 56. Balance sheet for boron after *Virippu* season, kg ha^{-1}

Treatments	Boron added						Crop uptake	Balance		
	Soil contribution (after summer)	FYM	Silt	Crop residue	Fertilizer	Total B		Computed balance	Actual balance	Net gain/loss
T_1: (R-R- Fallow)	0.33	0.05	0	0	0	0.38	0.06	0.32	0.26	-0.06
T_2: (R-R-Amaranthus)	0.37	0.05	0	0	0	0.42	0.07	0.35	0.28	-0.07
T_3: (R-R-Culinary melon)	0.43	0.05	0	0.01	0	0.49	0.06	0.43	0.23	-0.20
T_4. (R-R-Fodder Cowpea)	0.37	0.05	0	0	0	0.42	0.07	0.35	0.23	-0.11
T_5: (R+F)-(R+F)-(Amaranthus+F)	0.37	0.05	0.01	0	0	0.43	0.03	0.39	0.32	-0.07
T_6: (R+F)-(R+F)-(Culinary melon+F)	0.36	0.05	0.01	0.02	0	0.43	0.03	0.40	0.29	-0.11
T_7: (R+F)-(R+F)-(Fodder cowpea+F)	0.28	0.05	0.01	0	0	0.34	0.04	0.30	0.27	-0.03

R: Rice; F: Fish

Discussion

5. DISCUSSION

The present study entitled "Nutrient budgeting in rice based farming system" was undertaken with the objectives to study the effect of component crops on soil nutrient status, to characterize and study the effect of trench silt on the performance of rice and to work out the nutrient balance sheet of the rice based farming systems. The results obtained from the study are discussed in this chapter.

5.1 SUMMER CROP (2015-'16)

5.1.1 Yield and Total Drymatter Production

Among the sole crops, higher yield (23.70 t ha^{-1}) was recorded by fodder cowpea followed by culinary melon (10.9 t ha^{-1}). Among the crops integrated with fish, culinary melon + fish recorded higher yield (19.4 t per 0.5 ha). In the case of amaranthus and culinary melon, fish integration resulted in higher yield compared to the respective sole crops. *i.e.,* amaranthus + fish (T_5)yielded more than sole crop of amaranthus (T_2) and culinary melon + fish (T_6)yielded more than sole crop of culinary melon (T_3).Total dry matter production also showed the same trend as yield with the sole crop of fodder cowpea recording higher drymatter production (2.37 t ha^{-1}), followed by culinary melon (1.20 t ha^{-1}) among the sole crops. Integration with fish resulted in higher total drymatter production (1.49 t per 0.5 ha) from T_6 (culinary melon + fish) followed by T_7 (fodder cowpea + fish).

The increased yield obtained from treatments integrated with fish might be due to the high nutrient status of soil observed in those treatments. Water availability in the plots integrated with fish might also have been more due to the capillary rise of water from the fish trenches into the raised beds.

In the case of culinary melon integrated with fish, the field duration of the crop was longer than the sole crop of culinary melon. Consequently the number of harvests was also more. But in the case of sole crop of culinary melon the vines decayed earlier due to heavy rains at the end of summer season (Fig 1a). During the summer season, all the component crops were cultivated on raised beds. However, the beds with fish integration had better drainage since these beds were slightly more elevated than the sole crop beds, probably due to repeated addition of trench silt over the years.

In amaranthus the number of leaves and plant height was more when the crop was integrated with fish. This could possibly due to the less weed pressure in plots with fish integration. Weed growth was comparatively less in plots integrated with fish compared to sole crop plots. These might be contributed to higher yield in amaranthus + fish. Fish integration could not bring about significant increase in the yield and drymatter production of fodder cowpea.

5.1.2 Rice Equivalent Yield

Culinary melon followed by amaranthus recorded higher REY both under sole crop (7.62 t ha^{-1} and 4.63 t ha^{-1}) and on integration with fish (13.57 t and 7.16 per 0.5 ha). The REY of amaranthus and culinary melon were significantly higher when they were raised along with fish compared to the sole crops (Fig.3). This reflected the same trend as that of yield. Even though fodder cowpea gave higher yield, the REY was less.REY was a single measurement comparison, wherein the yield of one crop is converted into the yield equivalent of rice on the basis of the existing market price of the economic produce. Thus the REY of fodder cowpea was less since the market price of the crop was only ₹ 7 kg^{-1}as compared to higher price of culinary melon (₹ 15 kg^{-1}) and amaranthus (₹ 20 kg^{-1}). Further, the higher REY recorded by culinary melon could also be attributed to its higher yield.

5.1.3 Productivity

Productivity was higher (38.78 t ha^{-1}) for culinary melon integrated with fish. Fish integration was observed to increase the productivity of amaranthus and culinary melon as compared to their respective sole crop productivity. The productivity of

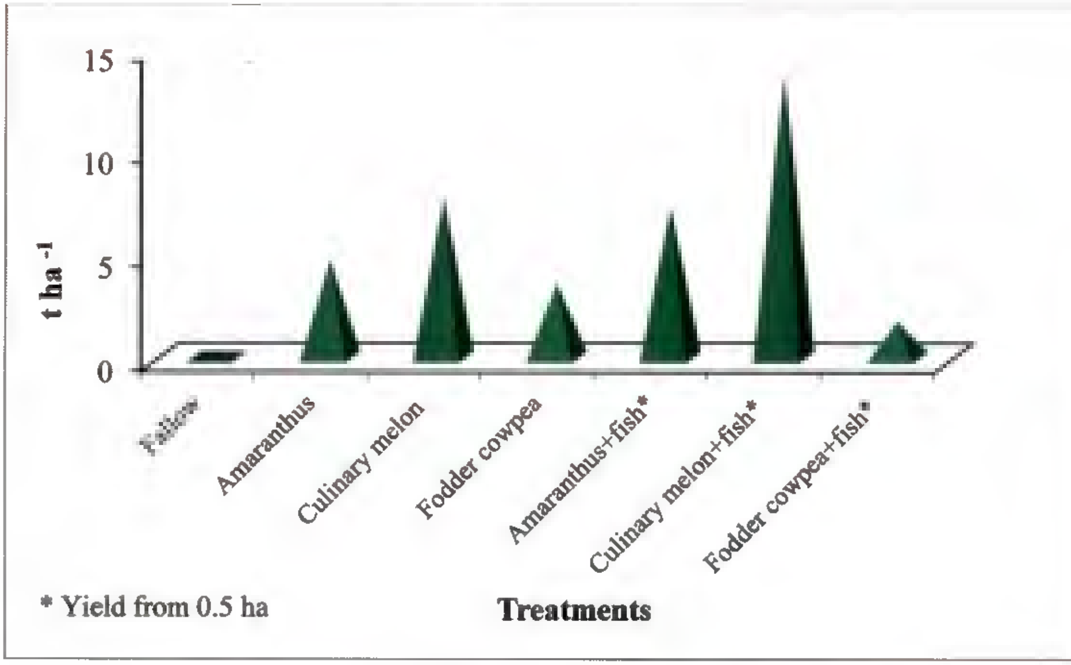

Fig.3. Rice equivalent yield (REY) of summer crops, t ha^{-1}

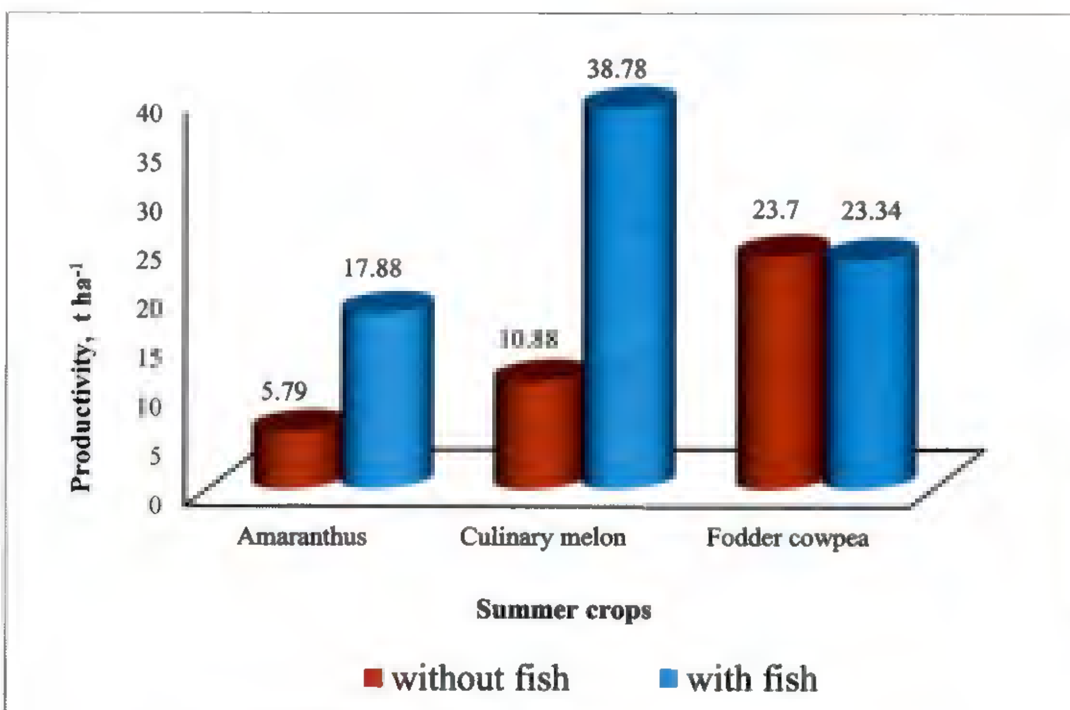

Fig. 4. Productivity of summer crops with fish and without fish, t ha^{-1}

amaranthus + fish was 208.80 per cent higher than the sole crop of amaranthus and in the case of culinary melon, it was 256.43 per cent higher on integration with fish, than the sole crop of culinary melon. However, appreciable variation could not be observed between the productivity of sole crop and fish integrated fodder cowpea (Table 57 and Fig. 4).

The positive effect of fish integration in increasing the productivity of the summer crops as compared to the respective sole crops might be due to the higher status of P, K, Ca and Mg in soils where fish was integrated with the crops as indicated by the status of these nutrients before the summer season (Tables, 34, 35, 36, 37).

Table 57. Percentage difference in productivity of summer crops with fish and without fish

Component crop	Productivity (t ha^{-1})		Percentage difference over sole crop
	With fish	Without fish	
Amaranthus	17.88	5.79	+208.80
Culinary melon	38.78	10.88	+256.43
Fodder cowpea	23.34	23.70	-1.52

5.2 CHARACTERIZATION OF TRENCH SILT

5.2.1 Quantification of Trench Silt

Significant quantity (20.93 t per 0.5 ha on dry weight basis) of trench silt was added to the plots before raising the *Virippu* crop. Based on the cultural practices followed for the crops and fish, the trench silt would comprise bottom mud along with soil eroded from the raised beds, fish excreta and remnants of fish feed. Desilting is considered to be an important practice for the management of fish ponds. Excessive accumulation of sediments in ponds reduces the volume of ponds and space available for fishes. Nutrient accumulation in trenches leads to organic accumulation and hence reduces dissolved oxygen contents and the pond become unfavourable for growth of aquatic organisms (Mizanur *et al.*, 2004).

5.2.2 Physical Properties of Trench Silt

The trench silt was characterized as clayey in texture with low bulk density (0.78 Mg m^{-3}) and high water holding capacity (47.38 per cent). This is in line with the findings of Munsiri *et al.* (1995) who observed higher moisture percentage and lower bulk density for pond bottom sediments with more silt and clay fractions. The lower bulk density of trench silt might be due to the accumulation of hydrated organic matter in trench silt as reported by Avnimelech *et al.* (2001).

5.2.3 Chemical Properties of Trench Silt

The trench silt was strongly acidic in reaction (5.41) and normal in electrical conductivity (0.51 dS m^{-1}). However, it was observed to be less acidic than the soil of the experimental site. It was rich in organic carbon (2.12 per cent), available N (709.33 mg kg^{-1}), available K (204.28 mg kg^{-1}), available S (33.99 mg kg^{-1}) and Zn (14.24 mg kg^{-1}).

The lowering of pH might be due to the presence of high organic matter content in the trench silt. Higher organic matter content of sediments is reflected from the estimated organic carbon values (Table 8). In the present study the organic matter amounted to 3.67 per cent based on the organic carbon content. Fish pond sediments have been identified to serve as biological filter through the adsorption of organic residues of food, excretory products and algal metabolites (Kumar *et al.*, 2012). Sipauba-Tavares *et al.* (2013) also observed lowering of pH in the sediments and they reported a pH between 4.5 and 6.5. They have attributed this to the high organic matter content of the sediments. Boyd and Tucker (2014) observed the possibility of release of H^+ ion during the nitrification of ammoniacal N in fish feed by bacteria, resulting in pH reduction.

Fish ponds have been identified as nutrient traps where high proportion of nutrients accumulate in the sediments (Green and Boyd, 1995; Hargreaves, 1998). The nutrients leached out from the cropped area, fish feed and excreta of fish might have contributed for the higher nutrient status of trench silt. The fish feed mainly comprised coconut oil cake and groundnut oil cake in 1:1 ratio. The fish feed mixture used in the study had higher contents of nutrients especially, N (3.12 per cent), K (1.14 per cent), S (0.69 per cent) and Zn (82 mg kg^{-1}). This might have contributed to the higher nutrient status of these nutrients in the trench silt. Further, the higher content of available nutrients might also be due to a higher level of mineralization of nutrients in the fish trenches as reported by Kumar *et al.* (2012). Trench silt proved to be rich in available K. The presence of cations like K in sediments has been attributed to the nature of the clay mineral (Mollah *et al.*, 1979).

5.2.4 Total Microbial Count in Trench Silt

Microbial properties showed that among the microorganisms, bacterial population was the highest followed by fungi and actinomycetes. This is in confirmation of the results of the studies conducted by Vezzulli *et al.* (2002) who reported higher population of benthic bacteria with organic enrichment. The bacteria might have been released from the excreta of fish or its body part as reported by Panicker and Sebastian (2002). They also observed that the abundance in bacterial population in pond water and sediments played vital role in organic recycling by contributing to the detritus food chain.

5.3 WATER ANALYSIS

The trench water observed to be near neutral in reaction (pH - 7.18) and normal in electrical conductivity (1.30 dS m^{-1}). It was rich in nutrients such as N, P, K and S (Table 10). The biological oxygen demand (5.20 mg L^{-1}) was within the safe limits for the growth of aquatic organisms.

Bihari *et al.* (2015) recorded a near neutral pH in the water from rice – fish system. The debris and nutrients from feeds might have contributed to the rise in EC. Similar results have been reported by Danba *et al.* (2015). The nutrients detected in trench water might be the contribution from the organic and inorganic fertilizers applied to the adjacent fields and from the trench silt. Studies conducted by Nhan *et al.* (2008) revealed that on an average only 5 to 6 per cent of the nutrients and organic carbon introduced into the ponds were recovered in the harvested fish. The remaining may either get accumulated in the sediments or in the pond water. The higher level of organic matter added to the fish pond could also result in accumulation of P in pond water (Bihari *et al.*, 2015).

BOD indicates the level of dissolved oxygen used by microorganisms for organic matter decomposition (Bhatnagar and Devi, 2013) and it depends on temperature, density of plankton and concentration of organic matter (Boyd and Tucker, 2014). The BOD of trench water could be rated as within safe limits for the normal activities of fishes. As per the reports of Bhatnagar *et al.* (2004) the BOD level within 3 to 6 is optimum for normal activities of fishes.

5.4*VIRIPPU* CROP (2016-'17)

5.4.1 *Virippu* Crop Yield Attributes and Yield

In general, the rice crop integrated with fish was found to be superior in yield and yield attributes compared to the sole crop of rice. The productive tiller count did not vary significantly among the treatments. Though the productive tiller count was non-significant among treatments it was relatively higher in the systems with rice - fish integration.

Significantly higher grain weight panicle^{-1} was obtained in the system rice + fish succeeding fodder cowpea + fish and it was at par with other systems where rice was integrated with fish.

Total number of grains panicle^{-1}, filled grains panicle^{-1} and sterility percentage were significantly different among the treatments. The treatment rice + fish succeeding fodder cowpea + fish recorded significantly more number of grains and filled grains per panicle. It was on a par with rice + fish succeeding amaranthus + fish and culinary melon + fish combinations. Vromant *et al.* (2002) observed an increase in the number of grains per panicle which compensated the decrease in the number of panicles m^{-2} in a rice-fish integration system.

Sole crop of rice succeeding fallow recorded significantly lower number of filled grains panicle^{-1}and it remained at par with T_2, T_3 and T_4. Significantly lower sterility percentage (5.69 per cent) was recorded in T_5 (rice + fish succeeding amaranthus + fish) and it was observed to be on a par with T_6. The highest percentage of chaffy grains (13.18 per cent) was observed in T_2 (rice succeeding amaranthus) which was at par with T_4, T_1 and T_3. Fish integration was observed to reduce sterility percentage.

Fish integration resulted in increased productivity for *Virippu* rice (Fig. 5). In general, during *Virippu* season, productivity of rice was 15.56 per cent higher with fish integration. Similar increase in yield with fish integration have been recorded by Mohanty *et al.* (2010). The grain yield was significantly higher in the rice + fish succeeding fodder cowpea + fish.

Productivity of straw was significantly higher and comparable in the systems of rice+fish preceded by fodder cowpea+fish during summer and rice+fish preceded by amaranthus+fish during summer. The productivity of rice grain and straw was less in the rice – rice – fallow system. The grain : straw ratio was found non-significant among treatments.

Yield is a function of yield attributes. Significantly higher grain weight panicle^{-1}, total number of grains and filled grains panicle^{-1} might have contributed to increased grain yield of *Virippu* rice in the system rice + fish succeeding fodder

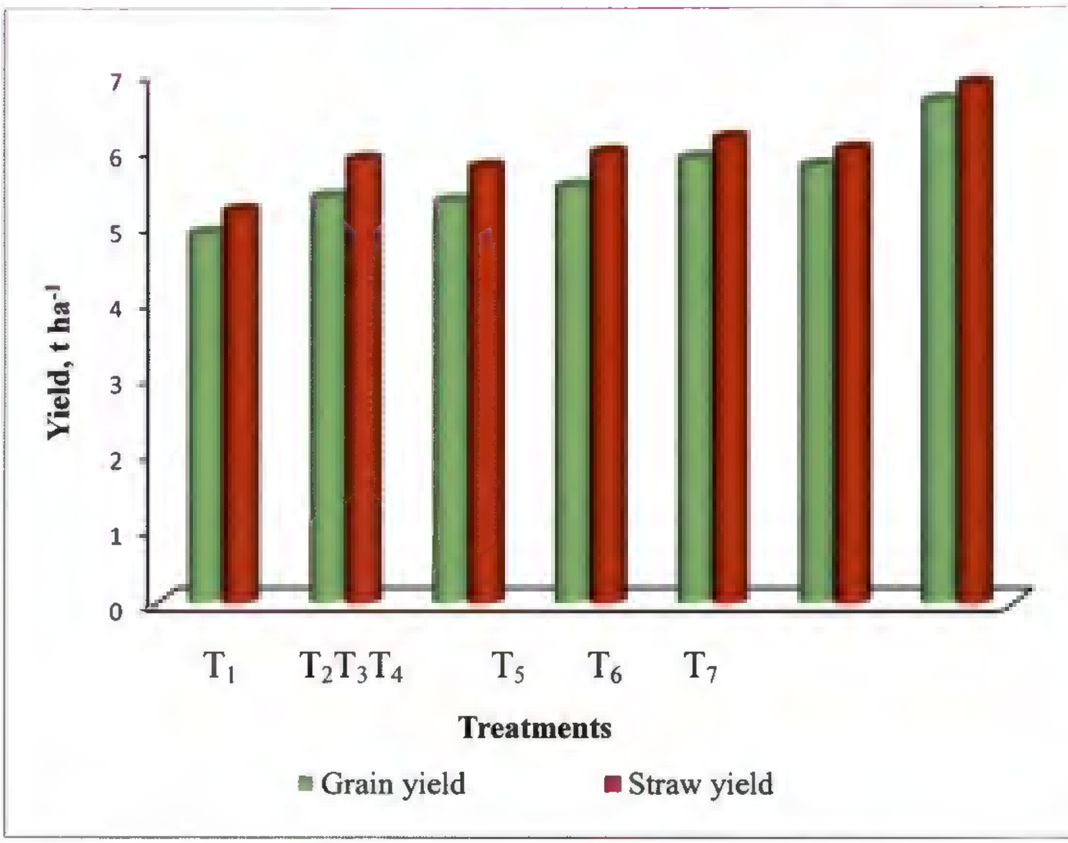

Fig. 5. Effect of treatments on grain and straw yield of *Virippu* rice, t ha^{-1}

cowpea + fish. The increased yield attributes and yield realized with fish integration could also be due to the addition and incorporation of the nutrient rich trench silt. Further, being an experiment in vogue for the past four years, trench silt addition might have also improved the soil physical conditions. Mohanty (2003) observed a similar increase in yield attributes and yield of rice with fish integration and attributed this to the improvement in soil fertility and consumption of planktons, weeds, insects and bacteria by fish. The positive effect of fish sediments in improving soil structure and soil fertility by enhancing soil aeration, water and nutrient holding capacities, root penetration by crops and thereby increasing crop growth and yield have also been reported by Ihejirika *et al*. (2012).

The specific yield increase recorded by rice + fish succeeding fodder cow pea + fish might be due to the legume effect. Legumes can be considered as small nitrogen factories in the field. Legumes also help to solubilize insoluble soil P, improve the soil physical conditions and increase the soil microbial activity (Ghosh *et al.,* 2007). The residual effect of fodder cowpea raised during summer might have contributed to improving the yield attributes of the succeeding *Virippu* rice. Prabhakaran and Janardhana (1997) reported that the grain yield of *Kharif* rice increased from 4.7 t ha^{-1} to 5.4 t ha^{-1} in rice – groundnut – cowpea system while a decline in grain yield was observed from (4.5 t ha^{-1} to 4.1 t ha^{-1}) in rice – rice sequential cropping system. Bationo *et al.* (2002) observed that the yields of cereals succeeding cowpea could be double compared to continuous cereal cultivation.

Sterility percentage was found to decrease in treatments integrated with fish. The treatments with fish integration had higher biomass production which might have contributed to better grain filling as suggested by Peng *et al.* (1999). Fish integration meant incorporation of trench silt also. The trench silt was rich in N and K. The higher N content of trench silt might have improved photosynthesis and consequently increased the amount of photosynthates available for grain filling in the crop (Moridani and Amiri, 2014). While N is important in the production of assimilates, K is the key nutrient that determines the source-sink relationship that favors better grain filling (Hayashi *et al.*, 2013).

5.5 PLANT ANALYSIS

5.5.1 Nutrient Content and Uptake by Summer Crops

5.5.1.1 Uptake of Nitrogen, Phosphorus and Potassium

The content of N, P and K was not significantly influenced by fish integration. However, N, P and K uptake of amaranthus and culinary melon showed significant variation between the respective sole crops and fish integration. Amaranthus and culinary melon recorded significantly higher N, P and K uptake on integration with fish. Fodder cowpea failed to record significant variation in uptake of N, P and K (Fig. 6, 7 and 8).

The uptake of N by amaranthus and culinary melon integrated with fish was 3.25 and 2.48 times more than that recorded by the respective sole crops. Fish integration was observed to increase the P uptake of amaranthus and culinary melon by 2.88 and 3.01 times respectively. In the case of K, uptake was more by 3.33 and 2.31 times with fish integration in amaranthus and culinary melon respectively.

Nutrient content in a plant is determined by the type of plant and its genotype. However, nutrient uptake is the product of drymatter production and nutrient content. Fageria and Baligar (2005) have stated that nutrient uptake in plants follows the same pattern as drymatter accumulation. Thus the increase in drymatter production exhibited by amaranthus and culinary melon might have contributed to the higher uptake of major nutrients. The lack of response of fodder cowpea to fish integration is also a reflection of its drymatter production.

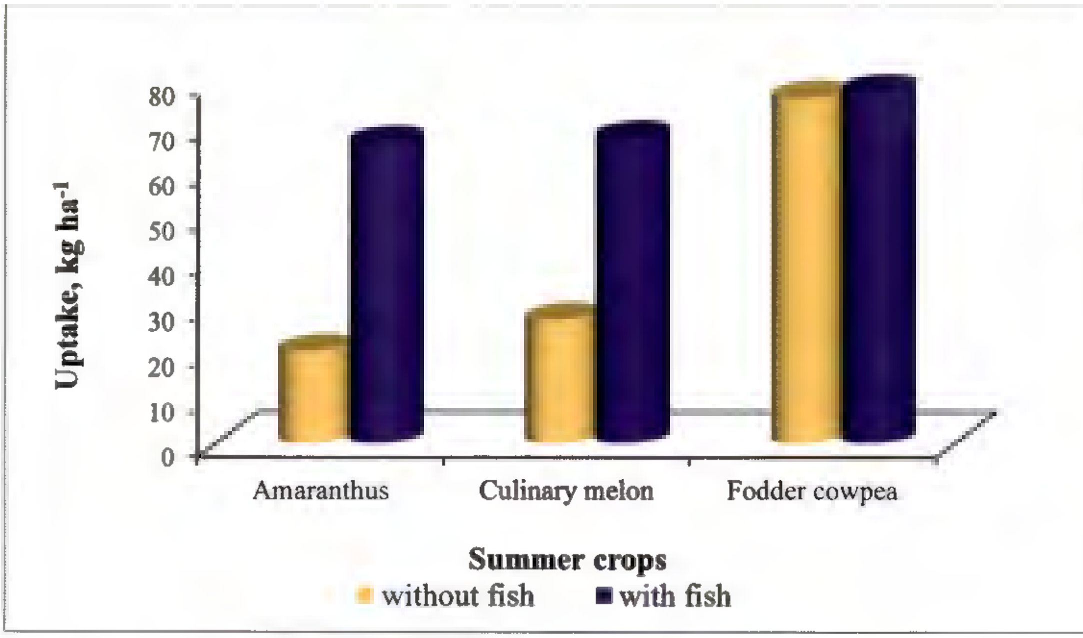

Fig. 6. Effect of fish integration on nitrogen uptake by summer crops, kg ha^{-1}

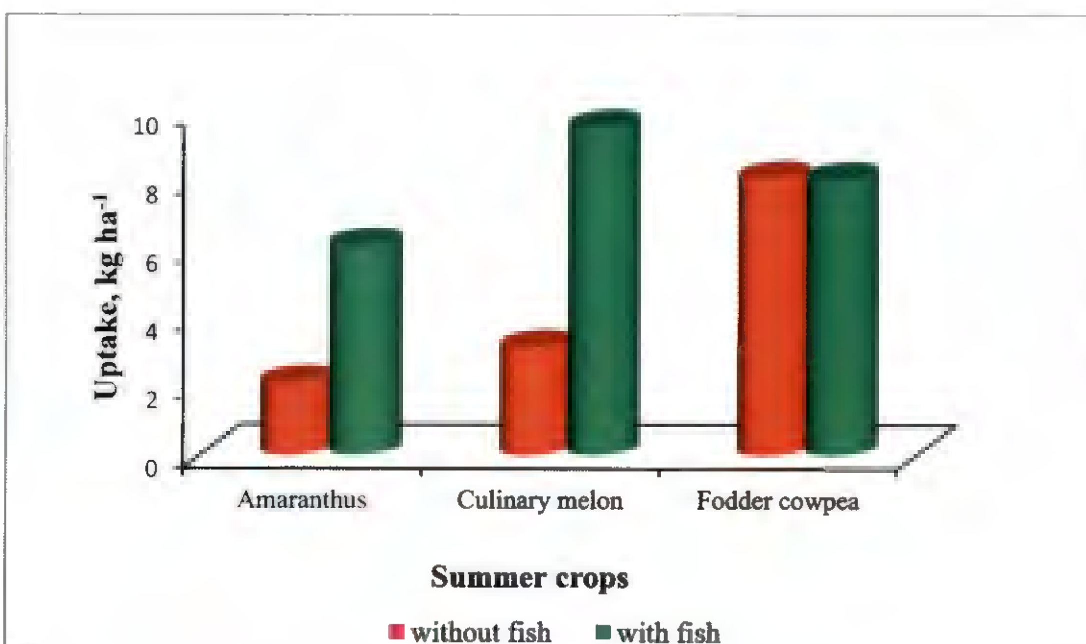

Fig. 7. Effect of fish integration on phosphorus uptake by summer crops, kg ha^{-1}

5.5.1.2 Uptake of Calcium, Magnesium, Sulphur

The content of Ca in amaranthus and culinary melon was not affected by fish integration. Uptake of Ca by amaranthus also did not vary significantly. The uptake of Ca by culinary melon was significantly higher (2.42 times) with fish integration. In the case of fodder cowpea, significantly higher Ca content and uptake were observed in the sole crop than fodder cowpea + fish (Fig. 9, 10 and 11).

Cucurbits in general absorb more Ca and it is an element taken up in larger quantities than any other nutrient except K (Ward, 1973). The higher Ca uptake recorded by culinary melon integrated with fish might have been contributed by the trench silt which had 190.02 mg kg^{-1} Ca. The higher uptake of Ca by the sole crop of fodder cowpea might be due to the higher Ca content recorded by the crop.

The content and uptake of Mg and S exhibited similar pattern as that followed in N, P and K. The content of Mg and S in amaranthus, culinary melon and fodder cowpea were not significantly influenced by fish integration. While their uptake by amaranthus and culinary melon was significantly higher with fish integration, the same remained unaffected in fodder cowpea.

Fish integration was observed to record higher Mg and S status in the soil as evidenced by the soil nutrient status before summer season (Table 37). Thus the higher availability of Mg and S might have increased the uptake also. Similar relationship between nutrient availability and uptake has been reported by Anjanappa *et al*. (2012).

5.5.1.3 Uptake of Zinc and Boron

The content of Zn in amaranthus and culinary melon was not affected by fish integration. But, it was significantly higher in fodder cowpea integrated with fish. Zn uptake was significantly higher in amaranthus and culinary melon integrated with fish, while it was not significant in the case of fodder cowpea (Fig. 12 and 13).

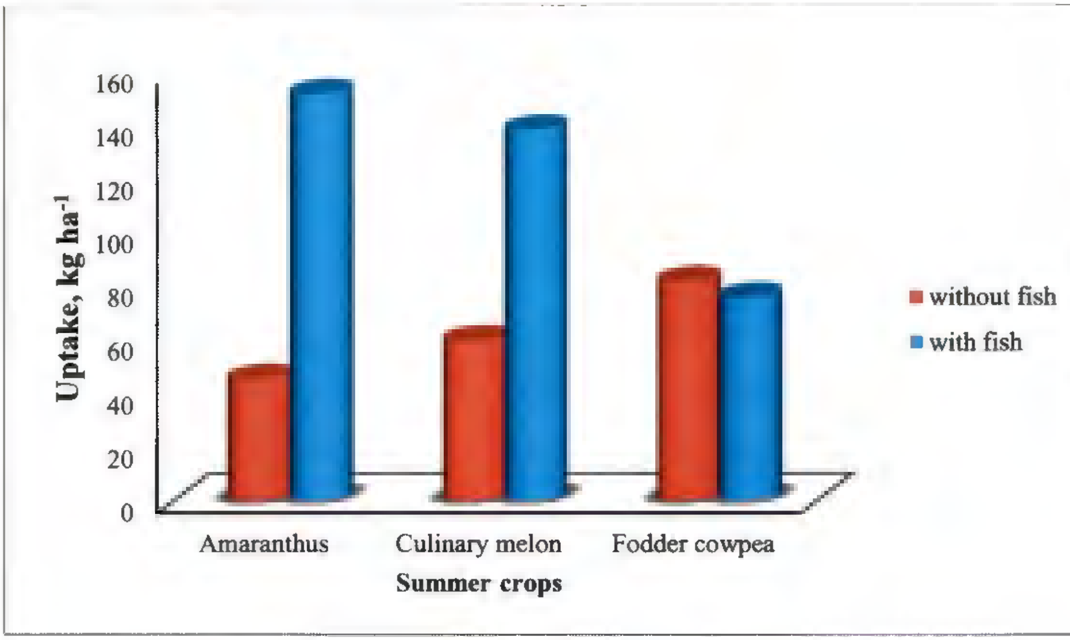

Fig. 8. Effect of fish integration on potassium uptake by summer crops, kg ha^{-1}

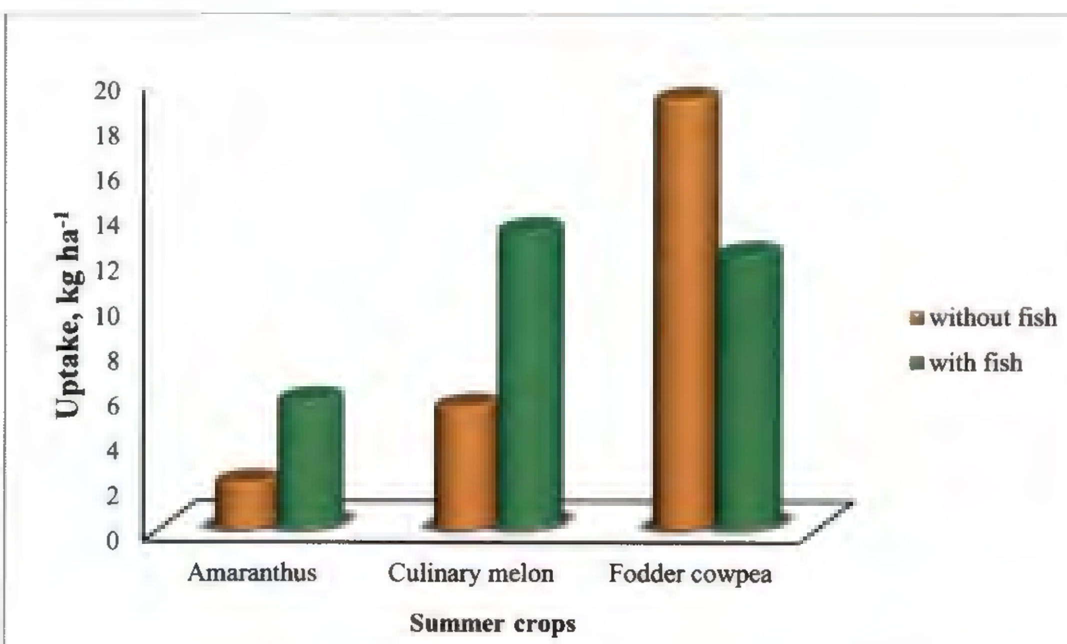

Fig. 9. Effect of fish integration on calcium uptake by summer crops, kg ha^{-1}

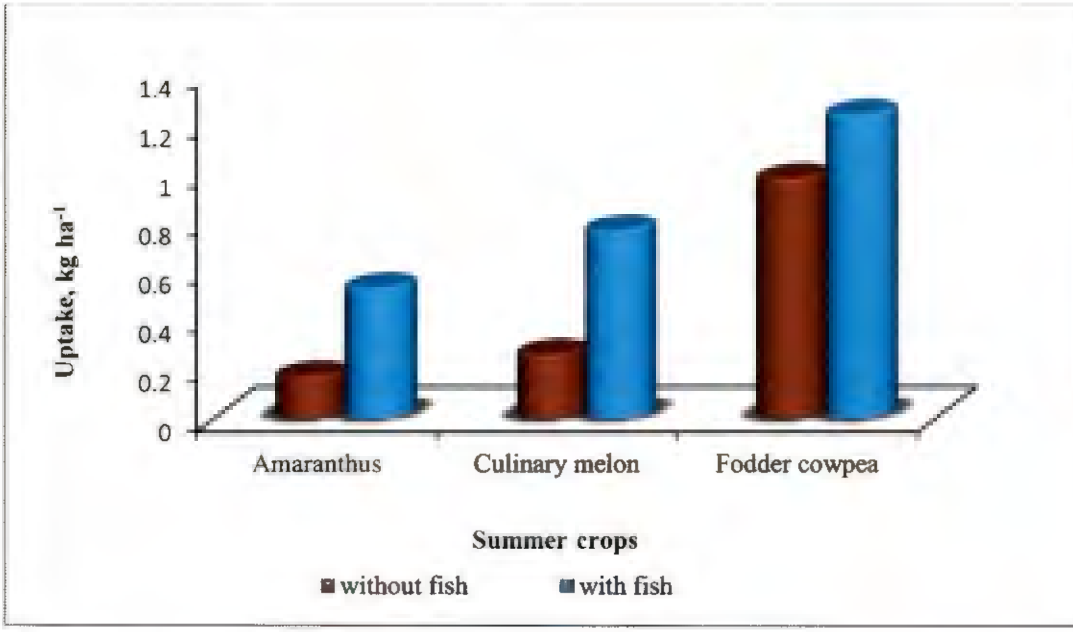

Fig. 10. Effect of fish integration on magnesium uptake by summer crops, kg ha^{-1}

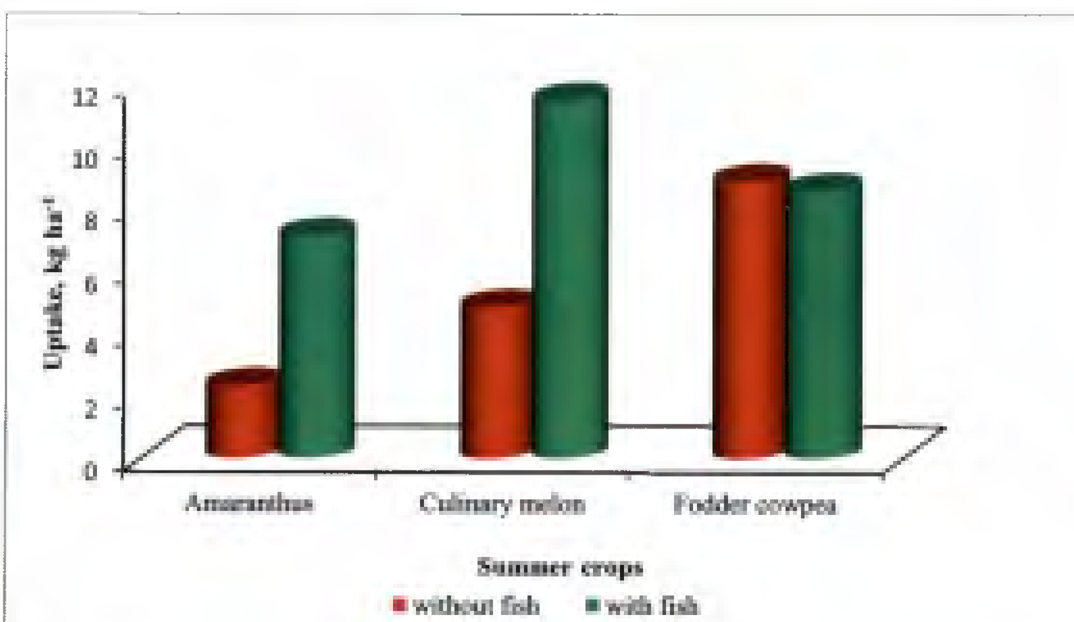

Fig. 11. Effect of fish integration on sulphur uptake by summer crops, kg ha^{-1}

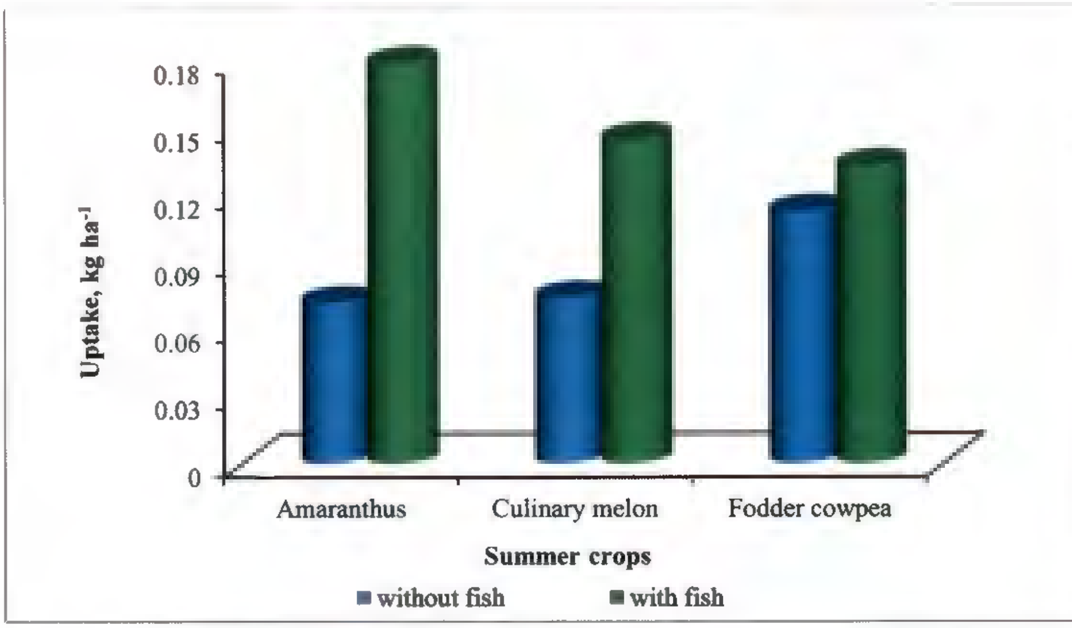

Fig. 12. Effect of fish integration on zinc uptake by summer crops, kg ha^{-1}

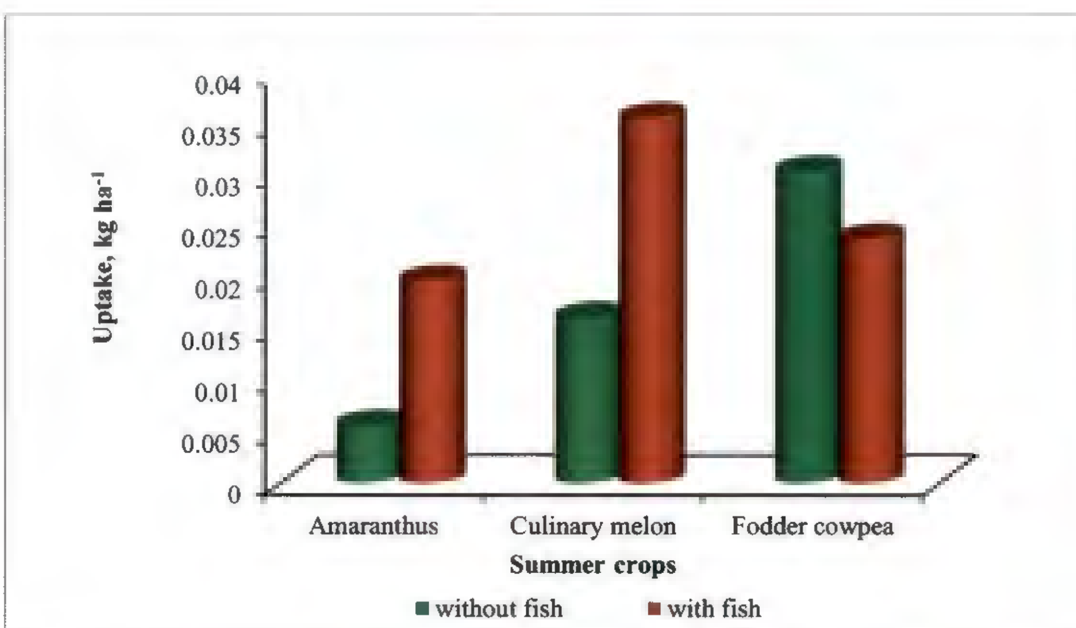

Fig. 13. Effect of fish integration on boron uptake by summer crops, kg ha^{-1}

Roots of legumes have a tendency to acidify the rhizosphere through the release of protons (Uratsu *et al.*, 1982). Rhizosphere acidification has been reported to affect micro nutrient acquisition by liberating cations from negative adsorption sites on clay surfaces (Munns and Schmidt, 2010). Zn availability increases with acidification (Metwally *et al.*, 1993). The possible rhizosphere acidification of fodder cowpea clubbed together with the higher content of Zn in the trench silt (Table 8) incorporated soil might have resulted in higher Zn content in fodder cowpea.

Integration of fish could not bring about significant difference in the content of B in all the three summer crops. But B uptake was observed to be significantly higher in amaranthus and culinary melon integrated with fish. Moisture availability and B uptake have been reported to exhibit a positive correlation. Huang *et al.* (1996) reported that higher water availability increases B availability, leaf transpiration and eventually a higher net uptake of B. Trench silt, by virtue of its lower bulk density and higher water holding capacity might have improved the soil physical properties including the hydraulic properties. In addition to the higher drymatter production, fish integration might have facilitated a better capillary rise of moisture and consequently a higher B uptake.

5.5.2 Nutrient Content and Uptake by *Virippu* Rice

5.5.2.1 Uptake of Nitrogen, Phosphorus and Potassium

N, P and K content in grain and straw was not influenced by the different farming systems. Whereas total N and P uptake by the crop was significantly higher in rice + fish succeeding fodder cowpea + fish (T_7). The uptake of P by *Virippu* rice remained at par with T_6 (rice + fish succeeding culinary melon + fish) and T_5 (rice + fish succeeding amaranthus + fish). Uptake of K was not significantly influenced by the different farming systems.

The significant increase in N and P uptake in rice + fish following fodder cowpea + fish could be attributed to legume effect, improvement in soil fertility and consequent increase in crop productivity. Fodder legumes have been reported to be more effective in increasing the productivity of succeeding cereals because they are harvested when the N fixation is at its maximum (Ghosh *et al.*, 2007). Further, legumes are also considered as catalysts that can improve the availability of both native and fixed P (Nimje and Seth, 1987). Fish integration and subsequent addition of trench silt also improved the availability of P resulting in better P uptake in rice crop integrated with fish.

5.5.1.2 Uptake of Calcium, Magnesium, Sulphur, Zinc and Boron

Significant variation was not observed in the content and uptake of secondary nutrients (Ca, Mg, and S) and the micronutrients *viz.*, Zn and B of *Virippu* rice crop.

5.6 SOIL CHEMICAL PROPERTIES

5.6.1 Soil Reaction

In general, soil acidity was observed to increase after summer season. On the other hand, after the *Virippu* season soil acidity decreased. According to Ponnamperuma (1972), acidity of submerged soils increased when exposed to air and that of aerobic soil decreased when submerged. The same trend was observed in the present experiment also as indicated by an increase in pH after summer season followed by a decrease after *Virippu* season.

Significant difference was observed among treatments in soil reaction before summer, after summer and after *Virippu* crops (Table 30 and Fig.14). The treatment rice + fish – rice + fish –amaranthus + fish (T_5) recorded the higher soil pH (less acidic).While, it was at par with T_7 (rice + fish – rice + fish – fodder cowpea + fish) before summer, T_5 remained on a par with T_6 (rice + fish – rice + fish – culinary melon + fish) also after summer and *Virippu* seasons.

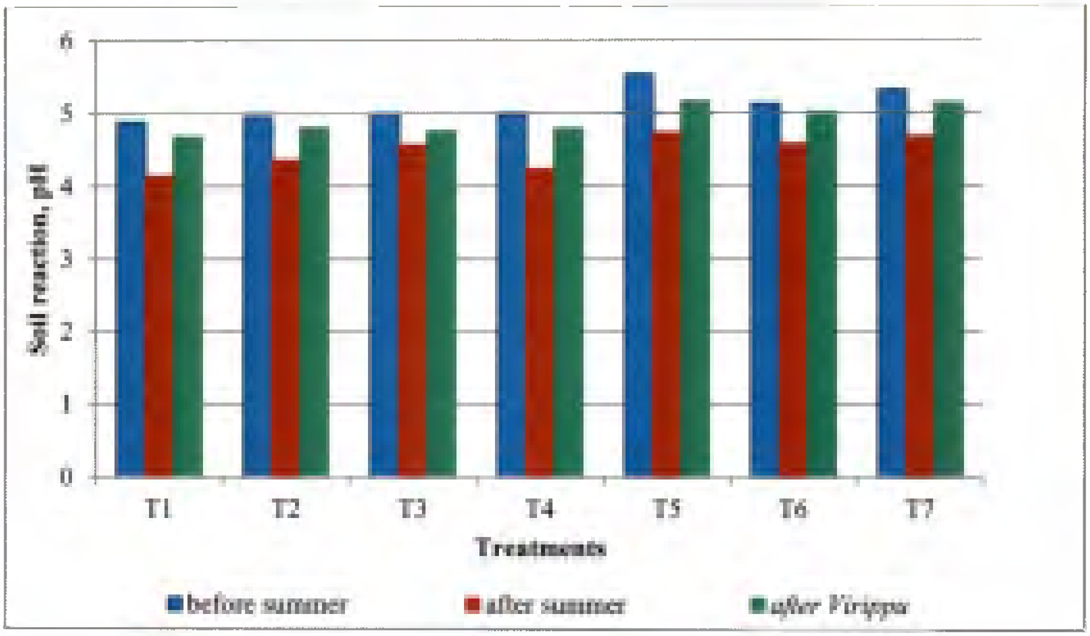

Fig. 14. Effect of treatments on soil reaction (pH)

Harvest of crops has been identified as one of the reasons of soil acidification. Plants absorb more cations than anions. Cation absorption results in the excretion of H^+ ions into the soil for the maintenance of electrical balance. During harvest, there is a net export of alkalinity resulting in residual H+ ions in the soil and this contributes to soil acidity (Gazey, 2016). Fish integration also resulted in a less acidic soil. The long term incorporation of less acidic trench silt might have contributed in making the soil less acidic. The effect of vegetation in increasing soil acidification has been attributed to excessive uptake of cations over anions by the vegetation (Fujii *et al.*, 2009).

5.6.2 Electrical Conductivity

The electrical conductivity (EC) of soil collected before the summer season exhibited significant variation in different farming systems. Significantly higher EC value was observed in rice – rice – fallow (T_1) and was on a par with T_6. Electrical conductivity of soil increased after summer season. The treatments had significant effect on EC of soil and significantly higher EC was recorded from rice – rice – fallow (T_1), which remained at par with rice – rice – culinary melon(T_3).

A notable reduction could be observed in electrical conductivity of soil after *Virippu* crop and the treatments varied significantly. Significantly higher electrical conductivity value was observed in rice – rice – amaranthus (T_2) and was on par with T_3 and T_1. EC was observed to be lower in treatments with fish integration as indicated by significantly lower EC in T_6, which was on a par with T_7 and T_5.

The increase in EC after the summer season could be related to the increase in temperature during summer. Similar increase in EC with temperature has been reported by Zhang and Wienhold (2002). The decrease in EC with fish integration might be due to the cumulative effect of trench silt addition over years. Jeyamangalam *et al.* (2012) observed similar reduction in EC with tank silt incorporation. They attributed this change in EC to the formation of organic compounds during decomposition of organic matter contained in tank silt as suggested by Sarwar *et al*. (2008).

5.6.3 Organic Carbon

There was significant difference among treatments in soil organic carbon status, both before and after the summer crop. Significantly higher organic carbon status was recorded with the farming system T_1 (rice – rice – fallow) before and after summer season. While, the treatment T_2 (rice – rice – amaranthus) remained at par with T_1 before summer season, it was observed to be at par with T_2 (rice – rice – amaranthus) and T_3 (rice – rice – culinary melon) after the summer season.

There was no significant effect for treatments in organic carbon status of soil after *Virippu* season.

The higher organic carbon recorded in T_1 comprising fallow after summer could be a reflection of the heavy weed growth that was observed during the fallow period. The organic carbon status of T_1 remained unaltered before and after summer. This might be due to the comparatively lower rate of organic matter decomposition since the land configuration remained the same without tillage and soil disturbance. Tillage aerates the soil, incorporates the crop residues and improves microbial activity and accelerates carbon cycle. Thus decomposition become faster, resulting in the reduction in soil organic matter (FAO, 2005). Studies conducted by Nishimura *et al*. (2008) showed that there was significant loss in organic carbon content of soil when paddy land was modified for cultivation of upland crops.

In farming systems where amaranthus and culinary melon were grown as component crop, soil organic carbon status was high. This is possibly due to the high dose of FYM applied to amaranthus (50 t ha^{-1}) and culinary melon (25 t ha^{-1}) as per KAU POP. Further, the shorter duration of these crops might have not been sufficient for complete mineralization of the applied manure.

5.6.4 Soil Nutrient Status before and after Each Season

5.6.4.1 Available Nitrogen

The different farming systems varied significantly in available N status for all the three seasons (after *Mundakan*, after summer and after *Virippu*). Before summer crop (after *Mundakan*), significantly higher soil available N content was observed in rice – rice – amaranthus (T_2) and was on par with T_3, T_4, T_5 and T_6.

In the case of soil available N content after summer season, significantly higher value was recorded in rice – rice – amaranthus (T_2). It was on a par with T_3, T_4 andT_5.Available N status after *Virippu* crop was significantly higher for T_5 (rice + fish – rice + fish– amaranthus + fish) and was at par with T_2, T_6 and T_7.

The higher status of available N observed after amaranthus and culinary melon might be due to the higher doses of organic manure applied to the crops. The available N status of soil increased after fodder cowpea. This enrichment of soil N (13 kg ha^{-1} without fish and 20 kg ha^{-1} with fish) primarily due to legume effect. Legumes are important in sustaining soil fertility in cropping systems for higher productivity. Ghosh *et al.* (2007) have reported a carryover effect of 35-60 kg N $ha^{-1}$for succeeding crops by fodder cowpea.

In general, an increase in soil N status was observed after summer season. However, a reverse trend was noticed in rice – rice – fallow system. The study revealed that, crop diversification improved the available N status of the soil as indicated by a lower value for available N in T_1 (rice – rice – fallow).

5.6.4.2 Available Phosphorus

Available P status of soil varied significantly among the treatments before and after summer season. Significantly higher available P status was observed in T_5 (rice + fish – rice + fish– amaranthus + fish) in both season. After summer T_5

remained at par with T_2 (rice – rice – amaranthus). There was no significant difference among different farming systems in availability of P after *Virippu* season.

The increased P status observed in the systems T_5 and T_2after summer season might be due to the effect of higher quantity of FYM applied to the summer crop of amaranthus. Addition of organic matter have been proved to increase the availability of P directly by the P content in them and indirectly by release of organic acids, improved microbial activity and by blocking P fixation thus increasing P mobilization (Ayaga *et al.*, 2006).

5.6.4.3 Available Potassium

The soil analysis before summer revealed that available K varied significantly among the treatments. The treatment T_5 recorded significantly higher available K status and was on a par with T_2 and T_7. There was no significant difference among treatments in soil available K status both after summer and after *Virippu* season.

Available K did not exhibit any definite trend with respect to season and crops. This might be due to the typical behavior of K to maintain a dynamic equilibrium in the soil as suggested by Sparks (1987).

5.6.4.4. Exchangeable Calcium, Exchangeable Magnesium and Available Sulphur

There was significant difference among treatments in exchangeable Ca, Mg and available S status of soil in all the three seasons. The rice + fish – rice + fish – amaranthus + fish (T_5) system recorded significantly higher exchangeable Ca, Mg and available S status.

A notable increase in exchangeable Ca and Mg status of soil was observed in treatments integrated with fish as compared to those without fish. This could be attributed to the addition of trench silt which contains considerable quantity of Ca and Mg (Table 8).The increase in Ca, Mg and S status of soil observed in T_5 may be due to the combined effect of high dose of FYM (50 t ha^{-1}) and trench silt addition. The

FYM used in the present study analysed to be rich in Ca (420 mg kg^{-1}) and Mg (39 mg kg^{-1}).

The available S status of soil was higher in the treatments where amaranthus was grown as a component crop irrespective of fish integration. As per the KAU POP recommendation amaranthus requires NPK at the rate of 50: 50: 50 as basal dose (KAU, 2016). Since Factamphos (ammonium phosphate-sulphate) with a fertilizer grade of 20-20-0-15 contains equal quantities of N and P, it was used for basal application in amaranthus. The S contained in the fertilizer material might have contributed to the higher available S status of the soil.

5.6.4.7 Zinc and Boron

Soil Zn status varied significantly after summer and *Virippu* season. The treatment T_5 (rice + fish – rice + fish – amaranthus + fish) recorded significantly higher soil Zn status and it remained at par with T_2. There was no significant difference in soil B status before and after summer season. Soil B status varied significantly after the *Virippu* rice. Significantly higher B status was recorded from T_5 and it remained at par with T_6.

The higher content of Zn observed in treatments T_5 and T_2might be due to the application of higher quantity of FYM which was rich in Zn (251 mg kg^{-1}). Buildup of available Zn in soil by application of organic amendments was also observed by Narwal *et al*. (1983).

The higher status of available B observed with fish integration after *Virippu* season could be due to the organic matter addition *via* trench silt and consequent improvement in soil physical properties including moisture retention. This finding is in agreement with Goldberg *et al*. (2000).

5.7 NUTRIENT BALANCE SHEET

5.7.1. Balance Sheet of Nitrogen

Among the different farming systems, in T_4 (rice – rice – fodder cowpea) and T_7 (rice + fish – rice + fish – fodder cowpea + fish) the N balance of soil was observed to be positive after summer season (44.10 kg ha^{-1}and 52.99 kg ha^{-1} respectively). For all other systems the balance sheet was negative. Fish integration was observed to reduce the loss of N from the soil as indicated by lesser difference between the actual and computed balance of N (less negative) when compared to the respective sole crop treatments. The N balance for T_5 (-83.79 kg ha^{-1}) and T_6 (-32.29 kg ha^{-1}) were higher than T_2 (-134.72 kg ha^{-1}) and T_3 (-54.24 kg ha^{-1}) respectively (Fig. 15).

The positive balance of N with fodder cowpea as a component might be due to legume effect. Similar results have been reported by Singh *et al.*(1996) and Pillai *et al*. (2007).

After *Virippu* season all farming systems except rice – rice – fallow (T_1) showed a negative balance (21.33 kg ha^{-1}) for nitrogen. Among the other systems, N loss was less (-5.89 kg ha^{-1}) in T_7 (rice + fish – rice + fish – fodder cowpea + fish) as compared to the other farming systems tested. In general, a negative trend in available N status of soil was observed after *Virippu* season. Applied fertilizer N is subject to several losses like leaching, volatilization and denitrification in low land rice resulting in a fertilizer N use efficiency of 30 to 40 per cent only (Ladha *et al*., 2005). A positive balance of N after *Virippu* rice in T_1 (rice – rice – fallow) could be related mathematically to the low initial available N status of soil (after summer). The net loss of available N was comparatively lesser in T_7 possibly due to the added carryover effect of fodder cowpea and N rich trench silt.

5.7.2 Balance Sheet of Phosphorus

The P balance sheet after the summer season was negative for all the systems except T_1. In rice – rice – fallow system (T_1) there was a net gain in the soil which amounts to 1.72 kg ha^{-1}. After *Virippu* season balance sheet for all farming systems was negative irrespective of integration with fish (Fig. 16).

Soil was acidic in reaction. The negative balance of P observed might be due to P fixation under acidic pH. Similar cases P fixation as iron and aluminium phosphate was reported by Huck *et al*. (2014).

5.7.3 Balance Sheet of Potassium

A negative balance sheet of K was observed in T_1 (-0.22 kg ha^{-1}), T_2 (-93.74 kg ha^{-1}) and T_3 (-21.09 kg ha^{-1}). However, a positive balance for K was observed for T_4 (49.42 kg ha^{-1}), T_5 (10.91 kg ha^{-1}), T_6 (58.94 kg ha^{-1}) and T_7 (19.36 kg ha^{-1}) after summer season. There was a net gain of K in soil after *Virippu* season in all the seven farming systems. Among them, T_4 (106.35 kg ha^{-1}) followed by T_7 (98.26 kg ha^{-1}) showed higher balance for K (Fig. 17).

Net gain of available K after sole crop of fodder cowpea might be an indicator of fodder cowpea placing less demand for K from the soil. This is evident from data on the available K status of soil before and after summer season (Table 35). Legumes have deeper and ramified root system compared to vegetables and consequently higher root CEC. Further, root system of crops tends to grow deeper when moisture content is less. Hence, the sole crop of fodder cowpea might have developed a deeper root system compared to fodder cowpea integrated with fish where moisture availability was more. Legumes are dicots with greater affinity for divalent cations than monovalent cations like K^+ as evidenced by the higher Ca uptake of fodder cowpea (Table 17). This might have contributed to the net gain (positive balance) in available K status after sole crop of fodder cowpea.

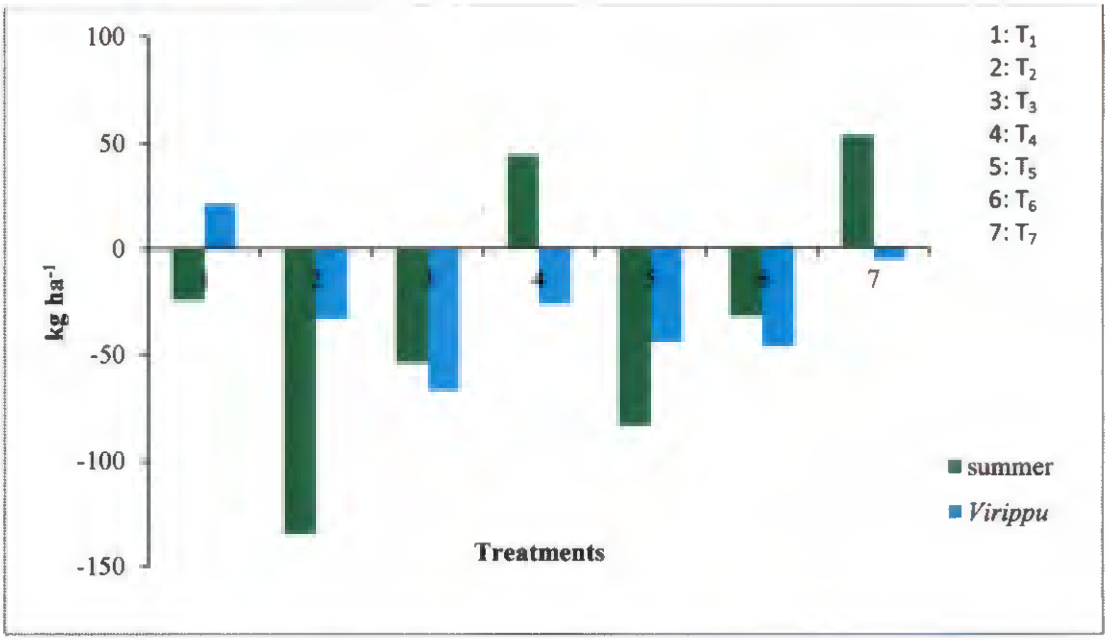

Fig. 15.Balance sheet of nitrogen, kg ha^{-1}

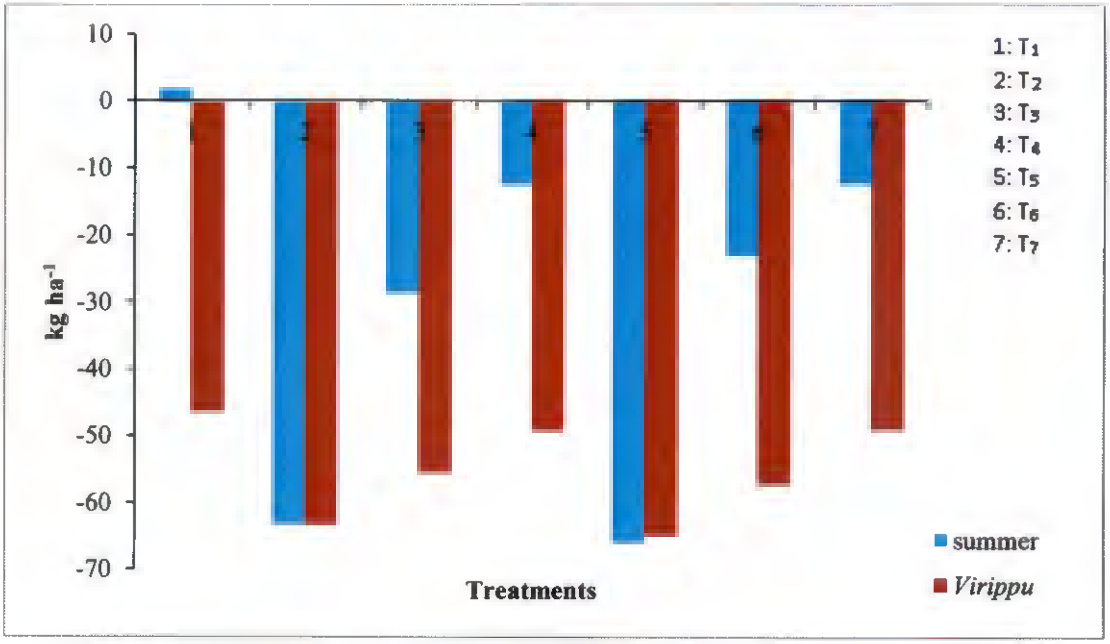

Fig. 16. Balance sheet of phosphorus, kg ha^{-1}

Fish integration has resulted in positive balance for available K during both the seasons. The higher available K content in trench silt might have contributed to this positivity in the balance sheet of available K.

5.7.4 Balance Sheet of Calcium

After summer season, the balance sheet for Ca tended to be positive for the farming systems T_1 (rice – rice - fallow), T_4 (rice – rice – fodder cowpea) and T_7 (rice + fish – rice + fish – fodder cowpea + fish). For all the other four systems, the balance sheet was negative. Generally a positive balance sheet could be obtained after *Virippu* season, in all the farming systems, except for T_2 (rice – rice – amaranthus). The balance of Ca was higher in treatments integrated with fish (Fig. 18).

The initial and final status of exchangeable Ca in fallow did not show appreciable variation. This might be the reason for the positive balance of exchangeable Ca in fallow. Legumes contribute to soil fertility partly because of their higher leaf fall. In the present study the average Ca content of fodder cowpea (0.67 per cent) was higher than that for amaranthus (0.36 per cent) and culinary melon (0.52 per cent). This might have contributed to the positive balance for Ca after fodder cowpea.

The balance sheet of available Ca after *Virippu* rice might be a direct reflection of the soil status of exchangeable Ca before and after *Virippu* season. Thus rice following amaranthus recorded negative balance owing to high status of exchangeable Ca before the crop compared to that after the crop. Fish integration was observed to result in a highly positive balance sheet for exchangeable Ca in soil. The Ca content of trench silt incorporated into the fish integrated fields might have resulted in this positive balance.

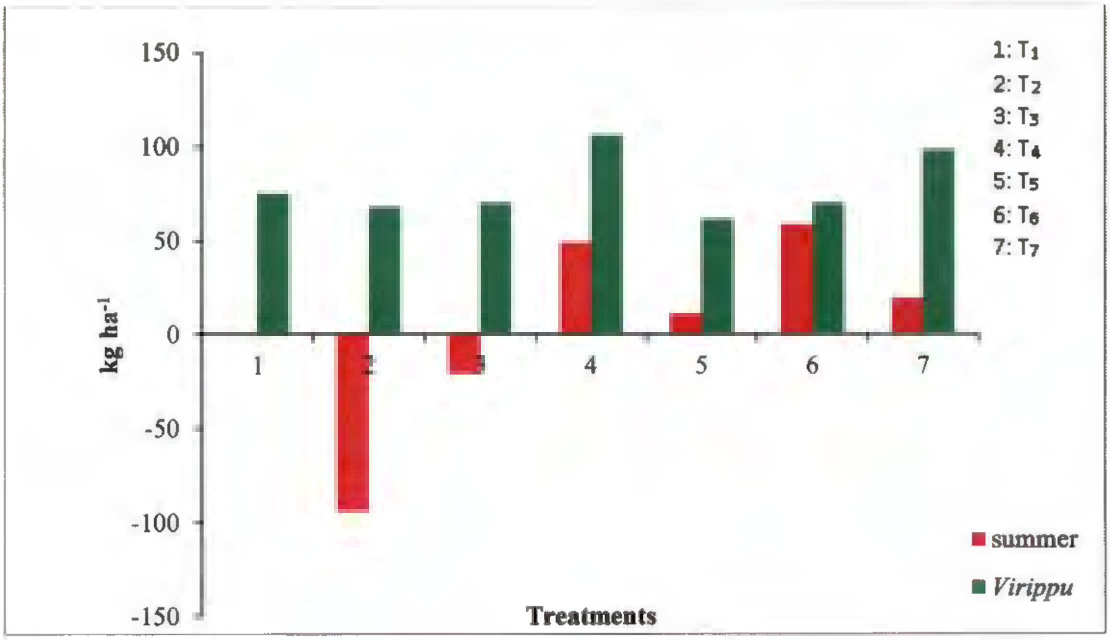

Fig. 17. Balance sheet of potassium, kg ha^{-1}

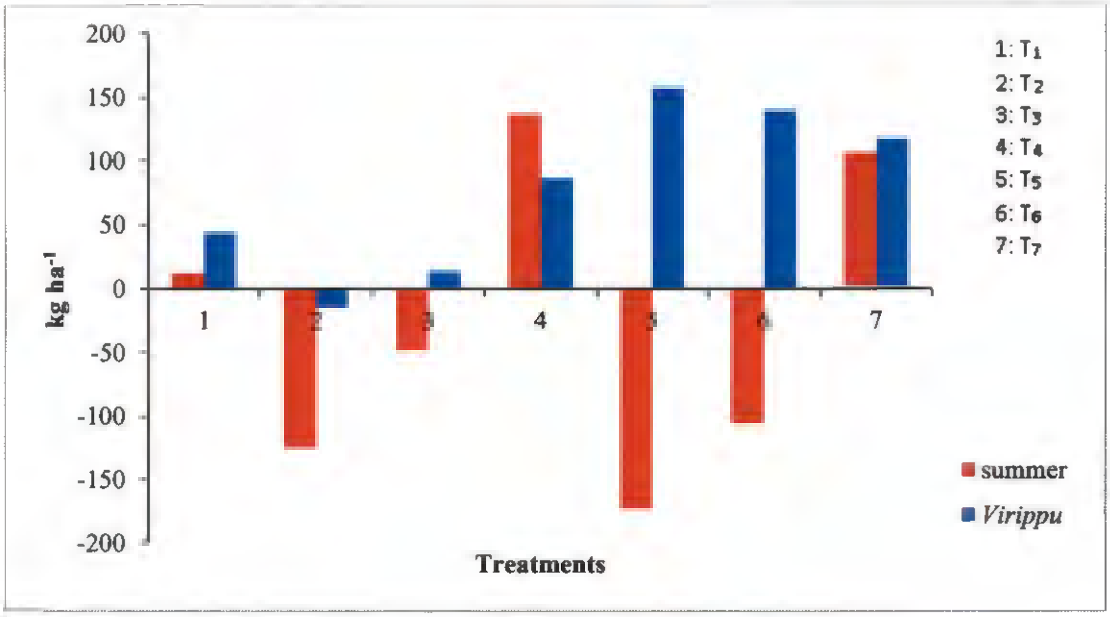

Fig. 18. Balance sheet of calcium, kg ha^{-1}

5.7.5 Balance Sheet of Magnesium

The Mg balance after summer season proved to be positive only for T_1 (rice – rice – fallow) In the case of all the other farming systems it was negative. After *Virippu* season balance sheet was positive for all farming systems (Fig. 19).

In the case of fallow exchangeable Mg followed the same trend as exchangeable Ca. The negative balance sheet of exchangeable Mg following amaranthus, culinary melon and fodder cowpea might be because of the greater preference of dicots towards divalent cations like Mg. The preference for monovalent cations by monocots like rice was clearly indicated by the net gain of exchangeable Mg after *Virippu* rice in all the systems.

5.7.5 Balance Sheet of Sulphur

The balance sheet for S was negative in all the farming systems after summer season. The difference between actual balance and computed balance was more in treatments T_2 (rice – rice – amaranthus) and T_5 (rice + fish – rice + fish – amaranthus + fish) compared to the other systems. In T_1 (rice – rice – fallow) the difference was less. The effect of crop components on the balance sheet of S was almost similar irrespective of fish integration. After the *Virippu* season balance sheet of S was negative for all the farming systems (Fig. 20).

Sulphur is highly amenable to leaching losses as sulphates which accumulate in the subsoils. This might be the reason for the general net loss of available S in the farming systems. . The comparatively higher net loss in S in systems with amaranthus as a component crop could be explained mathematically as due to the higher computed balance of available S, the reason for which was the use of S containing Factamphos as nutrient source in amaranthus.

The net loss of available S observed after *Virippu* rice might be because of S reduction under submergence encountered with low land rice. In submerged

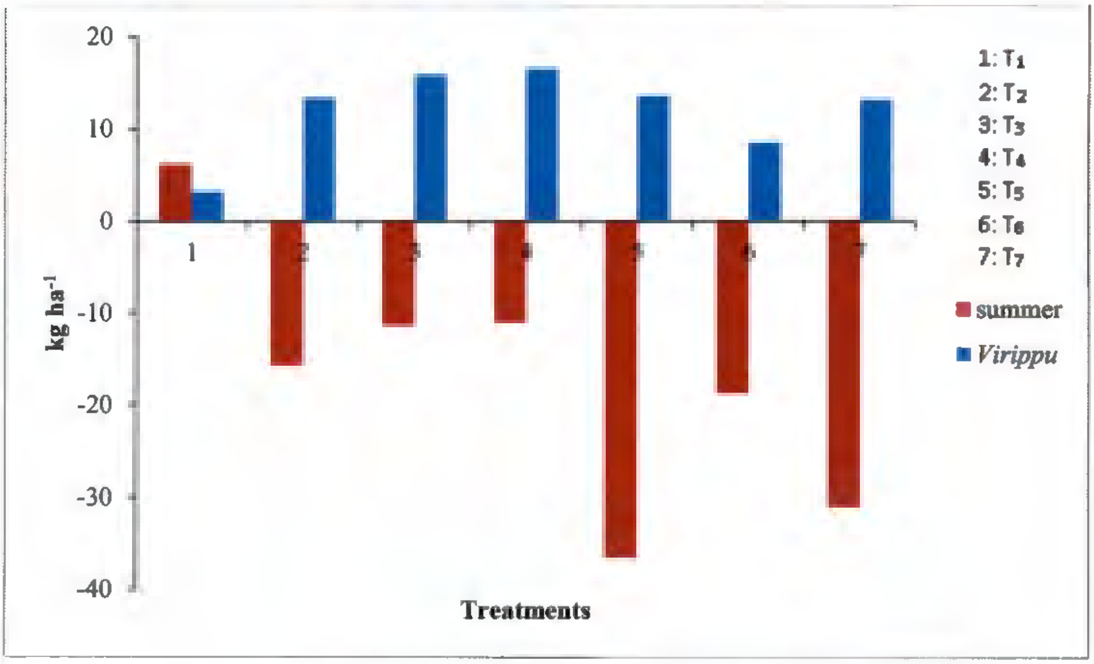

Fig. 19. Balance sheet of magnesium, kg ha^{-1}

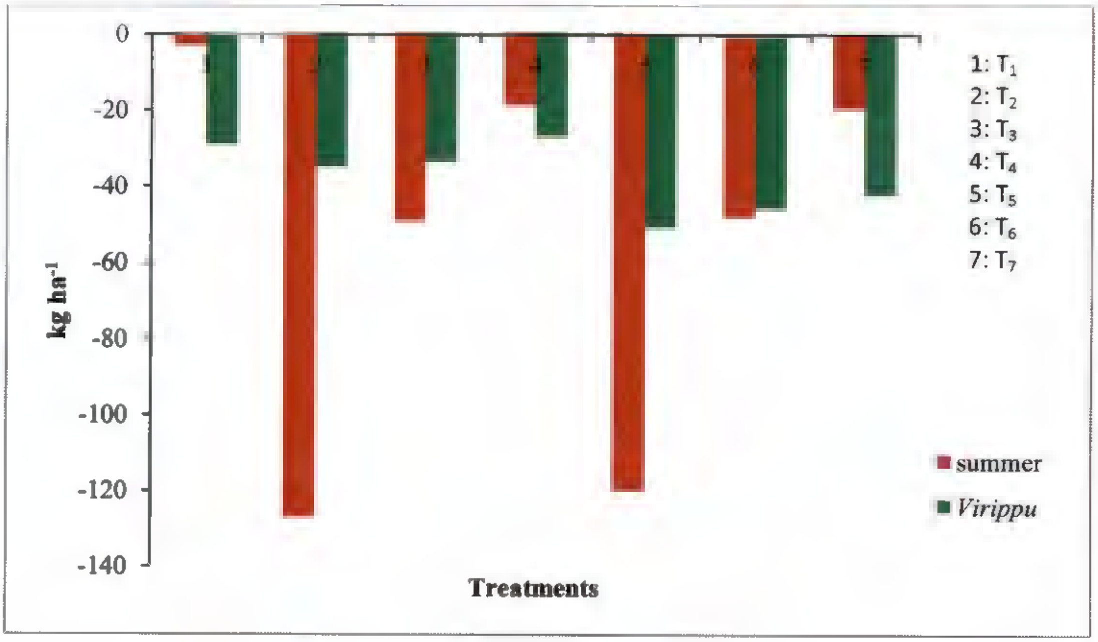

Fig. 20. Balance sheet of sulphurt, kg ha^{-1}

condition sulphates get reduced to hydrogen sulphide as well as it may react with various heavy metals viz., Zn, Cu, Cd and Pb thus reducing its availability (Ponnamperuma, 1972).

5.7.7 Balance Sheet of Zinc and Boron

All the farming systems recorded negative balance sheet for soil Zn after summer season. The difference between actual balance and computed balance was more in the farming systems, T_2 (rice – rice – amaranthus) and T_5 (rice + fish – rice + fish – amaranthus + fish). But it was less in T_1 (rice – rice – fallow).The soil Zn balance after *Virippu* rice was negative in all farming systems (Fig. 21).

The computational balance of Zn was higher in T_2 and T_5 due to heavy dose of FYM rich in Zn applied to amaranthus. Zn has reported to be moderately mobile in slightly acidic soil as that encountered in the present study. This might have contributed towards leaching loss of Zn as suggested by Zhang *et al.*(2003). The negative net balance of Zn and S might also be due to the formation of Zn S which is relatively resistant to re-oxidation (Peltier *et al.*, 2011).

The balance sheet of B after the summer season was positive in farming systems T_3, T_4 and T_7, zero in T_1 and negative in T_2, T_5 and T_6.After *Virippu* season, the balance sheet was negative for all the farming systems (Fig. 22).

No definite trend could be observed in the balance sheet of B. The availability B is dependent on multitude of factors like soil texture, nature of clay, organic matter content, soil reaction, sesquioxides contents, free iron and aluminium oxides and anion exchange capacity (Togoro and Makoto, 1968). This type of a complex interaction of B with several factors might be the reason or the variable trend of B observed among the different farming systems.

In general, fodder cowpea grown as component crop in rice based farming system resulted in positive balance for N, K and Ca. Integration of fish resulted in

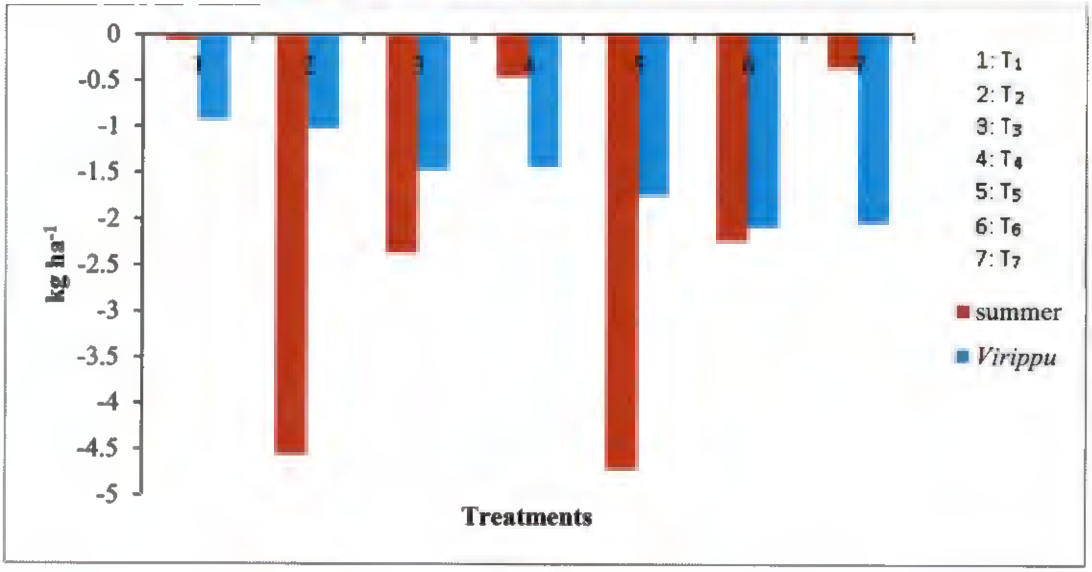

Fig. 21. Balance sheet of zinc, kg ha^{-1}

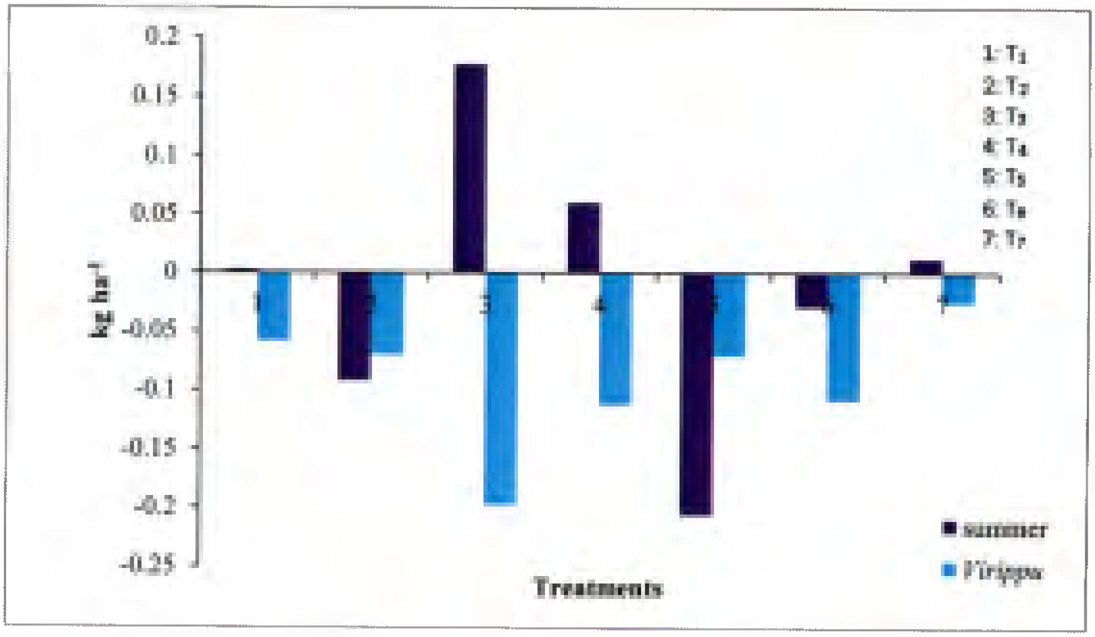

Fig. 22. Balance sheet of boron, kg ha^{-1}

positive balance for K. The balance sheet of P, Mg, S and Zn was observed to be negative. No definite trend could be observed in the case of B.

Summary

6. SUMMARY

The study entitled "Nutrient budgeting in rice based farming system" was undertaken at the Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, as a part of an ongoing experiment under the AICRP on Integrated Farming Systems (ICAR), being implemented since 2011. The objectives were to study the effect of component crops on soil nutrient status, to characterize and study the effect of trench silt on the performance of rice and to work out the nutrient balance sheet of the rice based farming systems.

The experiment was laid out in randomised block design with seven treatments, replicated thrice. The treatments comprised seven rice based farming systems [T_1 : rice-rice-fallow; T_2 : rice – rice – amaranthus; T_3 : rice – rice-culinary melon; T_4 : rice – rice – fodder cowpea; T_5 : (rice + fish) - (rice + fish) - (amaranthus + fish); T_6 : (rice + fish) - (rice + fish) - (culinary melon + fish); T_7 : (rice + fish) - (rice + fish) - (fodder cowpea + fish). The present study was undertaken during the summer 2015-'16 (February to May) and *Virippu* 2016-'17 (June to October) seasons. The varieties of rice, amaranthus, culinary melon and fodder cowpea were Uma, Arun, Vellayani local and Aiswarya respectively. The fishes *viz*., catla (*Catla catla*) and rohu (*Labio rohita*) were introduced into the trenches (6 m x 3 m x 1 m) after transplanting *Virippu* crop and were harvested after the summer crop. After summer season, the trenches were desilted and the silt was added to the respective plots, before raising *Virippu* rice. The characterization of trench silt was carried out in terms of quantity, physico-chemical and biological properties. The soil nutrient status of *Mundakan* season 2015-'16 was also taken into account for working out the nutrient balance sheet of the systems.

The observations on yield and yield attributes of component crops, nutrient content and uptake by the crops and soil chemical properties were statistically analysed and the salient findings of the study are briefed below.

In summer, fodder cowpea grown as a sole crop (T_4) recorded the highest yield(23.70t ha^{-1}) and total dry matter production. Among the treatments integrated with fish, culinary melon + fish (T_6) gave higher yield compared to amaranthus and fodder cowpea. The treatments varied significantly in the rice equivalent yield (REY), with culinary melon recording significantly higher REY both under sole crop (7.62 t ha^{-1}) and on integration with fish (13.57 t per 0.5 ha). The REY of amaranthus and culinary melon were significantly higher when they were raised along with fish compared to the sole crop. It was observed that fish integration increased the drymatter production of amaranthus and culinary melon. But fish integration could not bring about significant increase in the drymatter production of fodder cowpea. The productivity of amaranthus and culinary melon was found to increase to the tune of 208.80 per cent and 256.43 per cent respectively, with fish integration. Rice equivalent yield was significantly higher (13.57 t ha^{-1}) for culinary melon + fish.

After the summer season, the trench water and trench silt were collected and analysed. The trench water analysed to be near neutral in pH (7.18)with higher contents of N, P and K and near safe limitswith respect to biological oxygen demand (5.20) for the growth of aquatic organisms. Substantial quantity of trench silt (20.93 t per 0.5 ha on dry weight basis) was added to the plots with fish integration and incorporated, before raising the *Virippu* rice. Trench silt was found to be clayey in texture with lower bulk density (0.78 Mg m^{-3}), higher water holding capacity (47.38 %) and rich in available N (709.33 mg kg^{-1}), available K (204.28 mg kg^{-1}), available S (33.99 mg kg^{-1}) and Zn (14.24 mg kg^{-1}).

. In *Virippu* rice, grain weight $panicle^{-1}$(4.08 g), total number of grains $panicle^{-1}$ (159.80), filled grains $panicle^{-1}$ (144.35) and grain yield (6.62 t ha^{-1}) were significantly higher in the farming system rice + fish succeeding fodder cowpea + fish (T_7). It was on a par with other treatments integrated with fish *viz.,* rice + fish succeeding amaranthus + fish (T_5) and rice + fish succeeding culinary melon +

fish(T_6). Sterility percentage decreased with fish integration and it was the lowest (5.69 %) in T_5 and remained at par with T_6.

Among the summer crops, the uptake of N, P, K, Mg, S, B and Zn were significantly higher in amaranthus and culinary melon integrated with fish as compared to the respective sole crops. Fodder cowpea grown as sole crop recorded the highest content and uptake of Ca. In *Virippu* rice, significantly higher uptake of N and P was observed in rice+fish succeeding fodder cowpea+fish (T_7).

Soil chemical properties were analysed before and after each component crop. Soil reaction (pH) was significantly higher (less acidic) in T_5 (rice+fish)-(rice+fish)-(amaranthus+fish). In general, treatments with fish integration recorded higher soil pH compared to treatments without fish. The treatment rice-rice-fallow recorded the highest electrical conductivity after *Mundakan* and summer seasons and T_2 (rice-rice-amaranthus) recorded the same after *Virippu* season.

Organic carbon content of soil was higher in T_1 (rice-rice-fallow) before and after summer season. The highest soil available N was recorded in rice-rice-amaranthus (T_2) before and after summer and in T_5 (rice+fish)-(rice+fish)-(amaranthus+fish) after *Virippu* seasons. Available P was the highest in T_5 before and after summer crop. Significantly higher available K content was observed in T_5 before summer crop. Exchangeable Ca and Mg, available S and Zn were found to be the highest in T_5. Rice + fish integration (T_5, T_6, T_7) resulted in significantly higher B content in soil. In general, fish integration was observed to improve the soil nutrient status.

Pests and diseases were not observed during the summer season to magnitudes causing economic loss. A mild incidence of bacterial leaf blight (score -1) was recorded in rice crop uniformly over all plots and the effect on crop yield was negligible.

Balance sheet of N was positive after the summer season with fodder cowpea, irrespective of fish integration. Fish integration was observed to reduce the loss of N from the soil as indicated by lesser difference between the actual and computed balance of N (less negative) when compared to the respective sole crop treatments The N balance for T_5 (-83.79 kg ha^{-1}) and T_6 (-32.29 kg ha^{-1}) were higher than T_2 (-134.72 kg ha^{-1}) and T_3 (-54.24 kg ha^{-1}) respectively. A positive N balance was recorded in T_1 (rice-rice-fallow) after the *Virippu* season. The P balance was observed to be negative in all the treatments after summer and *Virippu* seasons, except in T_1 (rice-rice-fallow) after summer. Fish integration resulted in a positive balance for K after summer in T_5, T_6 and T_7. All the treatments recorded a positive balance for K and Mg after the *Virippu* season. After summer season, the balance sheet for Ca tended to be positive for the farming systems T_1 (rice – rice - fallow), T_4 (rice – rice – fodder cowpea) and T_7 (rice + fish – rice + fish – fodder cowpea + fish), while after *Virippu* all the treatments except T_2 recorded positive balance for Ca. The balance of Ca was higher in treatments integrated with fish. Balance sheet was negative for S and Zn. A varying trend was observed for B. After summer season, the balance sheet of B was positive in farming systems T_3, T_4 and T_7, zero in T_1 and negative in T_2, T_5 and T_6, while it was negative for all the farming systems after *Virippu* season.

The present study revealed that integrating fish in rice based farming systems resulted in higher soil residual nutrient status (P, Ca, Mg, S, Zn). Trench silt had low bulk density, high water holding capacity and was rich in N, K, S and Zn. Fish integration and consequent trench silt incorporation increased the rice yield by 15.56 per cent as compared to sole crop of rice. Fodder cowpea grown as component crop in rice based farming system resulted in positive balance for N, K and Ca. Integration of fish resulted in positive balance for K. The balance sheet of P, Mg, S and Zn was observed to be negative. But a definite trend could not be observed in the case of B.

Future line of work

1. Studies to precisely assess the mineralization pattern and nutrient availability of trench silt.

2. Investigations to explore the possibility of partial substitution of chemical fertilizers with trench silt in rice and other crops.

3. Feasibility of diversifying the rice based farming systems by including ancillary enterprises and other crop components in summer for making the systems more productive, profitable and sustainable.

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NUTRIENT BUDGETING IN RICE BASED FARMING SYSTEM

by

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ABSTRACT

The study entitled "Nutrient budgeting in rice based farming system" was undertaken at College of Agriculture, Vellayani during 2015 –'17. The main objectives were to study the effect of component crops on soil nutrient status, to characterize and study the effect of trench silt on the performance of rice and to work out the nutrient balance sheet of the rice based farming systems.

The field experiment was conducted as a part of an ongoing experiment under the AICRP on Integrated Farming Systems (ICAR), at the Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram. The experiment was laid out in randomised block design with seven treatments, replicated thrice. The treatments comprised seven rice based farming systems [$\mathbf{T_1}$: rice-rice-fallow; $\mathbf{T_2}$: rice-rice-amaranthus; $\mathbf{T_3}$: rice-rice-culinary melon; $\mathbf{T_4}$: rice-rice-fodder cowpea; $\mathbf{T_5}$: (rice + fish)-(rice + fish)-(amaranthus + fish); $\mathbf{T_6}$: (rice + fish)-(rice + fish)-(culinary melon + fish); $\mathbf{T_7}$: (rice + fish)-(rice + fish)-(fodder cowpea + fish). The present study was undertaken during the summer 2015-'16 (February to May) and *Virippu* 2016-'17 (June to October) seasons. The varieties of rice, amaranthus, culinary melon and fodder cowpea were Uma, Arun, Vellayani local and Aiswarya respectively. The fishes *viz*., catla (*Catla catla*) and rohu (*Labio rohita*) were introduced into the trenches (6 m x 3 m x 1 m) after transplanting *Virippu* crop and were harvested after the summer crop. After summer season, the trenches were desilted and the silt was added to the respective plots, before raising *Virippu* rice. The soil nutrient status of *Mundakan* season 2015-'16 was also taken into account for working out the nutrient balance sheet of the systems.

In summer, fodder cowpea grown as a sole crop recorded the highest yield (23703 kg ha^{-1}) and total dry matter production. Among the treatments integrated with fish, culinary melon + fish (T_6) gave higher yield compared to amaranthus and fodder cowpea. The productivity of amaranthus and culinary melon was found to increase to the tune of 208.80 per cent and 256.43 per cent respectively,

with fish integration. Rice equivalent yield was significantly higher (13.57 t ha^{-1}) for culinary melon + fish (T_6).

After the summer season, the trench water and trench silt were analysed. The trench water had near neutral pH (7.18) and had higher contents of N, P and K. Substantial quantity of trench silt (20.93 t per 0.5 ha on dry weight basis) was added to the plots with fish integration and incorporated, before raising the *Virippu* rice. Trench silt was found to be clayey in texture with lower bulk density (0.78 Mg m^{-3}), higher water holding capacity (47.38 %) and rich in N, K, S and Zn.

In *Virippu* rice, grain weight $panicle^{-1}$(4.08 g), total number of grains $panicle^{-1}$ (159.80), filled grains $panicle^{-1}$ (144.35) and grain yield (6.62 t ha^{-1}) were significantly higher in T_7 (rice + fish succeeding fodder cowpea + fish). It was on a par with T_5 (rice + fish succeeding amaranthus + fish) and T_6 (rice + fish succeeding culinary melon + fish). Sterility percentage decreased with fish integration and it was the lowest (5.69 %) in T_5 and remained at par with T_6. In general, productivity of rice was 15.56 per cent higher with fish integration.

Among the summer crops, the uptake of N, P, K, Mg, S, B and Zn was significantly higher in amaranthus and culinary melon integrated with fish as compared to the respective sole crops. While, fodder cowpea grown as sole crop recorded the highest content and uptake of Ca. In *Virippu* rice, significantly higher uptake of nitrogen and phosphorus was observed in T_7 (rice+fish succeeding fodder cowpea+fish).

Soil chemical properties were analysed before and after each component crop. Soil reaction (pH) was significantly higher (less acidic) in T_5 (rice+fish)-(rice+fish)-(amaranthus+fish). In general, treatments with fish integration recorded higher soil pH compared to treatments without fish. The treatment T_1 (rice-rice-fallow) recorded the highest electrical conductivity after *Mundakan* and summer seasons and T_2 (rice-rice-amaranthus) recorded the same after *Virippu* season. Organic carbon content of soil was higher in T_1 (rice-rice-fallow) before and after summer season. The highest soil available N was recorded in T_2 (rice-rice-amaranthus) before and after summer and in T_5 after *Virippu* seasons. Available P was the highest in T_5 before and after summer crop. Significantly higher available K content was observed in T_5 before summer crop. Exchangeable Ca, exchangeable Mg, S and Zn were found highest in T_5. Rice + fish integration (T_5, T_6 and T_7) resulted in significantly higher B content in soil. In general, fish integration was observed to improve the soil nutrient status.

Nitrogen balance was positive after summer with fodder cowpea, irrespective of fish integration. A positive N balance was recorded in T_1 (rice-rice-fallow) after the *Virippu* season. The P balance was observed to be negative in all the treatments after summer and *Virippu* seasons, except in T_1 (rice-rice-fallow) after summer. Fish integration resulted in a positive balance for K after summer in T_5, T_6 and T_7. All the treatments recorded a positive balance for K and Mg after the *Virippu* season. After summer, T_1, T_4 and T_7 recorded positive balance, while after *Virippu* all the treatments except T_2 recorded positive balance for Ca. Balance sheet was negative for S and Zn. A varying trend was observed for B.

The present study revealed that integrating fish in rice based farming systems resulted in higher soil residual nutrient status (P, Ca, Mg, S and Zn). The trench silt had low bulk density, high water holding capacity and was rich in N, K, S and Zn. Fish integration and consequent trench silt incorporation increased the rice yield by 15.56 per cent as compared to sole crop of rice. Fodder cowpea grown as component crop in rice based farming system resulted in positive balance for N, K and Ca. Integration of fish resulted in positive balance for K. The balance sheet of P, Mg, S and Zn was observed to be negative.

സംഗ്രഹം

നെല്ലധിഷ്ഠിത കൃഷി സമ്പ്രദായങ്ങളിൽ മണ്ണിലെ പോഷക മൂലക ബജറ്റിങ് എന്ന വിഷയത്തെ സംബന്ധിച്ച ഒരു പഠനം കേരള കാർഷിക സർവകലാശാലയുടെ അധീനതയിൽ തിരുവനന്തപുരം കരമനയിൽ സ്ഥിതി ചെയ്യുന്ന സംയോജിത കൃഷി സമ്പ്രദായ ഗവേഷണ കേന്ദ്രത്തിൽ നടത്തുകയുണ്ടായി. മണ്ണിലെ പോഷകാംശത്തിന്റെ നിലയിൽ കൂട്ടുവിളകളുടെ സ്വാധീനം, മത്സ്യചാലിൽ നിന്നും പുനചംക്രമണം ചെയ്ത ചെളിയുടെ സവിഷേതകൾ, ഇതിന് വിരിപ്പ് വിളയിലുള്ള സ്വാധീനം എന്നിവ മനസിലാക്കുക, കൂടാതെ , വിവിധ നെല്ലധിഷ്ഠിത സമ്പ്രദായങ്ങളുടെ പോഷക മൂലക ബാക്കിപത്രം തയ്യാറാക്കുക എന്നിവയായിരുന്നു പഠനത്തിന്റെ മുഖ്യ ലക്ഷ്യങ്ങൾ.

രണ്ടായിരത്തി പതിനഞ്ച് - പതിനാറു വേനലിലും തുടർന്നുള്ള വിരിപ്പ് കാലത്തുമായി നടത്തിയ പഠനത്തിൽ ഏഴ് വ്യത്യസ്ത നെല്ലധിഷ്ഠിത കൃഷി സമ്പ്രദായങ്ങളാണ് ഉൾപ്പെടുത്തിയിരുന്നത്. നെല്ല്-നെല്ല്-തരിശ്, നെല്ല്-നെല്ല്-ചീര, നെല്ല്-നെല്ല്-വെള്ളരി, നെല്ല്-നെല്ല്-തീറ്റപ്പയർ എന്നീ കൃഷി സമ്പ്രദായങ്ങൾക്ക് പുറമേ മത്സ്യകൃഷി കൂടി സംയോജിപ്പിച്ചുള്ള (നെല്ല്+മത്സ്യം) – (നെല്ല്+മത്സ്യം) - (ചീര+മത്സ്യം), (നെല്ല്+മത്സ്യം) - (നെല്ല്+മത്സ്യം) - (വെള്ളരി+മത്സ്യം), (നെല്ല്+മത്സ്യം) – (നെല്ല്+മത്സ്യം) – (തീറ്റപ്പയർ+മത്സ്യം) എന്നീ വ്യത്യസ്ത കൃഷി സമ്പ്രദായങ്ങളായിരുന്നു പരീക്ഷിച്ചത്. ഉമ, എന്ന നെല്ലിനം, അരുൺ എന്ന ചീരയിനം, വെള്ളായണി ലോക്കൽ എന്ന വെള്ളരിയിനം, ഐശ്വര്യ എന്ന തീറ്റപ്പയറിനം എന്നിവയാണ് കൃഷി ചെയ്തത്. മത്സ്യ ഇനങ്ങൾ കട്ല, രോഹു എന്നിവയായിരുന്നു. മത്സ്യം സംയോജിപ്പിച്ചുള്ള കൃഷി സമ്പ്രദായത്തിൽ കൃഷിയിടത്തിന്റെ പകുതിഭാഗം 6 മീ. X 3 മീ. X 1 മീ. വലിപ്പമുള്ള ചാലുകളാക്കി തിരിച്ചിരുന്നു. വിരിപ്പ് നെല്ലിന്റെ പറിച്ചു നടീലിനു ശേഷം മത്സ്യക്കുഞ്ഞുങ്ങളെ ഒരു ചതുരശ്ര മീറ്ററിന് ഒന്ന് എന്ന തോതിൽ ചാലുകളിൽ നിക്ഷേപിക്കുകയും അതേ വിളപര്യയനകാലത്തിലെ വേനലിൽ വിളവെടുക്കുകയും ചെയ്തു.

പഠനത്തിന്റെ മുഖ്യ കണ്ടെത്തലുകളിവയാണ്. വേനലിൽ തനിവിളയായി വളർത്തിയ തീറ്റപ്പയർ ഏറ്റവുമധികം വിളവു നേടി. എന്നാൽ വെള്ളരിയിലും ചീരയിലും മത്സ്യസംയോജിത കൃഷിരീതി അതതു തനിവിളകളെക്കാൾ 3 ഇരട്ടിയും 3.5 ഇരട്ടിയും അധിക വിളവ് രേഖപ്പെടുത്തി.

വേനൽ വിളകളുടെയും മത്സ്യത്തിന്റെയും വിളവെടുപ്പിനു ശേഷം ചാലുകൾ വറ്റിച്ച് മത്സ്യച്ചാലിൽ അടിഞ്ഞുകൂടിയ ചെളി കോരി അതാതു പ്ലോട്ടുകളിൽ കൂട്ടിച്ചേർക്കുകയും ഇതിൽ വിരിപ്പ് നെല്ല് കൃഷി ചെയ്യുകയും ചെയ്തു. ജല ആഗിരണ

ക്ഷമത കൂടിയതും കുറഞ്ഞ സാന്ദ്രത (ബൾക്ക് ഡെൻസിറ്റി) ഉള്ളതുമായ ഈ ചെളി നൈട്രജൻ, ഫോസ്ഫറസ്, സൾഫർ, സിങ്ക് എന്നീ മൂലകങ്ങളാൽ സമ്പുഷ്ടവുമായിരുന്നു. മത്സ്യച്ചാലിലെ വെള്ളം ന്യൂട്രൽ അമ്ല-ക്ഷാരനില രേഖപ്പെടുത്തി.

വേനലിനെ തുടർന്നുള്ള വിരിപ്പ് വിളയിൽ (നെല്ല്+മത്സ്യം) – (നെല്ല്+മത്സ്യം) – (തീറ്റപ്പയർ+മത്സ്യം) എന്ന സമ്പ്രദായം കതിരുകളുടെ എണ്ണം, ഭാരം, ഓരോ കതിരിലുമുള്ള നിറവിത്തുകളുടെ എണ്ണം, വിളവ് എന്നിവയിൽ മുന്നിട്ടു നിന്നു. മത്സ്യ സംയോജനം നെല്ലിന്റെ ഉതപാദനക്ഷമതയിൽ 15.56 ശതമാനം വർധനവുണ്ടാക്കി.

മത്സ്യസംയോജിത കൃഷി മണ്ണിലെ അമ്ല-ക്ഷാര നിലയും പോഷകാംശവും മെച്ചപ്പെടുത്തുന്നതായികണ്ടെത്തി. ഇവയിൽ തന്നെ, മണ്ണിലെ ഫോസ്ഫറസ്, പൊട്ടാസ്യം, കാത്സ്യം, മഗ്നീഷ്യം, സൾഫർ, സിങ്ക് എന്നീ മൂലകങ്ങളുടെ അളവിൽ നെല്ല്+മത്സ്യം – നെല്ല്+മത്സ്യം - ചീര+മത്സ്യം എന്ന സമ്പ്രദായം മുന്നിട്ടു നിന്നു.

മത്സ്യസംയോജനവും ഇതിനെ തുടർന്നുള്ള മത്സ്യച്ചാലിലെ ചെളിയുടെ പുനചംക്രമണവും വിരിപ്പ് നെല്ലിന്റെ വിളവ് മെച്ചപ്പെടുത്തി. ഇതിനു പുറമേ മണ്ണിന്റെ ഫലഭൂയിഷ്ഠതയിലും ഗണ്യമായ വർധനവുണ്ടായി. തീറ്റപ്പയർ ഉൾപ്പെട്ട സമ്പ്രദായം മണ്ണിലെ നൈട്രജൻ, പൊട്ടാസ്യം, കാത്സ്യം എന്നീ മൂലകങ്ങളിലും മത്സ്യസംയോജനം പൊട്ടാസ്യത്തിന്റെ അളവിലും നേട്ടം രേഖപ്പെടുത്തി. എന്നാൽ ഫോസ്ഫറസ്, മഗ്നീഷ്യം, സൾഫർ, സിങ്ക് എന്നിവയിൽ കുറവ് രേഖപ്പെടുത്തി.

Appendices

Appendix I a.

Weather data during summer crop period (February to May 2016)

Standard week	Month and date	Temperature °C		Relative humidity (%)	Rainy fall (mm)
		Maximum	Minimum		
4	Jan 22-28	30.93	23.95	88.805	0
5	Jan 29-Feb 4	30.31	20.89	84.15	0
6	Feb 5-11	30.94	23.19	87.09	0
7	Feb 12-18	31.92	24.58	80.985	0.25
8	Feb 19-25	32.69	24.05	82.2	0
9	Feb 26-Mar 4	32.50	24.01	78.135	0.25
10	Mar 5-11	32.35	24.39	84.465	0.76
11	Mar 12-18	33.53	25.73	83.375	0
12	Mar 19-25	33.13	26.70	84.54	0
13	Mar 26-Apr 1	33.00	25.59	83.845	0
14	Apr 2-8	33.57	26.96	82.37	0
15	Apr 9-15	33.01	26.45	86.565	58.42
16	Apr 16-22	33.20	27.01	87.04	9.14
17	Apr 23-29	33.16	27.39	84.605	0
18	Apr 30-May 6	33.60	25.87	85.265	14.22
19	May 7-13	33.07	25.67	88.145	39.88
20	May 14-20	30.32	23.59	92.155	280.16
21	May 21-27	31.79	25.70	90.35	35.05

Appendix I b.

Weather data during *Virippu* crop period (June to October 2016)

Standard week	Month and date	Temperature °C		Relative humidity (%)	Rainy fall (mm)
		Maximum	Minimum		
22	May 28-Jun 3	31.32	24.79	86.73	7.11
23	Jun 4-10	30.07	24.58	97.53	167.13
24	Jun 11-17	30.38	23.97	89.38	128.52
25	Jun 18-24	29.79	23.49	84.32	68.33
26	Jun 25-Jul 1	30.45	24.21	83.48	25.91
27	Jul 2-8	31.71	24.57	80.07	35
28	Jul 9-15	29.86	23.86	83	60.4
29	Jul 16-22	30.64	25.21	80.64	0
30	Jul 23-29	29.93	24.57	83	36.8
31	Jul 30-Aug 5	30.21	25.29	82.5	8
32	Aug 6-12	30.93	25.21	77.86	0
33	Aug 13-19	30.57	25.07	83.21	11.3
34	Aug 20-26	30.29	25.14	82.79	17.6
35	Aug 27-Sep 2	30.36	24.71	81.57	2
36	Sep 3-9	29.79	24.07	84.36	3
37	Sep 10-16	30.50	25.07	81.57	0
38	Sep 17-23	30.43	25.00	83.36	0
39	Sep 24-30	30.79	25.00	81.93	0.6
40	Oct 1-7	30.36	24.12	94.88	0
41	Oct 8-14	30.68	23.94	94.12	1.27
42	Oct 15-21	30.33	24.62	96.56	33.53

Appendix- II

Media used for the enumeration of microorganisms

Sl. No.	Microorganism	Media used	Reference
1.	Bacteria	Nutrient agar	Atlas and Parks (1993)
2.	Fungi	Martin's Rose Bengal agar	Martin (1950)
3.	Actinomycetes	Ken Knight's agar	Cappuccino and Sheman (1996)

Appendix-III

Scoring of Bacterial Leaf Blight (IRRI, 2002)

SCALE	Affected leaf area
0	No lesions observed
1	Small brown specks of pin-point size or larger brown specks without sporulating center
3	Lesion type is the same as in scale 2, but a significant number of lesions are on the upper leaves
5	Typical blast lesions infecting 4-10% of the leaf area
7	Typical blast lesions infecting 26-50% of the leaf area
9	More than 75 % of the leaf area affected