PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH FODDER CROPS

BINDHYA.B.N

(2017-11-133)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH FODDER CROPS"** 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.

Vellayani
Date: 30-9-19

BINDHYA.B.N

(2017-11-133)

CERTIFICATE

Certified that this thesis entitled **"PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH FODDER CROPS"** is a record of research work done independently by Mrs. Bindhya.B.N under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

30/9/19

Vellayani
Date: 30/9/19

Dr. Jacob John
(Major advisor, Advisory Committee)
Professor (Agronomy) & Head
Integrated Farming System Research Station
Karamana, Thiruvananthapuram

CERTIFICATE

We, the undersigned members of the advisory committee of Mrs. Bindhya.B.N, a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH FODDER CROPS"** may be submitted by Mrs. Bindhya.B.N, in partial fulfilment of the requirement for the degree.

30/9/19

Dr. Jacob John
Professor (Agronomy) and Head
Integrated Farming System Research Station
Karamana, Thiruvananthapuram-695 002

30/09/2019

Dr. O. Kumari Swadija
Professor and Head
Department of Agronomy
College of Agriculture, Vellayani,
Thiruvananthapuram- 695 522

30/9/19

Dr. Usha C. Thomas
Assistant Professor (Agronomy),
AICRP on Forage Crops and Utilization,
College of Agriculture, Vellayani,
Thiruvananthapuram- 695 522

30/9/19

Dr. Meera A.V.
Assistant Professor
(Soil Science & Agrl. Chemistry)
Integrated Farming System
Research Station, Karamana,
Thiruvananthapuram- 695 002

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LIST OF ABBREVIATIONS

ANOVA	:	Analysis of variance
B: C	:	Benefit cost
Ca	:	Calcium
CD (0.05)	:	Critical difference at 5 % level
CGR	:	Crop growth rate
C: N	:	Carbon to nitrogen
cm	:	Centi meter
DAS	:	Days after sowing
DAT	:	Days after transplanting
dS m^{-1}	:	Deci Siemens per metre
day^{-1}	:	Per day
EC	:	Electrical conductivity
EDTA	:	Ethylenediaminetetraacetic acid
et al.	:	Co-workers/ Co-authors
FIB	:	Farm Information Bureau
FYM	:	Farm yard manure
Fig.	:	Figure

g	:	Gram
GOI	:	Government of India
GOK	:	Government of Kerala
ha	:	Hectare
ha^{-1}	:	Per hectare
i.e.	:	That is
K	:	Potassium
KAU	:	Kerala Agricultural University
kg^{-1}	:	Per kilogram
LAI	:	Leaf area index
m^{2}	:	Square metre
m^{-2}	:	Per square metre
Mg	:	Milligram
Mm	:	Millimetre
M ha	:	Million hectare
M t	:	Million tonnes
MO	:	Moncompu
MSL	:	Mean sea level
N	:	Nitrogen
NAR	:	Net assimilation rate
NS	:	Non-significant

No.	:	Number
OC	:	Organic carbon
P	:	Phosphorus
POP	:	Package of practices recommendations
pH	:	Potenz hydrogen
q ha^{-1}	:	Quintal per hectare
RBD	:	Randomized block design
RDN	:	Recommended Dose of Nitrogen
REY	:	Rice equivalent yield
SCMR	:	SPAD chlorophyll meter reading
SPAD	:	Soil plant analysis development
SRI	:	System of rice intensification
SEm	:	Standard error of mean
t	:	Tonnes
USDA	:	United States Department of Agriculture
viz.,	:	Namely
WSE	:	Weed smothering efficiency
Zn	:	Zinc

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
°C	:	Degree Celsius
μ	:	Micro
₹	:	Rupee
&	:	And

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INTRODUCTION

1. INTRODUCTION

Kerala is well known for its typical wetland ecosystems enclosing paddy fields which have the role of aquifers besides being a source of food. Despite the multi-dimensional role of paddy fields, the cultivated area is on decline. Farmers opt for more renumerative crops resulting in a reduction of cultivated area from 6.78 lakh ha in mid 1980s to 1.96 lakh ha in 2015-16 (FIB, 2019). The challenges faced by rice farmers can be overcome by intensifying the rice based cropping system with other crops during the fallow period. Inclusion of fodder crops is a viable option to augment the rice based integrated farming systems.

Livestock rearing is an integral part of our agrarian economy. In India, the significance of inclusion of livestock component is more pronounced in case of small and marginal farmers, as it enhances the sustainability of the production system. In case of the livestock population status of India, there is an increasing trend year after year. On the contrary, fodder production and availability is declining. In India, currently there is a deficiency of 64.21 and 24.81 per cent of green and dry fodder respectively (GOI, 2017). To meet the deficit, green forage supply has to be increased at the rate of 1.69 per cent annually (Rakesh, 2016). In Kerala, green fodder requirement during 2014 was 7.04 M t but only 1.75 M t was produced indicating a deficiency of 75 per cent (GOK, 2015).

Livestock are mainly fed with concentrates, roughages and fodder crops. Crop residues and collected weeds form the major source of forage, especially during lean period. However, it is mandatory to include fodder crops as feed component, as it provides critical nutrients needed for the ruminant's gut. The feed accounts for 60 to 70 per cent of the cost of livestock rearing. Fodder crops are the cheapest source of nutrients (Meena and Singh, 2014).

In India, there is almost 11.695 M ha of unexploited rice fallows (Singh *et al.*, 2016). Rice-rice-fallow is the major rice based cropping system followed especially in the districts of Thiruvananthapuram, Kollam and Pathanamthitta

(John *et al*., 2014). Inclusion of fodder crops during the summer season from existing practice of keeping the field fallow is a prospective option to enhance the fodder production and also the system productivity.

Cultivation and maintenance of fodder crops in any cropping system has paramount importance in ecological sustainability as they act as erosion controlling agents, cover crops which reduce weed growth and sequestrates carbon . In addition, legume fodders help in fixing atmospheric nitrogen (N), thereby enhancing soil fertility. The farmer gets benefited in multiple dimensions like efficient use of available stored moisture, nutrients and increased income.

The nitrogenous fertilizers applied to the first and second rice crops along with the incorporated stubbles, might have a positive residual effect on the succeeding crop and hence, there is a prospect for reducing the N supply to the summer fodder crops. The leguminous fodders raised during summer are likely to improve the productivity of the succeeding *virippu* crop. In this context, the present investigation entitled "Productivity enhancement of rice based cropping system with fodder crops" was undertaken with the following objectives:

i. To evaluate the suitability of different fodder crops in summer fallow of double cropped lowland rice fields under varying nitrogen regimes.
ii. To assess its residual effect on the succeeding *virippu* rice crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study entitled "Productivity enhancement of rice based cropping system with fodder crops" was undertaken with the objective of evaluating the suitability of different fodder crops in summer fallow of double cropped lowland rice fields under varying N regimes and assessing the residual effect on the succeeding *virippu* rice crop. The relevant literature on rice based cropping systems including fodder crops are reviewed in this chapter.

2.1 SEQUENTIAL CROPPING SYSTEMS INVOLVING FODDER

To meet the needs of growing live stock population, the National Commission on Agriculture in 1976 suggested that, at least 10 per cent of arable land of the country should be under improved forage crops (Singh *et al*., 2011). Currently, the country faces a green fodder deficiency of 35.6 per cent . This gap between demand and supply may further widen due to consistent growth of livestock population at the rate of 1.23 per cent in the coming years. Thus, to meet the deficit, green forage supply has to grow at 1.69 per cent annually (Rakesh, 2016). The most possible and scientific way of increasing the fodder cultivation is by introducing fodder crops in the existing cropping systems.

2.1.1 Rice Based Cropping System

Rahman (1994) reported that both non-legume and legume fodder must be integrated in rice-based cropping systems for enhanced and sustained productivity.

Akbar *et al*. (2000) revealed that fodder legume relay cropping in Aman rice with *Lathyrus sativus* was successful and suggested that fodder legume integration in rice based cropping system is the best solution for tackling fodder shortage and improving soil fertility.

Rajasree and Pillai (2001) suggested the possibility of raising *Sesbania rostrata* as a fodder crop in the summer rice fallows.

Singh and Sharma (2002) reported that, in foot hills of Himalayas, chick pea-maize + fodder cowpea – rice performed well with a cropping intensity of 300 per cent recorded the highest rice equivalent yield of 13.90 t ha^{-1} and production efficiency of 38.09 kg ha^{-1} per day.

Kar *et al.* (2004) suggested that in rice fallows, inclusion of short duration and low water requiring legumes (green manure or grain purpose) offered excellent chance to utilize carry over residual soil moisture.

Timsina *et al.* (2010) suggested that, in double or triple rice based cropping systems, there is a need for an alternative or additional crop to increase overall system productivity and profitability.

Singh *et al.* (2011) reported that inclusion of either summer grain, fodder legumes or green manure in rice-wheat cropping system resulted in higher economic rice equivalent yield, protein yield, nutrient uptake and increased soil nutrient balance due to improved soil physico-chemical properties.

Dubey *et al.* (2014) revealed that, among the different cropping systems, rice-berseem cropping system resulted in a rice equivalent yield of 115.49 q ha^{-1}, which was comparable with rice-vegetable pea-sorghum fodder system which gave a rice equivalent yield of 108.94 q ha^{-1}.

2.1.2 Other Crop Based System

Haque (1992) stated that fodder legume integration in crop or livestock production system helps in improving soil fertility and soil structure which ultimately enhance crop yields and forms good quality feed for the livestock.

Forage cowpea raised in summer fallow of rice- wheat cropping system increased the use efficiency of N and phosphorus (P). Forage cowpea also helped in minimizing the leaching loss of NO_3 –N below 45 cm depth of soil (Dwivedi *et al.*, 2003).

Fodder legumes are most economic feed supplement than commercial concentrates (Njarui *et al.,* 2004) and inclusion of fodder legumes in the fodder production system is the most efficient way to increase quality herbage production (Mwangi *et al.*, 2006).

Toaima *et al.* (2014) reported that when sorghum or sudan grass was included in the sequential cropping system, it enhanced the yield of faba bean, berseem and onion through the secretion of biologically active chemicals compared to fallow treatment.

Kumar *et al.* (2014) suggested the possibility of replacing existing maize-wheat cropping system with other fodder based cropping system in mid hills of north western Himalayas without any reduction in the economic yield. Wheat sequenced with fodder maize recorded a superior yield (3,676 kg ha^{-1} per year) and monetary efficiency of Rs. 109 ha^{-1} per day. The cropping system oat + fodder sarson - fodder maize + fodder cowpea resulted in higher green fodder equivalent yield of 60. 77 t ha^{-1} per year along with higher production efficiency of 166 kg ha^{-1} per day.

Jha and Tiwari, (2018) reported that higher green fodder yield of 1180 q ha^{-1} was obtained from maize + rice bean (2:1) - oat multi cut - sorghum multi cut + cowpea (2:1) cropping system and higher dry matter production of 247 q ha^{-1} was recorded from maize + rice bean (2:1) – oat multi cut - sorghum multi cut + cowpea (2:1).

Growing of rice bean before or after a maize crop or rice crop was beneficial due its N fixing property which helps in improving the N status of the soil and the N uptake by the next crop (Dahipahle *et al.*, 2017). Ali *et al.* (2019) suggested that, there is a scope for replacing the cotton-wheat rotation in the semi-arid regions with wheat and fodder crops, which is not only economical but also helps in improving the soil fertility.

2.2 PERFORMANCE OF FODDER CROP IN SEQUENTIAL CROPPING SYSTEM

2.2.1 Growth and Physiology

Rajasree (1994) observed that lime significantly increased growth attributes like number of branches, leaf area index (LAI), plant height and number of leaves of legume fodders which are raised in the summer rice fallows. She also reported that elevated levels of P and lime declined the nodulation in *Sesbania rostrata* which is a potential fodder supplement.

Akbar *et al.* (2000) reported that the relay crop of *Lathyrus sativus* in the Aman rice showed an average plant height of 42.7 cm and 7.7 average numbers of branches per plant.

2.2.2 Yield Attributes and Yield

Among *Sesbania rostrata* and different varieties of fodder cowpea *viz* CO-5, C-152 and Karnataka local, C-152 cowpea variety was best suited for summer rice fallows which gave 31.19 t ha^{-1} green fodder yield followed by CO-5 (30.66 t ha^{-1}). *Sesbania rostrata* produced the highest dry matter yield of 94.99 t ha^{-1} (Rajasree, 1994).

The relay cropped *Lathyrus sativus* in Aman rice gave a mean green fodder yield of 11.02 t ha^{-1} [Akbar *et al.* (2000)].

Ramachandra *et al.* (2007) observed that while the lowest rice grain equivalent yield was recorded with rice-rice and rice-fodder maize cropping sequences, the production use efficiency and energy equivalent was the highest in rice-fodder maize sequence.

Kumar *et al.* (2014) reported that, among the different cropping systems investigated, the green fodder equivalent yield (t ha^{-1} per annum) of oat + fodder sarson - fodder maize + fodder cowpea system was 60.77; oat + fodder sarson - guinea grass + fodder oat was 56.60; wheat - fodder maize was 55.64 wheat-annual guinea grass was 52.33 and oat + fodder sarson - sorghum + fodder cowpea system was 51.22 which is highly superior to wheat –maize cropping system.

The green fodder and dry fodder yield found to be maximum for the fodder crops which were grown after aerobic method of planting. Oats gave higher green and dry fodder yield of 28.16 t ha^{-1} and 6.52 t ha^{-1}, respectively after the kharif rice (Panda, 2015).

Madankumar (2017) studied the performance of different crops and fish in summer rice fallows. Fodder cowpea gave significantly highest crop yield of 23703 kg ha^{-1} and rice equivalent yield of 3556 kg ha^{-1}. He also studied the grain productivity and straw productivity of rice raised subsequent to different crops including fodder cowpea. Significantly higher grain yield (6623 kg ha^{-1}) was obtained in rice+fish succeeding fodder cowpea+fish and was on par with rice +fish succeeding amaranthus + fish and rice +fish succeeding culinary melon + fish. The straw yield was significantly higher (6837 kg ha^{-1}) in rice + fish succeeding fodder cowpea + fish and was on par with rice + fish succeeding amaranthus +fish.

Jha and Tiwari (2018) observed that among the different cropping systems, maize + rice bean (2:1) – oat multi cut - sorghum multi cut + cowpea (2:1) system provided highest green and dry fodder yield of 4.15 q ha^{-1} and 0.86 q ha^{-1}.

Ali *et al.* (2019) noted that wheat based cropping systems, which included fodder crops, resulted in significantly higher yield than that of wheat-cotton system. The yield of wheat -fodder maize- mashbean , wheat - fodder sorghum -mung bean, wheat-fodder-maize-soybean and wheat- mung bean-grain millet were significantly higher compared to the wheat- cotton system.

2.2.3 Fodder Quality

The crude protein content of the sequential crops of fodder cowpea and *Sesbania rostrata* in the summer rice fallow found to increase with the application of 125 kg of lime ha^{-1} and 60 kg of P_2O_5 ha^{-1}. The highest crude protein content was recorded by *Sesbania rostrata* (Rajasree, 1994).

Singh and Sharma (2002) reported that, among different cropping sequences, wheat -maize + fodder cowpea – rice gave highest carbohydrate of 9.68 t ha^{-1} and chemical energy of 50.51 K cal × 10^{-6} ha^{-1}.

Digestible protein was higher in rice-fodder maize (1372 kg ha^{-1}) cropping sequence than rice-rice (676 kg ha^{-1}) and rice-fallow (372 kg ha^{-1}) cropping system. Also, digestible carbohydrate and digestible fat was more in rice-fodder maize (8961 kg ha^{-1}and 231 kg ha^{-1}) cropping system than rice –rice (7771 kg ha^{-1} and 49 kg ha^{-1}) and rice fallow (3800 kg ha^{-1} and 24 kg ha^{-1}) cropping system (Ramachandra *et al.*, 2007).

Crude protein yield was higher for the fodder crops (443 kg ha^{-1}) grown after the aerobic rice which was on par with system of rice intensification (SRI) flat bed (413 kg ha^{-1}), SRI raised bed (66 kg ha^{-1}) methods of rice planting. The crude protein yield of oats (615 kg ha^{-1}) was higher than berseem and lathyrus (Panda, 2015).

Singh and Chauhan (2017) observed that among different fodder sorghum varieties, SPV 462 gave the highest crude protein content (7.08%) followed by CSV 19 SS (6.35%). Kumari (2017) revealed that, with elevated level of Zn application (18.5 kg ha^{-1}), protein content in fodder berseem (13.75 to 15.37 %) and lucern (18.5 to 19.7 %) was increased.

2.2.4 Nutrient Removal by Fodder Crops

Rajasree (1994) observed that, application of 60 kg P_2O_5 ha^{-1} for *Sesbania rostrata* resulted in the highest uptake of 219 kg N and 17 kg P_2O_5 ha^{-1} in summer rice fallows. Highest uptake of K_2O (94 kg ha^{-1}) was reported in *Sesbania rostrata* with 30 kg P_2O_5 ha^{-1}.

Patidar (2013) observed that, among the different genotypes of fodder rice bean, JRBJ-05-4 reported the maximum uptake of 201.36 kg N ha^{-1}, 3.63 kg P ha^{-1} and 52.20 kg potassium (K) ha^{-1}.

Bhavya *et al.* (2014) revealed that, in fodder cowpea, higher N and P (114.6 and 16.9 kg ha^{-1} respectively) uptake was effected by application of 25 kg N ha^{-1}over the treatments of 0, 15 and 35 kg N ha^{-1}.

Nitrogen uptake was reported higher for the fodder crops grown after aerobic rice which was on par with SRI flat bed and SRI raised bed methods of rice planting. The N uptake of oats was higher than berseem and lathyrus (Panda, 2015). Ali (2015) reported that, among fodder sorghum and fodder bajra, the nutrient uptake N, P, K, Ca and magnesium (Mg) was more in fodder sorghum with high dose of N and closer spacing.

Singh and Chauhan (2017), from 15 fodder sorghum varieties observed that the sorghum variety SPV 462 found to uptake more N (11 kg t^{-1} of dry matter production). The highest Ca uptake (76 kg ha^{-1}) was done by HJ 541 on par with CSV 21 F and CSV 19, Phule Revati and HJ 513 comparing the remaining varieties. Kumari (2017) observed that, in fodder berseem and lucerne, the N uptake significantly increased with elevated levels of zinc (Zn). The highest N uptake was reported with 4 kg Zn ha^{-1}. An increased uptake of K was reported with increased dose of Zn up to 4 kg ha^{-1}. Kumar *et al.* (2017) reported that the highest Zn uptake was done by the fodder maize variety, J 1006 than African tall.

2.2.5 Residual Effects

After the death of legumes, the fixed N is made available to the plants and also fertilize the soil (Brady, 1984).

The legume effect in rice based cropping system enhanced the grain yield, which is often accomplished through increased plant height, increased productive tillers, tiller number or straw yields (Mridha, 1987).

The decline in the yield of rice in the rice based cropping system can be due to the exhaustive nature of cereals included in the system (Jadhav, 1989).

Non legume residues with high carbon to nitrogen (C: N) ratio, such as maize when incorporated in soil led to decline in N availability. The order of N availability from crop residues was alfalfa > peanut > soybean > oat > sorghum >wheat > corn (Smith and Sharpley, 1990).

Rice subsequent to forage legumes recorded an yield increase of 0.6 to 2.4 t ha^{-1} (Carangal *et al.* 1994; Ladha *et al.* 1996).

The wider C: N ratio of sorghum and sudan grass reduced the availability of N to the subsequent crops despite the accumulated N in the crop residues long considerable (Sattell *et al.*, 1998).

The allelopathic effect of sorghum can operate sequentially, simultaneously and (or) with mechanisms of interference *viz*., nutrient deficiency. The exudates of sorghum can interfere with nutrient dynamics, mineralization and also mycorrhizae (Xiao *et al.*, 2007). Ramachandra *et al.* (2007) observed that the average yield of rice or fodder maize in sequence declined, whereas more or less equal yield was obtained for rice succeeding legumes.

Toaima *et al.* (2014) reported that sudan grass had positive allelopathic effect on the subsequent crops of berseem, faba bean and onion on forage yield, seed yield and bulb yield respectively. But the yield of fodder beet, wheat and sugar beet declined when grown after sudan grass and sorghum compared to the fallow treatments.

2.2.6 Soil Nutrient Status

Menon (1987) studied the nutrient dynamics of the top 0 to 15 cm and 15 to 30 cm soil influenced by preceding legume forage crops and fallows in the rice field. There was a significant increase in the available N content of the soil, the highest being in velvet bean plots, followed by cowpea plots. The lowest value was seen in the fallow plots. A significant difference in the available P content of the soil was noticed after the legume crops, but a specific trend could not be seen.

The soil fertility status of the soil is found to be increased after the legume fodders, especially the organic matter and N status (Haque, 1992) thereby improving the yield of the subsequent cereal crops (Balyan, 1997).

Akbar *et al*. (2000) recorded that there was a significant increase in the N and organic matter content of the soil after the relay cropped *Lathyrus sativus* in the Aman rice.

Ghosh *et al*. (2007) observed that legume fodders were highly potent in enhancing the productivity of subsequent cereals. Berseem, fodder cowpea and *Lathyrus* added 60 to 120 kg N ha^{-1}, 35 to 60 kg N ha^{-1} and 50 kg N ha^{-1} respectively.

Khadkam and Paudel (2010) recorded that legume inclusion in the cropping system, under irrigated conditions, improved the organic carbon (OC) status of the soil.

Kumar *et al*. (2014) reported that the cropping systems comprising of sorghum and guinea grass caused significant reduction in available NPK in the soil, which is due to the exhaustive nature of the fodder crops. The study also reported that there was an increase in organic matter content of the soil over the initial status as a result of addition of farmyard manure (FYM). Significantly more organic matter content was seen in wheat- fodder maize (0.80 %) which was on par with oat+ fodder sarson - fodder maize+ fodder cowpea (0.79 %) cropping systems. Similarly there was an increase in available N, P and K. Dubey *et al*.

(2014) noted that there was an elevated trend in OC and N in rice -- berseem and rice-vegetable cowpea-fodder sorghum, where 100 per cent organics was used compared to 100 per cent inorganic and integrated (50 % each of organic and inorganic) nutrient management.

Ali *et al*. (2019) reported that cropping systems involving fodder crops had significant effect on the nutrient status of the soil. The highest organic matter content of soil was noted after wheat - mashbean - soybean cropping system and thereafter, wheat-fodder maize – mashbean. Wheat -mashbean - soybean cropping system resulted in an increased N content of the soil followed by wheat-fodder, maize – mash bean and wheat-mungbean- grain millet, which was very high comparing to cotton-wheat system.

2.2.7 Economics

Rajasree (1994) observed that different levels of P and lime had significant effect on the benefit cost (B: C) ratio of leguminous fodders raised in the summer rice fallow. Economics of cultivation of legume crops indicated that the application of 250 kg lime and 60 kg P_2O_5 ha^{-1} produced higher net returns and B: C ratio.

Singh and Sharma (2002) suggested the best rice based cropping system suitable in the foot hills of Himalaya was chick pea -maize+ fodder cowpea –rice with higher mean economic returns.

The REY and production use efficiency was higher for rice –fodder maize (57.15 q $ha^{-1}$and 111.0 kg ha^{-1} day^{-1} respectively) was significantly higher than rice-rice (48.87 q ha^{-1} and 34.12 kg ha^{-1} day^{-1} respectively) cropping sequence (Ramachandra *et al*., 2007).

Sunil and Faruqui (2009) reported that based on the net returns and system productivity, ground nut-berseem-fodder maize-fodder cowpea system was best followed by groundnut-wheat-fodder maize-fodder cowpea and multi cut sorghum-berseem.

The fodders crops grown after the rice crops under different methods of rice cultivation, the oat green fodder equivalent yield was found to be maximum for the fodder crops grown succeeding to SRI- raised bed (69.67 t ha^{-1}) which was on par with fodder crops succeeding to SRI flat bed (64.27 t ha^{-1}). The highest B: C ratio was given by aerobic rice – fodder system (1.88) and thereafter SRI raised bed – fodder system and SRI flat bed - fodder system (1.87 and 1.77 respectively). Rice –oat system reported the most profitable B: C ratio of 2.05 followed by berseem (1.64) and lathyrus (1.68) (Panda, 2015).

Ramachandrappa *et al.* (2017) reported that among the different fodder crops in fodder crops- onion cropping system (fodder maize, sweet sorghum, fodder pearl millet), the highest gross returns, net returns and B: C ratio were recorded by sweet sorghum –onion crop.

Jha and Tiwari (2018) reported that among different fodder based cropping system, significantly higher gross returns (₹ 134943 ha^{-1}) and net returns (₹ 89108 ha^{-1}) were given by maize + rice bean (2:1) – oat multi cut – sorghum multi cut + Cowpea (2:1) system. The same system provided the highest economic efficiency of ₹ 313 ha^{-1} day^{-1} and B: C ratio of 1.94.

Ali *et al.* (2019) recorded that among the different wheat based cropping systems involving fodder crops, the highest B: C ratio was obtained by wheat - fodder millet - grain maize. Wheat - fodder maize – mash bean gave the second highest B: C ratio followed by wheat - fodder maize – mash bean while the least B: C ratio was obtained by wheat - guar cropping system.

2.3 WEEDS

2.3.1 Weeds in Cropping Systems Involving Fodders

The distribution of weed seeds is majorly influenced by the primary tillage thereby weed seeds scattering in different layers of soil (Fray and Olson, 1978).

The major weed *Echinochloa crusgalli* of density 100 plants m^{-2} found to reduce the maize yield by 18 per cent (Kropff and Laar, 1993). *Amaranthus retroflexus* declined the grain yield of maize by 20 per cent with 20 weeds m^{-2} and 30 per cent with 30 weeds m^{-2} (Rola and Rola, 1990).

Vijayabaskaran and Kathiresan (1993) reported that land management practices in the summer significantly reduced weed biomass during succeeding rice and cotton crops.

An investigation in the shift in weed flora due to the impact of rice-based cropping sequences revealed that summer cropping with bhindi, cassava and daincha resulted in a shift in the major weed species *Echinochloa crusgalli* from the field. Weed population was more in *virippu* rice where the preceding summer crop was bhindi and cassava which was due to the farmyard manure (FYM) liberally applied in these crops that served as a source of weed seeds (Varughese *et al.*, 2007).

The weed dry matter production in fodder maize in the summer fallows was found to be significantly less at 30 DAS when irrigated at IW/CPE ratio of 0.7 combined with zero tillage (Reddy, 2013). Fodder cowpea at 30 and 60 days after sowing (DAS) recorded significantly lower weed dry weight (35.93 and 19.56 g 0.25 m^{-2} respectively) over all other treatments. Among intercropping treatments, maize sown after three weeks at 1:2 row proportion recorded significantly lower weed dry weight at 30 and 60 DAS (40.85 and 30.86 g 0.25 m^{-2} respectively). However, at 90 DAS and at harvest, maize sown after three weeks with fodder cowpea at 1:1 row proportion recorded significantly lower weed dry weight (100.49 and 123.29 g 0.25 m^{-2} respectively). Sanodiya *et al.* (2013) recorded that in fodder maize (African tall) maximum weed control efficiency was with two hand weeding immediately followed by alachlor at 2.5 kg ha^{-1} + hand weeding at 30 DAS, atrazine @ 1.0 kg ha^{-1} + hand weeding @ 30 DAS, combined application of atrazine 0.75 kg ha^{-1} + pendimethalin @ 0.75 kg ha^{-1} and atrazine @ 0.75 kg ha^{-1} + alachlor @ 2.25 kg ha^{-1}.

Madankumar (2017) reported maximum population of weeds during summer at 20 DAS was in amarathus +fish (386 m^{-2}) followed by fodder cowpea (303 m^{-2}) and amarathus (268 m^{-2}) which were on par. Kumar and Murthy (2017) observed that the major weed flora associated with rice bean were *Cyperus rotundus*, *Digitaria margineta*, *Commelina benghalensis*, *Amaranthus virdis*, *Parthenium hysteroporus*, *Spillanthus acmella*, *Eleusine indica*, *Ageratum conyzoides* and *Euphorbia spp.*

2.3.2 Nutrient Removal by Weeds in Cropping Systems Involving Fodders

Moorthy and Mitra (1991) reported that the nutrient uptake of weeds in transplanted rice from one ha was 13.7 to 19.4 kg N, 1.5 to 1.8 kg P and 17.4 to 33.7 kg K.

Mahajan and Sardana (2003) revealed that, in wheat, the uncontrolled weeds resulted in an average depletion of 28.6 kg N, 4.2 kg P and 44.4 kg K (ha^{-1}).

Ali (2015) observed that, among fodder sorghum and fodder bajra the weed dry weight at harvest was more in fodder sorghum and also the nutrient uptake by weeds was more in fodder sorghum plots.

Madankumar (2017) reported that the N uptake of weeds in fodder cowpea and fodder cowpea + fish at 20 DAS in summer rice fallow was 5.14 and 5.16 kg ha^{-1} respectively. Whereas P uptake of weeds was 0.42 and 0.41 kg ha^{-1}. The K uptake by the weeds in fodder cowpea and fodder cowpea + fish plot at 20 DAS was 3.47 and 3.42 kg ha^{-1} respectively. Rathod and Somasundaram (2017) noted that the plot of unweeded check recorded the highest nutrient uptake of 10.1kg N, 0.81kg P and 8.15 kg K (ha^{-1}) at 20 days after transplanting (DAT) and 17.18 kg N, 1. 62 kg P and 15.16 kg K (ha^{-1}) at 30 DAT.

Gaurav *et al*. (2018) observed that, in rice, the NPK uptake by weeds were lower in raised bed method of planting and also with atrazine application followed by 2,4-D at 30 DAS.

2.4 INFLUENCE OF NITROGEN NUTRITION ON FODDER CROPS

Nitrogen is an important constituent of nucleic acids and amino acids. Provision of nitrogenous fertilizers is important as it help in enhancing growth and yield of both cereal and legume fodders. Even though the legume fodders are good at fixing atmospheric N, starter dose of N fertilizer is important for the initial growth.

In forage crop production, N plays a crucial role and is required in large quantity to reach the full potential of the production system (Balasubramanian *et al*., 2010).

The enhanced cultivation of legume crops in cropping system can ultimately reduce the dependency on inorganic fertilizers and renewable sources of N can be increased in the nutrient cycles (Foley *et al*., 2011; Seufert *et al*., 2012) thereby reducing the amount of reactive N lost from our ecosystem.

2.4.1 Growth and Physiology

Besides LAI, crop growth rate (CGR) of forage rice bean has also increased significantly with N fertilizer application (Qamar *et al*., 1999).

Genotypic differences for nutrient use, especially N use efficiency have been recognized in many crops including sorghum and may also reduce the reactive N vanished from the ecosystem Maranville *et al*. (2002).

Rice bean seeds when treated with rhizobium along with application of 20 kg of N ha^{-1} resulted in significantly increased number of nodules, plant height, dry weight of plant, number of leaves, test weight, number of pods and number of grains per pods (Kumar and Elamathi, 2007). The application of 30kg N ha^{-1} in kharif cowpea, there was significant increase in plant height, number of nodules and pods per plant, weight of nodules per plant, weight of pod, length per pod and also seed index (Singh *et al*., 2007).

Increase in N dose from 30 to 60 kg ha^{-1} in cowpea significantly increased the plant height and number of leaves and branches per plant (Abayomi *et al*., 2008).

Ayub *et al*. (2010) reported that under different N regimes (0, 25, 50 kg ha^{-1}) three cultivars of cluster bean gave maximum plant height and the highest number of branches per plant at 50 kg N ha^{-1}. Provision of N fertilizers significantly increased the plant height over the control plot of no fertilizer. The highest plant height of cluster bean (96.25 cm) was obtained when 25 kg N ha^{-1} was applied (Hasan *et al*., 2010). The elevating trend of plant height, chlorophyll content, LAI and stem diameter with respect to increased N application in fodder maize was reported by Hassan *et al*. (2010) and Mahdi *et al*. (2012).

Afsal *et al*. (2012) reported that, in fodder sorghum, taller plants of 193.92 cm, 195.24 cm and 192.79 cm respectively were seen in first, second and the third cutting when 100 kg of N acre^{-1} was applied. Plants of 179.70 cm at first cut and 168.62 cm height of plants at both second and third cut were obtained when 75 kg N acre^{-1} was applied.

In fodder cowpea, the application of 25 kg N ha^{-1} resulted in increased number of primary branches per plant, plant height, number of leaves per plant, leaf stem ratio at harvest and total dry weight of the plant (Bhavya *et al*., 2014). Meena and Chand (2014) reported that application of N significantly influenced the plant height and number of branches. Khan *et al*. (2014) revealed that under varying levels of N in fodder maize, there was an increasing trend in plant height with increased dose of N application. The tallest plants were observed when 180 kg N ha^{-1} was applied, followed by 150 and 120 kg N ha^{-1} respectively. The shortest plants was observed when 90 kg N ha^{-1} was applied. Leaf area per plant (cm^2) also shown an increasing trend with increased rate of N application.

Ullah *et al*. (2015) observed that, with a dose of 280 kg N ha^{-1}, the fodder maize obtained the highest plant height followed by the application of 240 and 200 kg N ha^{-1}. Fodder maize has shown similar trend with LAI. Nirmal *et al*.

(2015) observed that there was an increase in plant height, number of leaves and inter nodes per plant with the application of 125 per cent recommended dose of fertilizers (RDF) ha^{-1} and other treatments remained par with 100 per cent RDF ha^{-1} in fodder sorghum.

Balai *et al.* (2017) noted that application of 30 kg of N ha^{-1} in cowpea gave plant height significantly higher to 20 kg of N ha^{-1}, 10 kg of N ha^{-1} and 0 kg of N ha^{-1}.

Chaudhary *et al.* (2018) reported that application of 100 kg N ha^{-1} resulted in a significantly taller plants of forage sorghum with higher leaf area and wider stem diameter.

2.4.2 Fodder Yield

Maloth and Prasad (1976) reported that, application of starter dose of N significantly increased green fodder yield of two harvests of cowpea.

Tariq *et al.* (1998) noted that, in rice bean increased dose of N and P_2O_5 had a positive effect on green fodder yield. N and P @ 50:75 kg ha^{-1} gave higher green fodder yield and there was no significant difference between the treatments 50:50 and 50:25 kg ha^{-1} N and P.

Ayub *et al.* (1999) reported that, 100 kg of N ha^{-1}+ 50 kg P_2O_5 ha^{-1} gave more fodder yield of fodder sorghum. The herbage yield showed an elevated trend along with increased application of N. Application of 150 per cent of NPK along with FYM @ 25 t ha^{-1} resulted in the highest green fodder yield and dry fodder yield in cowpea followed by NPK at 100 per cent recommended dose of fertilizers (RDF) + FYM (Pandya and Bhutt, 1999).

Sultana *et al.* (2005) observed that green fodder yield of fodder cowpea responded positively with enhanced level of N fertilization.

Higher value of green fodder yield was found in fodder cowpea when urea fertilizer was applied @ 25 kg N ha^{-1} (Hasan *et al*., 2010).

A linear increase of 14.8 t ha^{-1} of dry matter yield was observed in fodder maize with enhanced application of N up to 120 kg ha^{-1} by Cerny *et al*. (2012). Afsal *et al*. (2012) reported that, in fodder sorghum, increased fresh weight per plant was noticed with the increased application of N. At first cut, the highest fresh weight per plant was obtained at 100 kg N $acre^{-1}$ followed by 75 N kg $acre^{-1}$.

Bhavya *et al*. (2014) reported that, among the different doses of N (15, 25 and 35 kg ha^{-1}) on fodder cowpea, 25 kg N ha^{-1} gave higher yield of 5.35 t ha^{-1}. Meena and Chand (2014) recorded an increase of green and dry fodder yield when N dose was increased from 0 to 30 kg ha^{-1}. Shukla *et al*. (2014) noted that the yield of rice bean at 100 per cent RDF which included 20 kg N ha^{-1} which was on par with 50 per cent RDF. Khan *et al*. (2014) noted that, fresh weight of fodder maize had a positive response towards the applied N.

Ullah *et al*. (2015) observed that the application of 240 kg N ha^{-1} in fodder maize resulted in the highest green fodder yield. There was a significant increase in the forage yield, forage weight per plant and forage production when 125 per cent of recommended dose of N was provided (Nirmal *et al*., 2015).

Balai *et al*. (2017) revealed that 30 kg N ha^{-1} resulted in maximum green and dry fodder yield of fodder cowpea. Behera *et al*. (2017) studied the response of different genotypes of rice bean under various N regimes. Maximum grain yield and stover yield was observed when N @ 40 kg ha^{-1} was applied, followed by 60 kg N ha^{-1}.

Chaudhary *et al*. (2018) reported that with the application of 100 kg N ha^{-1} forage sorghum gave higher green fodder yield compared to 60 and 80 kg N ha^{-1}.

2.4.3 Fodder Quality

Baran *et al.* (1987) noted that, increased level of N application to fodder maize, increased crude protein while reduced ash and crude fibre content.

Iqbal *et al.* (1998) reported that application of 50 kg N ha^{-1} to rice bean resulted in maximum crude protein content. Tariq *et al.* (1998) observed that, there was a positive increase in the crude protein content of rice bean as a result of increased application of N. Application of 50 kg N and 75 kg P ha^{-1} gave higher crude protein content followed by NP at 50:50 kg ha^{-1} which were statistically on par.

Ayub *et al.* (1999) revealed that the crude protein content, ash content and crude fibre content increased with increased level of N application in fodder sorghum.

Singh *et al.* (2007) reported that there was a significant increase in the crude protein content at 30 and 15 kg N ha^{-1} over 0 kg N ha^{-1} and were on par.

Afsal *et al.* (2012) noted that N application had significant effect on the crude protein content of fodder sorghum. In first cut, at 100 kg N acre^{-1} the crude protein content was maximum (12 %) and at 75 kg N acre^{-1}, the crude protein content was 10.6 per cent and at 0 kg N acre^{-1}, the least crude protein content of 7.5 per cent.

Ullah *et al.* (2015) reported that fodder maize gave a higher crude protein content of 12.70 and 12.20 per cent respectively with the application of higher N doses of 280 and 240 kg ha^{-1} wherein, crude protein content of 7.16, 8.10 and 9.60 per cent were obtained at 120, 160 and 200 kg N ha^{-1}. Likewise, crude fibre of 33 per cent decreased to 25.26 per cent when N dose was reduced from 280 to 80 kg N ha^{-1}.

Jha and Tiwari (2018) revealed that, among intensive fodder based cropping systems, pearl millet multi cut + rice bean (2:1) – berseem – maize +

cowpea (2:1) system provided significantly more crude protein yield. Chaudhary *et al.* (2018) reported that applied N had significantly increased chlorophyll content and crude protein as well as crude fibre content of forage sorghum.

Though the performance of different fodder crops when raised solely and its residual effect on succeeding crops have been studied, for which reviews are available, a cropping system based investigation in rice based systems has not been undertaken. Review on the fodder crops specifically included in this study under varied N levels in rice based cropping system is meagre. There is also a dearth of results on the residual effect of the fodder crops included in the present study on succeeding rice crop. Hence, undertaking the present study in terms of defined objectives is justified.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Productivity enhancement of rice based cropping system with fodder crops" was undertaken with the objectives of evaluating the suitability of different fodder crops in summer fallow of double cropped lowland rice fields under varying N regimes and to assess its residual effect on the succeeding *viruppu* rice crop. The experiment was conducted during the period from February 2018 to October 2018 at Integrated Farming System Research Station (IFSRS) of Kerala Agricultural University (KAU), Karamana, Thiruvananthapuram, Kerala. The details of the materials used and methods adopted for the study are described in this chapter.

3.1 MATERIALS

3.1.1 Experimental Site

The study was conducted in the double cropped low land rice fields of IFSRS of KAU located at Karamana, Thiruvananthapuram, Kerala. The experimental site is geographically located at 8° 28' 43'' N latitude and 76° 57'46'' E longitudes and an altitude of 5m above mean sea level. The selected field was planted to rice during *virippu* and *mundakan* seasons of 2017-18.

3.1.2 Climate

A warm humid tropical climate prevailed over the experiment site. The data on various weather parameters *viz.*, mean maximum and minimum temperature, relative humidity (RH) and rainfall during the cropping period were collected from the Agromet observatory, IFSRS, Karamana, which are condensed in Appendix 1 and illustrated graphically in Fig. 1a and 1b.

The summer season 2018 ranged from 8^{th} standard meteorological week to 19^{th} standard meteorological week. The minimum temperature during the summer crop season 2018 varied from 23.53 to 26.57 °C while the maximum temperature

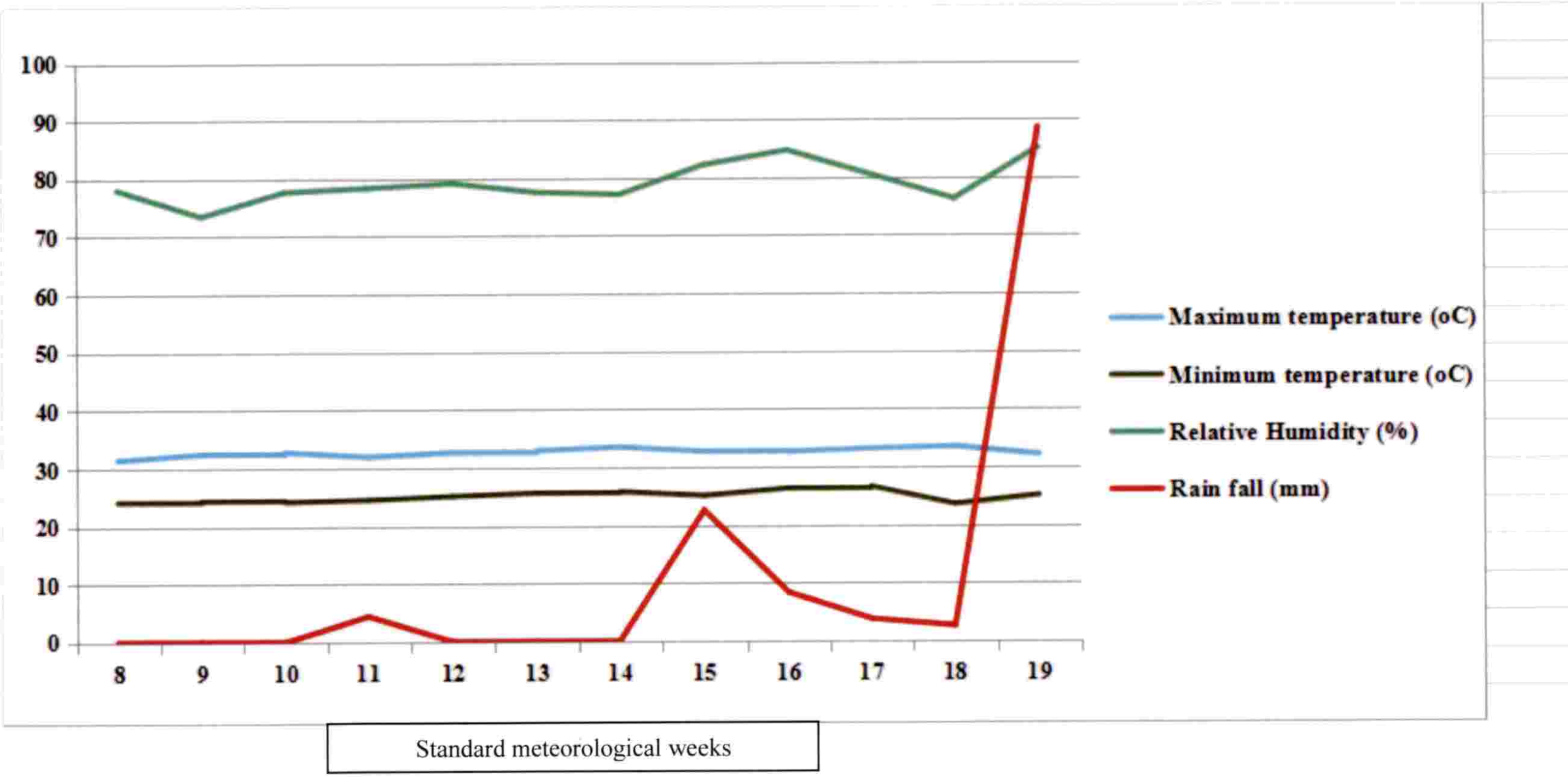

Fig. 1a. Weather data during summer fodder crop period (February to May 2018)

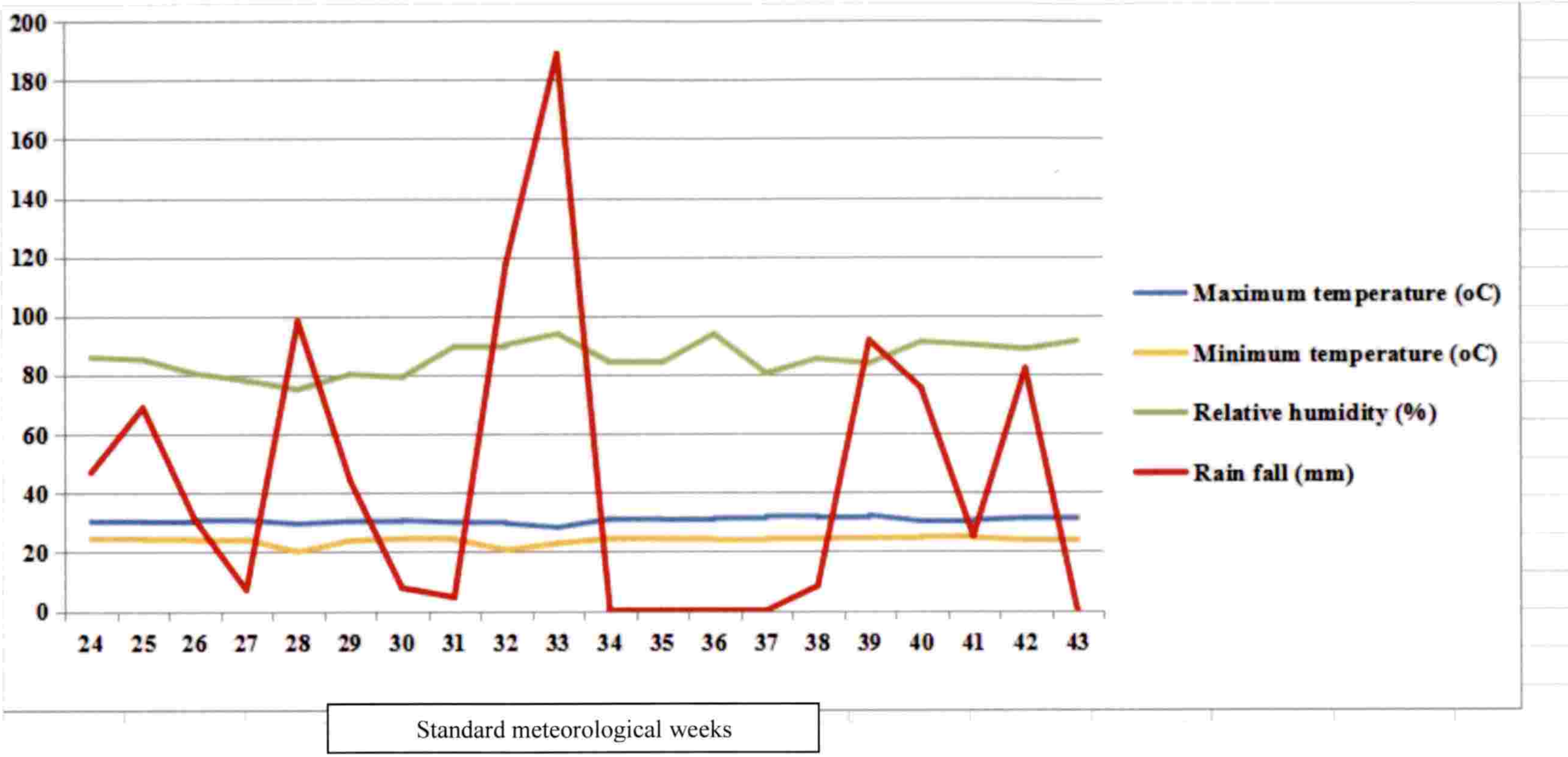

Fig. 1b. Weather data during *viruppu* rice crop period (June to October 2018)

varied from 31.40 to 33.50 °C. The relative humidity of the crop season varied from 73.42 to 85.07 per cent. The total rainfall received during the summer crop season was 130.6 mm.

The *virippu* season of 2018 ranged from 8th (February 21st) to 17th (11th May) standard meteorological week. The minimum temperature during this period ranged from 20.07 to 24.64°C while the maximum temperature varied from 28.28 to 32.21 °C. The relative humidity of the area ranged from 75.07 to 93.85 per cent. The total rain fall received during the *viruppu* season was 898.48 mm.

3.1.3 Cropping Season

The experiment was conducted in two seasons, summer (21st February- 11th May 2018) during which crops *viz*., fodder cowpea, rice bean, fodder maize, fodder sorghum were raised followed by *viruppu* rice (11th June – 26th October 2018).

3.1.4 Soil

A composite sample was collected before the commencement of the present study at a depth of 15cm. The samples were analyzed for its mechanical composition and chemical properties. The soil properties were rated as per the Package of Practices (POP) of the KAU (KAU, 2016).

The soil in the site of experiment was sandy clay loam in texture, moderately acidic with normal electric conductivity, medium in OC, available N, P and K (Table 1 and Table 2).

3.1.5 Cropping History of the Field

The experiment was carried out in the lowland rice field of IFSRS, Karamana where the cropping sequence rice-rice-fallow was followed.

Table 1. Mechanical composition of initial soil sample of the experimental site

Sl. No.	Fractions	Content in soil (%)	Method adopted
1	Coarse sand	72.9	Bouyoucos hydrometer method (Bouyoucos, 1962)
2	Silt	07.1	
3	Clay	20.0	
Soil texture- Sandy clay loam			

Table 2. Chemical properties of initial soil sample of the experimental site

Sl. No.	Parameters	Content	Rating	Method adopted
1	Soil reaction (pH)	5.55	Moderately Acidic	1:2.5 soil solution ratio using pH metre with glass electrode (Jackson, 1973)
2	Electrical conductivity(1:2.5) (dSm^{-1})	0.20	Normal	Digital Conductivity meter (Jackson, 1973)
3	Organic carbon (%)	1.2	Medium	Walkley and Black rapid titration method (Jackson, 1973)
4	Available N ($kg\ ha^{-1}$)	351.23	Medium	Alkali Potassium permanganate method (Subbiah and Asija, 1956)
5	Available P ($kg\ ha^{-1}$)	14.5	Medium	Brays calorimetric method (Jackson, 1973)
6	Available K ($kg\ ha^{-1}$)	130.97	Medium	Ammonium acetate method (Jackson, 1973)

3.1.6 Crop and Variety

3.1.6.1 Rice

The rice (*Oryza sativa* L.) variety used was Uma (MO-16) released from Rice Research Station, Moncompu, Alapuzha, KAU. It is of medium duration (115 to120 days), dwarf, medium tillering, non-lodging and resistant to brown plant hopper. The seeds of the variety were obtained from IFSRS, Karamana.

3.1.6.2 Fodder Cowpea

The fodder cowpea (*Vigna unguiculata* (L.) Walp.) variety used was CO 9 released from Tamil Nadu Agricultural University (TNAU). It is of short duration (50 to 55 days), dwarf with reduced fibre portions which confers increased digestibility, palatability and intake. This variety, CO 9 is moderately resistant to yellow mosaic virus. The seeds of the variety were obtained from the All India Coordinated Research Project (AICRP) on Forage crops, Coimbatore, Tamil Nadu.

3.1.6.3 Fodder Rice Bean

Fodder rice bean variety, Bidhan-2, released from Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, West Bengal was selected for the study. The variety has erect growth habit during early growth stage which later on becomes viny with indeterminate and luxuriant growth. The legume has profuse branching nature and grows to a height of 150 to 160 cm. The plants have trifoliate broad leaves with lush green colour. The seeds of the variety were obtained from the AICRP on Forage crops, College of Agriculture, Vellayani, KAU, Kerala.

3.1.6.4 Fodder Maize

Fodder maize (*Zea mays* L.) variety African Tall was used for the study which is bred at Mahatma Phule Krishi Vidyapeeth (MPKV), Kolhapur and is a composite of seven genotypes developed through modified mass selection. It has more dry matter and crude protein content, more number of leaves, leaf area, good grain and seed yield potential than other grain varieties. The variety is resistant to foliar diseases and stem borer. The average plant height is 260 cm and provides 60 to 70 t ha^{-1} green fodder and 30 q ha^{-1} grain. The seeds of the variety were obtained from AICRP on Forage crops, Tamil Nadu.

3.1.6.5 Fodder Sorghum

Fodder sorghum (*Sorghum bicolor*) variety CO (FS) 31 was used for the study which is developed by TNAU, Coimbatore. It is a multi cut variety having a height of 270 to 290 cm. It has a leaf stem ratio of 0.26. Average green fodder yield is 190 t ha^{-1} for six to seven cuts. The seeds of the variety were obtained from the AICRP on Forage crops, Tamil Nadu.

3.1.7 Manures and Fertilizers

Manures and fertilizers were applied as per the recommendations of TNAU for fodder cowpea, fodder maize and fodder sorghum. As per the recommendations of AICRP on Forage crops for rice bean, as per POP, KAU (2016) for the rice crop.

Well decomposed FYM containing 0.5 per cent N, 0.2 per cent P_2O_5 and 0.4 per cent K_2O was applied as source of organic manure. Urea (46% N), rock phosphate (20% P_2O_5) and Muriate of potash (K_2O 60%) were used as inorganic sources of N, P and K respectively.

3.2 METHODS

3.2.1 Design and Layout

The experiment was laid out in Randomized Block Design (RBD) and comprised of 12 treatments and one control, replicated thrice.

Experiment 1: Fodder crops in summer rice fallows

Summer season (2018)

Design	:	RBD
Treatment combinations	:	12 + 1 (control)
Replication	:	3
Plot size	:	5 m x 4 m
Control	:	Fallow during summer

3.2.2 Treatment Details

Treatment combinations

T_1 : Fodder cowpea (100% *RDN)

T_2 : Fodder cowpea (75% RDN)

T_3 : Fodder cowpea (50% RDN)

T_4 : Rice bean (100% RDN)

T_5 : Rice bean (75% RDN)

T_6 : Rice bean (50% RDN)

T_7 : Fodder maize (100% RDN)

T_8 : Fodder maize (75% RDN)

T_9 : Fodder maize (50% RDN)

T_{10} : Fodder sorghum (100% RDN)

T_{11} : Fodder sorghum (75% RDN)

T_{12} : Fodder sorghum (50% RDN)

T_{13} : Fallow during summer

R_1	R2	R3
T_{12}	T_6	T_8
T_5	T_9	T_3
T_8	T_1	T_6
T_{11}	T_{10}	T_{11}
T_{13}	T_7	T_1
T_2	T_3	T_4
T_7	T_5	T_{13}
T_{10}	T_2	T_{12}
T_3	T_4	T_5
T_6	T_{12}	T_{10}
T_9	T_8	T_2
T_4	T_{11}	T_9
T_1	T_{13}	T_7

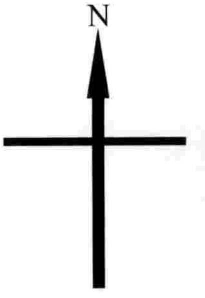

Fig 2. Lay out of the plot

*RDN: For fodder crops, except rice bean, recommended dose of N as per TNAU recommendation and for rice bean, the recommendation of the AICRP on Forage crops was followed (20:40:0 kg NPK ha^{-1}).

Experiment 2: Residual effect of fodder crops on succeeding (*virippu* 2018) rice crop.

A rice crop (*var.*Uma) was raised in all the treatment plots of Experiment 1 during *virippu* 2018 to study the residual effect on its productivity following the POP (KAU, 2016).

3.2.3 Crop Management

3.2.3.1 Summer Crop (2017-18)

3.2.3.1.1 Land Preparation and Layout

After the harvest of *mundakan* crop (2017-18), weeds were removed and crop residues incorporated. Raised flat beds of 5 m length, 4 m width and 30 cm height were prepared in each plot where fodder crops were raised. A distance of 30 cm was maintained between the beds. The beds were perfectly levelled and brought to a fine tilth.

3.2.3.1.2 Application of Manures and Fertilizers

Manures and fertilizers were applied as per the recommendations of TNAU for all fodder crops except for rice bean for which nutrients given as per AICRP on Forage crops in all plots except T_{13}- fallow during summer. Quantity of manures and nutrients applied to the fodder crops are given in Table 3.

For fodder cowpea, full NPK applied as basal; half N, full P as basal and remaining N at 30 DAS for rice bean; half N,P and K as basal, remaining half N at 30 DAS for fodder maize and fodder sorghum.

Table 3. Details of manures and nutrients applied

Sl. No.	Fodder crops	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
1	Fodder cowpea	12.5	25	40	20
2	Rice bean	12.5	20	40	0
3	Fodder maize	25.0	30	40	20
4	Fodder sorghum	12.5	45	40	40

Table 4. Seed rate and spacing of fodder crops

Sl. No.	Fodder crops	Seed rate (kg ha^{-1})	Spacing
1	Fodder cowpea	25	30 cm × 15 cm
2	Rice bean	27	30 cm × 10 cm
3	Fodder maize	40	30 cm× 15 cm
4	Fodder sorghum	05	30 cm × 15 cm

3.2.3.1.3 Sowing

All the fodder seeds were line sown. Sowing was done on 21th February 2018. The details of seed rate and spacing is given in Table 4.

3.2.3.1.4 Water Management

Need based irrigation was given to fodder crops.

3.2.3.1.5 Gap Filling and Thinning

Germination was uniform but gap filling was required in few plots which was done at 10 DAS. The crop stand was thinned at 15 DAS to maintain optimum population.

3.2.3.1.6 Weeding

Two weedings were done at 20 DAS and 40 DAS in all plots uniformly by leaving an area of 2 m^2 per plot for taking weed observations.

3.2.3.1.7 Harvesting

Fodder cowpea was harvested at 55 DAS (17th April 2018), fodder maize at milky stage of the cob, fodder sorghum at 60 DAS (22nd April 2018) and rice bean at 80 DAS (11th May 2018). All the crops were cut at base and bundled, weighed and values were recorded.

3.2.3.2 Virippu Rice Crop (2018-19)

3.2.3.2.1 Land Preparation and Sowing

Wet nursery method was adopted. Nursery area was ploughed, levelled and beds of 10 m length, 1 m width and 15 cm height were prepared with drainage channels between the beds. FYM was incorporated at the rate of 1 kg m^{-2}. Pre-germinated seeds were sown on the nursery beds @ 60 kg ha^{-1}. After the harvest of summer crops, the plots were puddled separately without disturbing the bunds, during first week of June, 2018. The soil was levelled during the second week of June 2018. The dimensions of the plots were same as that of summer crops. The sprouted seeds were sown in the nursery on 11th June 2018. Twenty day old

Plate 1. General view of experimental field during summer fodder crop

seedlings were uprooted from the nursery and transplanted on 30th June 2018 at two to three seedling per hill and maintaining a spacing of 20 cm×15 cm.

3.2.3.2.2 Application of Manures and Fertilizers

Well decomposed FYM @ 5 t ha^{-1} was applied uniformly to all the plots at the time of land preparation and mixed with soil. Fertilizers were applied @ 90:45:45 kg NPK ha^{-1}. Half dose of N, entire P and half K was applied basally. The remaining N and K were applied at panicle initiation stage. The sources of fertilizers were Urea, Rajphos and Muriate of Potash for N, P and K respectively.

3.2.3.2.4 Water Management

The water level was maintained at about 1.5 cm during transplanting. Thereafter, it was increased gradually to about 5 cm and maintained at that level throughout the growth period with occasional drainage. Water was drained 10 days before harvest.

3.2.3.2.5 Weeding

Hand weeding was done at 20 and 40 DAT.

3.2.3.2.6 Harvesting

The crop was harvested on October 28th 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 OBSERVATION ON CROPS

3.3.1 Fodder Crops

Five observational plants were randomly selected from the net plot area of each plot and tagged as observational plants. Growth attributes were recorded at monthly interval from the observational plants.

3.3.1.1 Growth Attributes

3.3.1.1.1 Plant Height

The height of the observational plants at monthly interval was taken from the ground level to the tip of the growing bud and mean expressed in cm.

3.3.1.1.2Number of Branches per Plant

At monthly interval, number of primary and secondary branches arising from the stems were counted for fodder cowpea and rice bean. Total number of tillers were counted in the case of fodder sorghum.

3.3.1.2 Yield Attributes and Yield

3.3.1.2.1 Leaf Stem Ratio at Harvest

The leaves and the main stem were separated from the observational plants which were uprooted without damaging. They were shade dried followed by oven drying at 60° ± 5° C till the attainment of constant weight. The dry weight of leaves and stem of each plant was estimated and the ratio of leaves to stem was calculated.

3.3.1.2.2 Green Fodder Yield

The plants in the net plot were cut at the base and made into bundles, in each plot. The weights of green fodder was recorded and expressed as kg ha^{-1}.

3.3.1.2.3 Dry Fodder Yield

The observational plants were cut at the base, separately packed and labelled. These were first shade dried and then oven dried at 60° ± 5° C till the attainment of constant weight. The weight of these dry samples were taken and total dry fodder yield from each treatment was calculated and expressed as kg ha^{-1}.

3.3.1.3 Physiological Parameters (at 20 and 40 DAS)

At 20 and 40 DAS, destructive sampling was done to record the physiological parameters.

3.3.1.3.1 Leaf Area Index

At 20 and 40 DAS, the leaf area was measured from the observational plants of each plot. The length and width of the fully opened and physiologically active leaves were measured in five plants per plot. Total leaf area per plant was worked out by multiplying average leaf area by number of leaves.

Leaf area was calculated by using the formula:

$LA = L \times W \times K$ (Watson, 1947)

Where,

LA : Leaf area per plant (cm^2)

L : Length of leaf (cm)

W : Width of leaf (cm)

K : Factor (0.66)

Leaf area index was calculated using the following formula.

$$LAI = \frac{\text{Total functional leaf area per plant } (cm^2)}{\text{Land area occupied per plant } (cm^2)}$$

3.3.1.3.2 Crop Growth Rate

The dry weight of sample plants from each plot at 20 and 40 DAS and the area occupied were calculated by the formula given below and expressed in g m^{-2} per day where, W_2 and W_1 are plant dry weights at time T_1 and T_2, respectively and A is the land area.

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{A}$$ (Watson, 1947)

3.3.1.3.3 Net Assimilation Rate

The total leaf area and dry weight of the plants were calculated at 20 and 40 DAS from each plot. The NAR was calculated using the formula given below and expressed in g cm^{-2} per day.

$$NAR = \frac{W_2 - W_1}{(L_2 - L_1)} \times \frac{(\log_e L_2 - \log_e L_1)}{(T_2 - T_1)}$$ (Gregory, 1926)

Where, L_1 and W_1 are leaf area and dry weight of the plants at time, T_1 ; L_2 and W_2 are leaf area and dry weight of the plants at time, T_2.

3.3.1.3.4 SPAD Chlorophyll Meter Reading

SPAD stands for Soil Plant Analysis Development. "Chlorophyll meter SPAD 502 plus" manufactured by Spectrum Technologies, USA (Model 2900P) was used for recording the readings. The model was 2900P. SPAD Chlorophyll meter reading indicates the greenness of the leaves. Readings were taken at 20 and 40 DAS from three different areas of three leaves from observational plants and the average worked out.

3.3.1.4 Quality Parameters (at harvest)

3.3.1.4.1 Crude Protein

Plant crude protein content at harvest was calculated by multiplying the N content with the Simpson factor 6.25 (Simpson *et al*., 1965) and expressed in percentage.

3.3.1.4.2 Crude Fibre

Plant crude fibre at harvest was analyzed using AOAC method and expressed in percentage (A.O. A. C, 1975).

3.3.2 SUCCEEDING *VIRIPPU* RICE

Two rows of plants were left as border on all the sides and observations on parameters associated with growth and yield of rice were taken from the net plot area.Ten hills were randomly selected from the net plot area and plants were tagged for recording observations. The following observations were recorded from these sample plants and mean values were worked out.

3.3.2.1 Growth and Growth Attributes

3.3.2.1.1 Plant Height

The plant height was recorded at 20 DAT, 40 DAT and at harvest, following the method described by Gomez (1972). The plant height was measured from the ground level to tip of the longest leaf or tip of the longest ear head and mean is expressed in cm.

3.3.2.1.2 Number of Tillers m^{-2}

The tiller number per hill was recorded at 20 and 40 DAT and harvest from the observational plants, mean was worked out and expressed as numbers per hill.

Plate 2. Transplanting of *viruppu* rice crop

3.3.2.2 Yield Attributes and Yield

3.3.2.2.1 Productive Tillers m⁻²

At the time of harvest, number of productive tillers was recorded from tagged plants in the net plot and expressed as number of productive tillers m^{-2}.

3.3.2.2.2 Thousand Grain Weight

Thousand numbers of clean, dry, fully filled grains were counted from the produce of each plot and the weight noted in grams.

3.3.2.2.3 Grain Yield

Each net plot was harvested individually, threshed, dried, winnowed and air dry weight of grains recorded and expressed as kg ha^{-1}.

3.3.2.2.4 Straw Yield

The straw was harvested from each net plot, dried under sun to a constant weight and expressed as kg ha^{-1}.

3.3.2.2.5 Harvest Index

The harvest index was worked out using the formula suggested by Donald and Hamblin (1976).

$$\text{Harvest index (HI)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

3.4 OBSERVATION ON WEEDS

3.4.1 Weed Composition

A quadrant of size 50 × 50 cm was placed at random at two sites in each net plot. The weed flora from the experimental site were identified and grouped into grasses, sedges and broad leaved weeds.

Plate 3. General view of *virippu* rice crop

3.4.2 Dry Matter Production

Weeds in the quadrant area were pulled out along with roots, washed and dried under shade and oven dried at 60 ± 5° C to constant weight. The dry weight of the weeds were recorded and expressed as g m^{-2}.

3.4.3 Weed Smothering Efficiency

Weed smothering efficiency (WSE) was computed using the given formula and was expressed in percentage.

$$WSE = \frac{WC-WT}{WC} \times 100$$

Mani and Gautham (1973)

where,

WC – Dry weight of weeds in control (fallow) plot

WT – Dry weight of weeds in treated plots

3.4.4 Absolute Density (number m^{-2})

Absolute density = Total number of weeds of a given species m^{-2}.

(Philips, 1959)

3.5 CHEMICAL ANALYSIS

3.5.1 Plant Analysis

The weed samples at 20 and 40 DAS and observational plants of summer (fodder crops) and *virippu* (succeeding rice) crops at the time of harvest were collected and analyzed for N, P and K content. The samples were dried under shade and to a constant weight in hot air oven at 60 ± 5^0 C and then powdered. Nutrient uptake was calculated by the formula:

Nutrient uptake = Nutrient content (%) × Dry matter (kg ha^{-1})

Table 5. Methods of plant nutrient analysis

Parameter	Method used	Reference
N (%)	Modified micro kjeldahl method	Jackson, 1973
P (%)	Vanado-molybdo phosphoric yellow colour method using spectrophotometer	Jackson, 1973
K (%)	Flame photometry method	Jackson, 1973

3.5.2 Soil Analysis

Soil samples were collected separately from each plot before and after the *virippu* rice crop and analyzed for available N, P and K and organic carbon status. The samples were analyzed following the methods specified in Table 2.

3.5.2.1 Nitrogen Balance Sheet

The N balance sheet of the soil was obtained by subtracting the computed balance of N from actual balance. The computed balance was worked out by subtracting the total N removed by the crops and weeds from that added by farmyard manure, fertilizer and available N in the soil. The actual balance of N was indicated by the available N status of the soil. A positive balance indicate soil storage and negative balance depletion (Palaniappan, 1985).

3.6 ECONOMIC ANALYSIS

To determine the economics of cultivation, gross income, net income and benefit cost ratio were calculated based on the cost of cultivation and prevailing price of crop produce.

3.6.1 Gross Income (₹ ha^{-1})

Gross income was computed by multiplying the marketable yield of each crop with their market price and expressed as ₹ ha^{-1}.

3.6.2 Net Income (₹ ha^{-1})

Net income was calculated using the formula,

Net income (₹ ha^{-1}) = Gross income (₹ ha^{-1}) - Total cost of cultivation (₹ ha^{-1}).

3.6.3 Benefit Cost Ratio

B: C ratio was calculated using the formula

$$\text{B: C ratio} = \frac{\text{Gross income (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.7 STATISTICAL ANALYSIS

The experimental data were analyzed statistically by using Analysis of Variance technique for RBD (Cochran and Cox, 1965) and the significance was tested using F test. The data which required transformation were appropriately transformed and analyzed. Wherever the F values were found significant, critical difference was calculated at five per cent probability level.

RESULTS

4. RESULTS

The present investigation entitled "Productivity enhancement of rice based cropping system with fodder crops" was conducted with the objectives of evaluating the suitability of different fodder crops in summer fallow of double cropped lowland rice fields under varying N regimes and to assess its residual effect on the succeeding *viruppu* rice crop. The data generated from the study were statistically analyzed and the results are presented in this chapter.

4.1 SUMMER FODDER CROP

4.1.1 Growth Attributes

4.1.1.1 Plant Height

The data on plant height of fodder crops are presented in Table 6. At 30 DAS, fodder maize plants at all levels of N (T_7 to T_9) were significantly taller than other fodder crops. At 60 DAS, fodder sorghum plants at all levels of N (T_{10} to T_{12}) were significantly taller and was on par.

4.1.1.2 Number of Branches per Plant

At 30 DAS (Table 6), branching was significantly more for fodder cowpea with 100, 75 and 50 per cent N (T_1 to T_3). At 60 DAS, significantly greater number of tillers was in fodder sorghum with 100 or 75 per cent N (T_{10} and T_{11}) which were on par.

4.1.2 Physiological Parameters

4.1.2.1 Leaf Area Index

The LAI at 20 DAS was significantly high and on par in all the treatments of fodder maize (T_7 to T_9) which was comparable with fodder cowpea (T_1, T_2 and T_3). At 40 DAS, LAI was not significantly influenced by the treatments (Table 7).

Table 6. Effect of treatments on plant height and number of branches at monthly interval

Treatments	Plant height		Number of branches	
	30 DAS	60 DAS	30 DAS	60 DAS
T_1 : Fodder cowpea with 100 % N	44.68	*	7.40	*
T_2 : Fodder cowpea with 75 % N	36.38	*	6.96	*
T_3 : Fodder cowpea with 50 % N	39.06	*	6.82	*
T_4 : Rice bean with 100 % N	22.54	33.37	4.15	6.42
T_5 : Rice bean with 75 % N	26.74	32.20	2.63	5.92
T_6 : Rice bean with 50 % N	22.17	31.57	3.88	5.43
T_7 : Fodder maize with 100 % N	76.60	139.37	**	**
T_8 : Fodder maize with 75 % N	66.00	136.40	**	**
T_9 : Fodder maize with 50 % N	70.71	135.09	**	**
T_{10} : Fodder sorghum with 100 % N	51.29	174.80	4.60	7.37
T_{11} : Fodder sorghum with 75 % N	52.49	180.27	5.27	7.40
T_{12} : Fodder sorghum with 50 % N	50.63	160.00	3.80	5.03
T_{13} : Fallow during summer	-	-	-	-
SEm (±)	6.99	7.71	0.58	0.30
CD (0.05)	20.391	22.490	1.685	0.869

*- Fodder cowpea harvested

**- No branching in fodder maize

Table 7. Effect of treatments on physiological parameters of fodder crops at 20 and 40 DAS

Treatments	LAI		CGR ($g\ m^{-2}\ day^{-1}$)		Net assimilation rate (NAR)* $g\ cm^{-2}$ per day		SCMR	
	20 DAS	40 DAS	1 to 20 DAS	20 to 40 DAS	1 to 20 DAS	20 to 40 DAS	20 DAS	40 DAS
T_1 : FC with 100 % N	1.52	2.79	0.78	21.08	1.18×10^{-4} (0.0104)	3.89×10^{-4} (0.0190)	49.13	49.27
T_2 : FC with 75 % N	0.82	1.75	0.73	13.82	1.42×10^{-4} (0.0115)	3.85×10^{-4} (0.0196)	43.07	48.47
T_3 : FC with 50 % N	0.96	1.58	0.84	10.45	1.96×10^{-4} (0.0140)	4.09×10^{-4} (0.0202)	51.90	47.50
T_4 : RB with 100 % N	0.63	0.70	0.39	2.42	1.35×10^{-4} (0.0112)	1.40×10^{-4} (0.0118)	23.53	29.10
T_5 : RB with 75 % N	0.68	1.82	0.33	1.49	1.99×10^{-4} (0.0140)	1.13×10^{-4} (0.0106)	26.53	25.60
T_6 : RB with 50 % N	0.63	0.53	0.33	1.56	2.60×10^{-4} (0.0160)	1.92×10^{-4} (0.0139)	20.53	27.40
T_7 : FM with 100 % N	2.39	1.70	1.36	16.54	1.21×10^{-4} (0.0109)	2.05×10^{-4} (0.0143)	30.60	37.97
T_8 : FM with 75 % N	2.36	1.53	1.28	17.03	1.19×10^{-4} (0.0107)	3.55×10^{-4} (0.0189)	31.03	32.57
T_9 : FM with 50 % N	2.91	1.53	1.47	14.77	1.20×10^{-4} (0.0109)	2.50×10^{-4} (0.0158)	34.80	32.73
T_{10} : FS with 100 % N	0.41	1.39	0.26	17.25	4.06×10^{-4} (0.0190)	2.76×10^{-4} (0.0526)	26.98	32.20
T_{11} : FS with 75 % N	0.36	3.32	0.22	16.13	2.74×10^{-4} (0.0164)	1.25×10^{-3} (0.0354)	28.92	31.37
T_{12} : FS with 50 % N	0.28	2.37	0.14	12.73	2.99×10^{-4} (0.0167)	1.69×10^{-3} (0.0421)	26.55	28.34
T_{13}: Fallow during summer	-	-	-	-	-	-	-	-
SEm (±)	0.77	0.85	0.23	2.15	7.884×10^{-5} (0.00178)	6.461×10^{-4} (0.00554)	5.07	4.96
CD (0.05)	1.603	NS	0.478	4.464	1.635×10^{-4} (0.005)	1.339×10^{-3} (0.016)	10.510	10.292

*The values in the brackets are square root transformed ones

4.1.2.2 Crop Growth Rate

From 1 to 20 DAS, among the different fodder crops, significantly higher CGR was observed in fodder maize at all N levels (Table 7).

From 20 to 40 DAS, CGR was significantly higher in T_1 in fodder cowpea which was comparable with T_8 in fodder maize and T_{10} in fodder sorghum.

4.1.2.3 Net Assimilation Rate

The NAR from 1 to 20 DAS was significantly higher in fodder sorghum with 100, 75 and 50 per cent N (T_{10} to T_{12})which were on par and also comparable with rice bean (T_6).

However, the highest NAR from 20 to 40 DAS was significantly higher in fodder sorghum with 100 or 50 per cent N (T_{10} and T_{12}).

4.1.2.4 SPAD Chlorophyll Meter Reading

The data on SCMR are presented in Table 7. At 20 and 40 DAS, significantly higher SCMR was recorded in fodder cowpea at all N levels and which were on par (T_1 to T_3).

4.1.3 Yield Attributes and Yield

4.1.3.1 Leaf Stem Ratio

Among the fodder crops, significantly higher leaf: stem ratio was recorded in fodder cowpea at all levels of N (T_1 -0.90, T_2 -0.84, T_3 -0.75) which were on par with T_4 (0.68) in rice bean (Table 8).

4.1.3.2 Green Fodder Yield

Among the fodder crops, the green fodder yield was significantly more in fodder maize (T_9 -31000 kg ha^{-1}, T_7-29333 kg ha^{-1}, T_8 -28933 kg ha^{-1}), T_9 recorded the higher value which was on par with T_7 and T_8.

Table 8. Effect of treatments on leaf stem ratio, green fodder yield and dry fodder yield

Treatment	Leaf: stem ratio	Green fodder yield (kg ha^{-1})	Dry fodder yield (kg ha^{-1})
T_1 : Fodder cowpea with 100 % N	0.90	18417	2696
T_2 : Fodder cowpea with 75 % N	0.84	17234	2523
T_3 : Fodder cowpea with 50 % N	0.79	13864	2030
T_4 : Rice bean with 100 % N	0.68	13248	2384
T_5 : Rice bean with 75 % N	0.66	12144	2186
T_6 : Rice bean with 50 % N	0.56	12055	2170
T_7 : Fodder maize with 100 % N	0.24	29333	5177
T_8 : Fodder maize with 75 % N	0.23	28933	5107
T_9 : Fodder maize with 50 % N	0.32	31000	5471
T_{10} : Fodder sorghum with 100 % N	0.23	17383	4502
T_{11} : Fodder sorghum with 75 % N	0.22	16190	4193
T_{12} : Fodder sorghum with 50 % N	0.19	14383	3725
T_{13} : Fallow during summer	-	-	-
SEm (±)	0.043	1540.18	271.62
CD(0.05)	0.125	4495.008	792.715

Table 9. Effect of treatment on crude protein and crude fibre content, per cent

Treatment	Crude protein (%)	Crude fibre (%)
T_1 : Fodder cowpea with 100 % N	20.58	24.60
T_2 : Fodder cowpea with 75 % N	19.15	28.30
T_3 : Fodder cowpea with 50 % N	18.62	27.10
T_4 : Rice bean with 100 % N	19.11	23.67
T_5 : Rice bean with 75 % N	17.41	26.00
T_6 : Rice bean with 50 % N	16.84	28.00
T_7 : Fodder maize with 100 % N	9.69	33.98
T_8 : Fodder maize with 75 % N	9.38	36.70
T_9 : Fodder maize with 50 % N	8.09	38.00
T_{10} : Fodder sorghum with 100 % N	8.69	28.33
T_{11} : Fodder sorghum with 75 % N	8.37	30.33
T_{12} : Fodder sorghum with 50 % N	7.70	34.00
T_{13} : Fallow during summer	-	-
SEm (±)	0.58	0.60
CD(0.05)	1.701	1.758

Table 10. Major weed composition observed in experimental field of fodder crops

Common name	Scientific name	Family
Grasses		
Rice (Nellu)	*Oryza sativa*	Poaceae
Blood grass (Naringa)	*Isachne miliacea*	Poaceae
Barnyard grass (Kavada pullu)	*Echinocloa crusgalli*	Poaceae
Sedges		
Umbrella sedge (Thalekkettan)	*Cyperus difformis*	Cyperaceae
Yellow nut sedge (Manjakkora)	*Cyperus iria*	Cyperaceae
Globe finger rush (Mung)	*Fimbristylis miliacea*	Cyperaceae
Oval Leaf Pondweed (Karinkuvvalam)	*Monochoria vaginalis*	Pontederiaceae
Broad leaved weeds		
Penny wort (Kodangal)	*Centella asiatica*	Apiaceae
False daisy (Kaiyunni)	*Eclipta postrata*	Asteraceae
Small flowered Lindernia	*Lindernia parviflora*	Linderniaceae
Perennial water primrose (Neerkarayambu)	*Ludwigia perennis*	Onagraceae
Indian madder (Nonganam pullu)	*Oldenlandia umbellata*	Rubiaceae
Stone breaker (Keezharnelli)	*Phyllanthus niruri*	Euphorbiacea
Sweet broom weed (Kallurukki)	*Scoparia dulcis*	Plantaginaceae
Wedgewort (Pongati)	*Sphenoclea zeylanica*	Sphenocleaceae

4.1.3.3 Dry Fodder Yield

Significantly higher dry fodder yield was produced by fodder maize with all N levels (T_9 -5471 kg ha^{-1}, T_7 -5177 kg ha^{-1}, T_8 -5107 kg ha^{-1}), which were on par.

4.1.4 Quality Parameters

4.1.4.1 Crude Protein

Among the fodder crops, T_1 in fodder cowpea had significantly higher crude protein, which was on par with T_2 in fodder cowpea and T_4 in rice bean (Table 9).

4.1.4.2 Crude Fibre

Crude fibre content was significantly lower in T_4 in rice bean which was on par with T_1 in fodder cowpea (Table 9).

4.1.5 Observations on Weeds

4.1.5.1 Weed Composition

The different weed species found in the experimental field during the study were collected, identified and classified into grasses, sedges and broad leaved weeds (Table 10).

Among grasses, rice (*Oryza sativa),* blood grass (*Isachne miliacea),* barnyard grass (*Echinocloa crusgalli)* were the major weed species observed.

Among sedges, umbrella sedge (*Cyperus difformis),* yellow nut sedge (*Cyperus iria),* globe finger rush (*Fimbristylis miliacea),* oval leaf pondweed (*Monochoria vaginalis)* were the major weed species observed.

Among broad leaved weeds, penny wort (*Centella asiatica),* false daisy (*Eclipta postrata),* small flowered lindernia (*Lindernia parviflora),* perennial

Table 11. Effect of treatments on absolute density of weeds at 20 DAS, number m^{-2}

Treatments	Grasses	Broad leaved weeds	Sedges	Total
T_1 : Fodder cowpea with 100 % N	40.33	29.00	24.00	93.33
T_2 : Fodder cowpea with 75 % N	17.67	26.67	32.33	76.67
T_3 : Fodder cowpea with 50 % N	20.67	24.00	45.00	89.67
T_4 : Rice bean with 100 % N	17.33	17.33	24.33	59.00
T_5 : Rice bean with 75 % N	66.33	12.00	10.67	89.00
T_6 : Rice bean with 50 % N	16.00	22.00	23.67	61.67
T_7 : Fodder maize with 100 % N	10.67	16.67	23.67	51.00
T_8 : Fodder maize with 75 % N	18.00	18.33	44.00	80.33
T_9 : Fodder maize with 50 % N	18.33	35.67	21.67	75.67
T_{10} : Fodder sorghum with 100 % N	12.33	13.33	27.00	52.67
T_{11} : Fodder sorghum with 75 % N	26.00	17.00	27.67	70.67
T_{12} : Fodder sorghum with 50 % N	20.33	19.00	40.33	79.67
T_{13} : Fallow during summer	18.67	73.33	20.33	112.33
SEm (±)	4.58	4.46	5.12	7.30
CD(0.05)	13.444	13.068	15.014	21.421
Treatment vs control	NS	S	NS	S

Table 12. Effect of treatments on absolute density of weeds at 40 DAS, number m^{-2}

Treatments	Grasses	Broad Leaved weeds	Sedges	Total
T_1 : Fodder cowpea with 100 % N	48.00	12.33	29.67	90.00
T_2 : Fodder cowpea with 75 % N	51.33	15.33	37.33	104.00
T_3 : Fodder cowpea with 50 % N	50.00	17.33	33.00	100.33
T_4 : Rice bean with 100 % N	44.67	13.00	24.67	82.33
T_5 : Rice bean with 75 % N	70.67	34.00	27.00	131.67
T_6 : Rice bean with 50 % N	45.67	24.00	24.67	94.33
T_7 : Fodder maize with 100 % N	61.33	30.67	31.33	123.33
T_8 : Fodder maize with 75 % N	62.00	20.33	51.33	133.67
T_9 : Fodder maize with 50 % N	50.67	31.67	44.33	126.67
T_{10} : Fodder sorghum with 100 % N	52.00	22.00	26.67	100.67
T_{11} : Fodder sorghum with 75 % N	46.33	35.33	50.67	132.33
T_{12} : Fodder sorghum with 50 % N	42.67	10.00	18.33	71.00
T_{13} : Fallow during summer	59.33	23.33	38.00	120.67
SEm (±)	5.06	3.18	4.31	7.10
CD(0.05)	14.848	9.328	12.631	20.814
Treatment vs control	NS	NS	NS	NS

water primrose (*Ludwigia perennis),* Indian madder (*Oldenlandia umbellata),* stone breaker (*Phyllanthus niruri),* sweet broom weed (*Scoparia dulcis),* wedgewort (*Sphenoclea zeylanica)* were the major weed species observed.

4.1.5.2 Absolute Density of Weeds

4.1.5.2.1 Absolute Density of Weeds at 20 DAS

At 20 DAS, in general, among the weeds present, sedges dominated in majority of the treatments (Table 11).

The absolute density of grasses was significantly less in T_7 in fodder maize which was on par with other treatments of fodder maize, T_2 and T_3 (fodder cowpea), T_4 and T_6 (rice bean), T_{10} and T_{12} (fodder sorghum) and T_{13} (fallow treatment). There was no significant difference between treatments and control.

The absolute density of sedges was significantly low in T_5 (rice bean) which was on par with other treatments of rice bean, T_1 (fodder cowpea), T_7 and T_9 (fodder maize) and T_{13} (fallow treatment). The absolute density of sedges did not differ significantly between treatment and control.

The absolute density of broad leaved weeds was significantly low in T_5 (rice bean) which was on par with other treatments of rice bean, T_3 (fodder cowpea), T_7 and T_8 (fodder maize) and all the treatments of fodder sorghum. There was significant difference between treatments and control with respect to absolute density of broad leaved weeds.

The total absolute density was significantly less in T_7 in fodder maize which was on par with T_4 and T_6 (rice bean), T_{10} and T_{11} (fodder sorghum). The total absolute density differed significantly between treatments and the control at 20 DAS.

Table 13. Effect of treatment on dry matter production of weeds and weed smothering efficiency

Treatment	Dry matter production (g m^{-2})		Weed smothering efficiency (%)	
	20DAS	40 DAS	20 DAS	40DAS
T_1 : Fodder cowpea with 100 % N	21.91	47.41	54.46	64.55
T_2 : Fodder cowpea with 75 % N	14.45	69.83	59.21	47.94
T_3 : Fodder cowpea with 50 % N	22.27	95.24	48.72	29.03
T_4 : Rice bean with 100 % N	17.40	113.39	54.86	17.20
T_5 : Rice bean with 75 % N	20.41	113.14	33.23	16.98
T_6 : Rice bean with 50 % N	19.71	105.77	69.94	22.67
T_7 : Fodder maize with 100 % N	14.28	106.23	65.64	22.28
T_8 : Fodder maize with 75 % N	17.01	89.31	55.00	34.10
T_9 : Fodder maize with 50 % N	19.09	75.58	57.76	44.94
T_{10} : Fodder sorghum with 100 % N	18.61	110.54	64.35	18.95
T_{11} : Fodder sorghum with 75 % N	19.29	101.38	61.75	25.29
T_{12} : Fodder sorghum with 50 % N	17.16	106.70	57.36	22.13
T_{13} : Fallow during summer	43.57	136.55	-	-
SEm (±)	3.32	8.46	5.39	5.90
CD(0.05)	9.746	24.800	15.720	17.231
Treatment vs control	S	S		

Table 14. Effect of treatment on N, P and K uptake by crops at harvest, kg ha^{-1}

Treatment	N	P	K
T_1 : Fodder cowpea with 100 % N	41.32	12.67	56.02
T_2 : Fodder cowpea with 75 % N	36.26	9.70	52.33
T_3 : Fodder cowpea with 50 % N	31.06	8.50	44.73
T_4 : Rice bean with 100 % N	34.85	7.69	34.36
T_5 : Rice bean with 75 % N	30.74	7.43	32.64
T_6 : Rice bean with 50 % N	30.67	6.54	28.07
T_7 : Fodder maize with 100 % N	70.89	16.53	56.32
T_8 : Fodder maize with 75 % N	69.58	16.06	50.23
T_9 : Fodder maize with 50 % N	75.23	17.30	60.58
T_{10} : Fodder sorghum with 100 % N	62.52	10.23	54.42
T_{11} : Fodder sorghum with 75 % N	57.36	8.73	47.87
T_{12} : Fodder sorghum with 50 % N	51.38	7.60	56.02
T_{13} : Fallow during summer	-	-	-
SEm (±)	4.13	0.83	4.47
CD(0.05)	12..066	2.428	13.049

4.1.5.2.2 Absolute Density of Weeds at 40 DAS

At 40 DAS, in general, among the weeds present, grasses dominated, followed by sedges and broad leaved weeds (Table 12).

The absolute density of grasses was significantly less in T_{12} in fodder sorghum, which was comparable with other treatments of fodder sorghum, all treatments of fodder cowpea, T_4 and T_6 (rice bean), T_9 in fodder maize. The absolute density of grasses did not differ significantly between treatments and control.

The population of sedges was significantly less in T_{12} in fodder sorghum, which was comparable with T_1 in fodder cowpea, all treatments of rice bean and T_{10} in fodder sorghum. There was no significant difference between treatments and control in the case of the population of sedges.

The absolute density of broad leaved weeds was significantly less in T_{12} in fodder sorghum, which was on par with all the treatments of fodder cowpea and T_4 in rice bean. The absolute density of broad leaved weeds did not differ significantly between treatments and control.

The total absolute density of weeds was significantly less in T_{12} in fodder sorghum, which was on par with T_4 in rice bean. The treatments and control did not differ significantly in the case of total absolute density.

4.1.5.3 Dry Matter Production

At 20 DAS, the dry matter of weeds was significantly less (Table 13) in T_7 (fodder maize with 100 % N), which was on par with all other treatments except fallow treatment (T_{13}). But, at 40 DAS, the dry matter production of weeds was significantly less in T_1 which was on par with T_2 (fodder cowpea with 100 and 75% N respectively). The weed dry matter production differed significantly between the control treatments both at 20 and 40 DAS.

Table 15. Effect of treatments on N, P and K removal by weeds at 20 and 40 DAS, kg ha^{-1}

Treatments	N removal		P removal		K removal	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1	28.86	26.07	12.52	4.05	30.61	21.90
T_2	16.48	33.33	9.06	6.12	17.65	35.16
T_3	18.15	37.50	8.45	5.40	20.40	40.71
T_4	23.21	75.24	8.87	8.64	23.77	50.68
T_5	25.77	58.02	8.68	8.73	27.97	57.54
T_6	17.00	56.40	8.42	7.70	19.63	42.28
T_7	23.85	76.74	5.64	6.31	23.27	56.86
T_8	21.64	54.17	9.55	8.20	18.15	48.54
T_9	30.87	63.51	11.92	8.34	26.37	48.05
T_{10}	24.88	71.33	11.67	10.60	21.69	64.91
T_{11}	25.45	58.84	10.91	10.36	19.91	47.20
T_{12}	18.52	64.92	9.01	10.35	15.48	48.04
T_{13}	56.98	106.48	18.90	11.63	35.43	55.36
SEm (±)	3.76	5.07	1.96	1.03	2.22	4.64
CD(0.05)	11.015	14.868	5.756	3.011	6.527	13.610
Treatment vs control	S	S	S	S	S	NS

4.1.5.4 Weed Smothering Efficiency

The data on weed smothering efficiency is furnished in Table 13. At 20 DAS, the weed smothering efficiency was significantly higher in T_6 in rice bean which was on par with all other treatments, except in T_3 (fodder cowpea) and T_5 (rice bean). However, at 40 DAS, the weed smothering efficiency was significantly higher in T_1 which was on par with T_2 (fodder cowpea with 100 and 75% N respectively).

4.1.6 Chemical Analysis

4.1.6.1 Nutrient (N, P, K) Uptake by Fodder Crops

The data on nutrient uptake by crops is presented in Table 14. The N uptake by fodder crops was significantly higher in fodder maize treatments (T_7 to T_9) which was on par with T_{10} in fodder sorghum.

The P uptake by fodder crops was significantly higher in fodder maize (T_7 to T_9).

The K uptake by fodder crops was significantly more in fodder maize (T_7 to T_9) which was on par with fodder sorghum (T_{10} to T_{12}) and fodder cowpea (T_1 and T_2).

4.1.6.2 Nutrient (N, P, K) Removal by Weeds

The data on nutrient removal by weeds are furnished in Table 15. At 20 DAS, the N removal by weeds was significantly low in T_2 in fodder cowpea, which was on par with all other treatments except, T_1 (fodder cowpea), T_9 (fodder maize) and T_{13} (fallow). At 40 DAS, N removal by weeds was significantly less in fodder cowpea. The N removal by weeds significantly differed between treatments and control, both at 20 and 40 DAS.

The P removal by weeds, at 20 DAS, was significantly less in T_7 in fodder maize, which was comparable with T_8 in fodder maize, T_2 and T_3 in fodder

Table 16. Effect of treatments on organic carbon and available N, P and K status after the summer fodder crops

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1 : Fodder cowpea with 100 % N	1.42	243.06	10.88	105.70
T_2 : Fodder cowpea with 75 % N	1.55	218.94	08.12	106.43
T_3 : Fodder cowpea with 50 % N	1.57	201.60	10.82	110.32
T_4 : Rice bean with 100 % N	1.59	263.54	11.98	110.78
T_5 : Rice bean with 75 % N	1.50	263.42	10.60	115.91
T_6 : Rice bean with 50 % N	1.56	202.12	08.29	122.28
T_7 : Fodder maize with 100 % N	1.50	146.44	08.03	120.04
T_8 : Fodder maize with 75 % N	1.36	144.06	10.86	121.20
T_9 : Fodder maize with 50 % N	1.44	151.68	11.29	126.01
T_{10} : Fodder sorghum with 100 % N	1.61	212.07	08.68	119.04
T_{11} : Fodder sorghum with 75 % N	1.65	212.46	08.79	109.73
T_{12} : Fodder sorghum with 50 % N	1.68	202.06	10.08	121.84
T_{13} : Fallow during summer	1.64	183.33	08.63	113.55
SEm (±)	0.136	19.206	1.212	1.671
CD(0.05)	NS	56.324	3.553	4.901
Treatment vs control	NS	NS	NS	NS

cowpea, all the treatments of rice bean, T_{11} and T_{12} in fodder sorghum. However at 40 DAS, significantly less P removal by weeds was in T_1 in fodder cowpea, which was on par with other treatments of fodder cowpea and T_7 in fodder maize. There was significant difference between treatments and control in case of P removal by weeds both at 20 and 40 DAS.

At 20 DAS, the K removal by weeds was significantly less in T_{12} in fodder sorghum which was comparable with other treatments of fodder sorghum, T_2 and T_3 (fodder cowpea), T_6 (rice bean), T_8 (fodder maize). At 40 DAS, was significantly less K removal by weeds was in T_1 in fodder cowpea which was on par with T_2. The K removal by weeds differed significantly between treatments and control at 20 DAS but, not at 40 DAS.

4.1.6.3 Organic Carbon Content and Available Nutrient Status of Soil After the Summer Fodder Crops

The OC content and available N, P and K status of soil after the summer fodder crops significantly differed between treatments (Table 16).

There was no significant difference between the treatments in case of OC content of soil after summer crop.

Available N was significantly more in T_4 in rice bean, which was on par with T_5, fodder cowpea (T_1 and T_2), fodder sorghum (T_{10} and T_{11}) treatments.

Available P was significantly high in T_4 in rice bean, which was on par with T_5, fodder cowpea (T_1 and T_3), all the treatments of fodder maize and fodder sorghum.

Available K was significantly the maximum in T_9 in fodder maize, which was on par with T_8 in fodder maize, T_6 in rice bean and T_{12} in fodder sorghum.

The OC content and available N, P and K after the summer crop did not differ significantly between treatments and control.

Table 17. Balance sheet of N after summer crop, kg ha^{-1}

Treatments	Soil contribution	FYM	Fertilizer	Total input	Crop uptake	Weed removal	Computed balance	Actual balance	Net gain/loss
T_1	351.23	62.5	25.00	438.73	15.54	26.07	397.12	243.06	-154.06
T_2	351.23	62.5	18.75	432.48	12.96	33.33	386.19	218.94	-167.25
T_3	351.23	62.5	12.50	426.23	10.95	37.50	377.78	201.60	-176.18
T_4	351.23	62.5	20.00	433.73	13.99	75.24	344.5	263.54	-80.96
T_5	351.23	62.5	15.00	428.73	10.28	58.02	360.43	263.42	-97.01
T_6	351.23	62.5	10.00	423.73	9.91	56.40	357.42	202.12	-155.3
T_7	351.23	62.5	30.00	506.23	33.89	76.74	395.6	146.44	-249.16
T_8	351.23	62.5	22.50	498.73	20.52	54.17	424.04	144.06	-279.98
T_9	351.23	62.5	15.00	491.23	19.56	63.51	408.16	151.68	-256.48
T_{10}	351.23	62.5	45.00	458.73	23.85	71.33	363.55	212.07	-151.48
T_{11}	351.23	62.5	33.75	447.48	15.43	58.84	373.21	212.46	-160.75
T_{12}	351.23	62.5	22.50	436.23	16.21	64.92	355.1	202.06	-153.04
T_{13}	351.23	62.5	0.00	351.23	0.00	106.48	244.75	183.33	-61.42

Table 18. Effect of treatments on economics of cultivation of fodder crops

Treatment	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
T_1 : Fodder cowpea with 100 % N	128917	76066	2.44
T_2 : Fodder cowpea with 75 % N	120642	67899	2.29
T_3 : Fodder cowpea with 50 % N	97050	44416	1.84
T_4 : Rice bean with 100 % N	79487	26989	1.51
T_5 : Rice bean with 75 % N	72867	20456	1.39
T_6 : Rice bean with 50 % N	72333	20009	1.38
T_7 : Fodder maize with 100 % N	146667	67729	1.86
T_8 : Fodder maize with 75 % N	144667	65860	1.84
T_9 : Fodder maize with 50 % N	155000	76323	1.97
T_{10} : Fodder sorghum with 100 % N	86917	33818	1.64
T_{11} : Fodder sorghum with 75 % N	75450	22547	1.43
T_{12} : Fodder sorghum with 50 % N	71917	19210	1.36
T_{13} : Fallow during summer	-	-	-
SEm (±)		9479.859	0.126
CD(0.05)		27666.93	0.367

Table 19. Effect of treatments on plant height of succeeding rice crop, cm

Treatments	20 DAT	40 DAT	At harvest
T_1 : Fodder cowpea with 100 % N	30.47	54.18	91.20
T_2 : Fodder cowpea with 75 % N	29.80	51.27	95.48
T_3 : Fodder cowpea with 50 % N	30.30	57.35	95.70
T_4 : Rice bean with 100 % N	31.83	56.08	96.97
T_5 : Rice bean with 75 % N	31.74	52.81	95.47
T_6 : Rice bean with 50 % N	32.32	52.37	96.63
T_7 : Fodder maize with 100 % N	28.53	55.49	98.68
T_8 : Fodder maize with 75 % N	31.90	54.18	98.13
T_9 : Fodder maize with 50 % N	32.97	54.01	95.57
T_{10} : Fodder sorghum with 100 % N	29.70	55.78	99.47
T_{11} : Fodder sorghum with 75 % N	33.38	55.80	97.90
T_{12} : Fodder sorghum with 50 % N	33.70	56.67	96.03
T_{13} : Fallow during summer	28.59	54.91	97.20
SEm (±)	0.892	2.055	1.060
CD (0.05)	2.617	6.027	3.110
Treatment vs control	S	NS	NS

4.1.6.4 Nitrogen Balance Sheet

The balance sheet of N after summer crop showed a negative balance of N in all the treatments (Table 17).

4.1.7 Economic Analysis of Fodder Crops Cultivation

The data on economics of the summer crops are presented in Table 18. The net income was significantly higher in (T_9 - ₹ 76323 ha^{-1}) fodder maize, which was comparable with other treatments of fodder maize (T_7- ₹ 67729 ha^{-1}), (T_8- ₹ 65860 ha^{-1}) and fodder cowpea (T_1 - ₹ 76066 $ha^{-1}$and T_2 - ₹ 67899 ha^{-1}).

In case of B: C ratio, significantly higher B: C ratio was obtained from T_1 (2.44) and T_2 (2.29) of fodder cowpea, which were on par.

4.2 SUCCEEDING RICE CROP DURING *VIRIPPU* (2018-19)

4.2.1 Growth Attributes

4.2.1.1 Plant Height

Significantly taller plants at 20 DAT was recorded in in rice crop which succeeded, T_{12} which was on par with T_{11}, all the treatments of rice bean, T_8 and T_9 in fodder maize (Table 19). The plant height differed significantly between treatments and control.

At 40 DAT, the plant height was significantly in rice crop which succeeded fodder cowpea with 50 per cent RDN, which was on par with all other treatments except fodder cowpea with 75 per cent RDN. The plant height did not differ significantly between treatments and control.

At harvest, significantly taller plants were observed in rice crop which succeeded T_{10} in fodder sorghum which was on par with T_{11}, T_4 and T_6 in rice bean, T_7 and T_8 in fodder maize, T_{13} in fallow treatment. But, there was no significant difference between the treatments and control.

Table 20. Effect of treatments on number of tillers m^{-2} of succeeding rice crop

Treatment	20 DAT	40 DAT	At harvest
T_1 : Fodder cowpea with 100 % N	100	585	377
T_2 : Fodder cowpea with 75 % N	107	496	329
T_3 : Fodder cowpea with 50 % N	139	551	308
T_4 : Rice bean with 100 % N	108	525	341
T_5 : Rice bean with 75 % N	128	524	304
T_6 : Rice bean with 50 % N	89	493	330
T_7 : Fodder maize with 100 % N	119	517	332
T_8 : Fodder maize with 75 % N	133	580	309
T_9 : Fodder maize with 50 % N	127	526	323
T_{10} : Fodder sorghum with 100 % N	119	503	337
T_{11} : Fodder sorghum with 75 % N	120	459	362
T_{12} : Fodder sorghum with 50 % N	97	528	337
T_{13} : Fallow during summer	111	495	283
SEm (±)	14.13	53.53	27.07
CD (0.05)	NS	NS	NS
Treatment vs control	NS	NS	NS

Table 21. Effect of treatments on yield attributes and yield of succeeding rice

Treatment	Productive tillers m^{-2}	Thousand grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 : Fodder cowpea with 100 % N	296	25.88	3750	4667	0.45
T_2 : Fodder cowpea with 75 % N	268	25.19	3250	3833	0.46
T_3 : Fodder cowpea with 50 % N	267	24.96	3417	4125	0.45
T_4 : Rice bean with 100 % N	240	25.21	3333	3625	0.48
T_5 : Rice bean with 75 % N	254	24.21	2967	3367	0.47
T_6 : Rice bean with 50 % N	251	24.46	3250	3750	0.47
T_7 : Fodder maize with 100 % N	284	24.93	3375	3875	0.47
T_8 : Fodder maize with 75 % N	263	24.76	3250	3792	0.46
T_9 : Fodder maize with 50 % N	267	24.21	3083	3792	0.45
T_{10} : Fodder sorghum with 100 % N	307	24.48	4000	4667	0.46
T_{11} : Fodder sorghum with 75 % N	311	24.13	3667	4042	0.47
T_{12} : Fodder sorghum with 50 % N	283	24.31	3250	3958	0.45
T_{13} : Fallow during summer	235	23.39	3167	3500	0.47
SEm (±)	19.99	0.52	257.01	284.87	0.02
CD (0.05)	NS	NS	NS	NS	NS
Treatment vs control	NS	NS	NS	NS	NS

4.2.1.2 Tillers m^{-2}

The tillers m^{-2} did not differ significantly between treatments at 20 and 40 DAT, and harvest (Table 20). Also, there was no significant difference between the treatments and control at 20 and 40 DAT and harvest.

4.2.2 Yield Attributes and Yield

4.2.2.1 Productive Tillers m^{-2}

The number of productive tillers m^{-2} did not differ significantly between treatments (Table 21). Also, the productive tillers m^{-2} did not differ significantly between treatments and control.

4.2.2.2 Thousand Grain Weight

The thousand grain weight was not significantly influenced by the treatments (Table 21). The thousand grain weight did not differ significantly between treatments and control.

4.2.2.3 Grain Yield, Straw Yield and Harvest Index

The data on yield and harvest index is furnished in Table 21. There was no significant difference between treatments in grain yield, straw yield and harvest index. The treatments and control also did not differ significantly in case of grain yield, straw yield and harvest index.

4.2.3.1 N, P and K Uptake by Rice at Harvest

The nutrient uptake by rice crop is given in Table 22. N uptake by rice crops was significantly higher which succeeded fodder sorghum treatments and on par with fodder cowpea (T_1 and T_3) and fodder maize (T_7). Also, there was significant difference between treatments and control.

Table 22. Effect of treatments on N, P and K removal by succeeding rice crop at harvest, kg ha^{-1}

Treatment	N removal	P removal	K removal
T_1 : Fodder cowpea with 100 % N	98.49	16.51	113.31
T_2 : Fodder cowpea with 75 % N	95.07	15.8	101.05
T_3 : Fodder cowpea with 50 % N	112.96	15.83	115.57
T_4 : Rice bean with 100 % N	83.50	18.43	91.27
T_5 : Rice bean with 75 % N	82.64	15.10	87.39
T_6 : Rice bean with 50 % N	85.04	15.49	92.66
T_7 : Fodder maize with 100 % N	102.72	16.21	108.16
T_8 : Fodder maize with 75 % N	81.34	15.90	93.77
T_9 : Fodder maize with 50 % N	89.96	15.95	94.52
T_{10} : Fodder sorghum with 100 % N	115.57	16.59	116.26
T_{11} : Fodder sorghum with 75 % N	109.02	15.83	115.94
T_{12} : Fodder sorghum with 50 % N	104.89	16.37	107.21
T_{13} : Fallow during summer	77.24	15.18	90.97
SEm (±)	6.185	0.552	6.474
CD (0.05)	18.138	1.618	18.986
Treatment vs control	S	NS	NS

Table 23. Effect of treatments on organic carbon and available N, P and K status of soil after rice crop

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	OC (%)
T_1 : Fodder cowpea with 100 % N	177.80	9.39	166.13	1.34
T_2 : Fodder cowpea with 75 % N	164.74	10.61	142.96	1.35
T_3 : Fodder cowpea with 50 % N	160.22	15.39	143.11	1.00
T_4 : Rice bean with 100 % N	173.84	10.25	147.58	1.29
T_5 : Rice bean with 75 % N	132.62	17.08	142.18	1.35
T_6 : Rice bean with 50 % N	143.01	6.10	134.14	1.47
T_7 : Fodder maize with 100 % N	147.32	6.56	121.57	1.21
T_8 : Fodder maize with 75 % N	172.43	10.20	118.36	1.26
T_9 : Fodder maize with 50 % N	167.25	12.32	125.81	1.54
T_{10} : Fodder sorghum with 100 % N	150.53	9.06	132.18	1.32
T_{11} : Fodder sorghum with 75 % N	167.59	14.69	137.61	1.95
T_{12} : Fodder sorghum with 50 % N	146.35	18.91	129.12	1.22
T_{13} : Fallow during summer	150.53	9.27	132.31	1.40
SEm (±)	17.01	7.87	20.63	0.29
CD (0.05)	NS	NS	NS	NS
Treatment vs control	NS	NS	NS	NS

Table 24. Effect of treatments on economics of cultivation of succeeding crop of rice

Treatment	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
T_1 : Fodder cowpea with 100 % N	135833	45833	1.51
T_2 : Fodder cowpea with 75 % N	116667	26667	1.30
T_3 : Fodder cowpea with 50 % N	123125	33125	1.37
T_4 : Rice bean with 100 % N	118125	28125	1.31
T_5 : Rice bean with 75 % N	105833	15833	1.18
T_6 : Rice bean with 50 % N	116250	26250	1.29
T_7 : Fodder maize with 100 % N	120625	30625	1.34
T_8 : Fodder maize with 75 % N	116458	26458	1.29
T_9 : Fodder maize with 50 % N	111458	21458	1.24
T_{10} : Fodder sorghum with 100 % N	143333	53333	1.59
T_{11} : Fodder sorghum with 75 % N	130208	40208	1.45
T_{12} : Fodder sorghum with 50 % N	117292	27292	1.30
T_{13} : Fallow during summer	112500	22500	1.25
SEm (±)		8637.35	0.09
CD (0.05)		NS	NS
Treatment vs control		NS	NS

In case of P uptake by rice, P uptake was significantly higher which succeeded T_4 (rice bean) than other treatments. But, P uptake did not differ significantly between treatments and control.

The K uptake by rice crop was significantly higher which succeeded fodder sorghum treatments which were on par with fodder cowpea and T_7 in fodder maize. There was no significant difference between treatments and control.

4.2.3.2 Organic Carbon Content and Available N, P and K Status of Soil After Rice Crop

The OC and available N, P and K status of soil after *virippu* rice crop did not differ significantly between treatments (Table 23). Also, there was no significant difference between the treatments and control in case of organic carbon and available N, P and K status of soil after *virippu* rice crop.

4.2.4 Economic Analysis of Rice Cultivation

The gross income, net income and B: C ratio did not differ significantly between treatments (Table 24). Also, the gross income, net income and B: C ratio did not differ significantly between treatments and control.

DISCUSSION

5. DISCUSSION

The study entitled "Productivity enhancement of rice based cropping system with fodder crops" was undertaken with the aim of evaluating the suitability of different fodder crops in summer fallow of double cropped lowland rice fields under varying N regimes and to assess its residual effect on the succeeding *viruppu* rice crop. The results obtained are discussed in this chapter.

5.1 SUMMER FODDER CROPS

5.1.1 Growth Attributes

The height of different fodder crops differed significantly at 30 and 60 DAS. Fodder maize and fodder sorghum were taller compared to other fodder crops. The difference noticed in height can be attributed to the difference in growth habit unique to each crop. At 60 DAS, fodder maize plants with 100 per cent RDN were significantly taller.

Branching habit between the fodder crops is different. Fodder cowpea and rice bean has a branching habit, while fodder sorghum produces tillers. Fodder maize does not branch. In fodder sorghum, greater number of tillers was observed with higher dose of N (75 and 100% RDN). The role of N resulting in better growth especially with increasing doses is proven as evident from the findings of Hassan *et al*. (2010) and Mahdi *et al.* (2011).

5.1.2 Physiological Parameters

Leaf area index differed significantly between fodder crops only at 20 DAS. By virtue of its robust growth habit, LAI was significantly higher in fodder maize, which was comparable with fodder cowpea at 100 per cent RDN. The possibility of an increased dose of N resulting in increased leaf production, and thereby a higher LAI was reported by Kumar and Elamathi (2007), Abayomi *et al*. (2008), Bhavya *et al*. (2014). This might be the reason for the higher LAI in fodder cowpea, supplied with 100 per cent RDN. Also, Chaudhary *et al.* (2018) suggested that, an increase in leaf area at higher N rate, may be a consequence of increase in the rate of leaf area expansion due to faster cell division and greater cell expansion, increased photosynthate formation thereby, leading to a greater leaf length and width.

Crop growth rate was significantly higher in fodder maize during the period from 1 to 20 DAS. However, from 20 to 40 DAS, fodder cowpea with 100 per cent RDN, fodder maize with 75 per cent RDN and fodder sorghum with 100 per cent RDN exhibited significantly higher and comparable CGR. The higher leaf production, as apparent from the higher LAI, might have attributed to the greater CGR in fodder maize and fodder cowpea. As in the case of LAI, the effect of higher N dose is reflected in CGR also.

Net assimilation rate was significantly higher in fodder sorghum during 1-20 DAS, irrespective of the N dose. However, during 20 to 40 DAS, NAR in fodder sorghum and fodder cowpea was significantly higher and on par irrespective of N dose. Fodder maize with 75 per cent RDN also had an on par NAR. Unlike in the case of CGR, the influence of varying dose of N did not reflect in NAR in fodder maize and fodder sorghum.

SPAD chlorophyll meter reading was significantly higher in fodder cowpea, irrespective of N dose, both at 20 and 40 DAS. However, at 40 DAS fodder maize grown with 100 per cent RDN had an equally high SCMR. SPAD chlorophyll meter reading is a measure of greenness of the leaves, which is to a great extent related to N content. The higher SCMR in fodder maize at 100 per cent RDN can be attributed to the higher N supplied. The effect of varying doses of RDN in fodder cowpea was probably negated owing to the fact that it is a leguminous crop.

5.1.3 Yield Attributes and Yield

Among the fodder crops significantly higher leaf: stem ratio was recorded in fodder cowpea, which was on par with rice bean with 100 per cent RDN. Higher leaf: stem ratio is a favourable characteristic in fodder crops, and fodder cowpea ranked first in this regard.

Among the fodder crops, green fodder yield was significantly more in fodder maize irrespective of N dose. The taller stature, higher LAI and CGR might have contributed to the higher yield of fodder maize.

Dry fodder yield was significantly more in fodder maize, irrespective of the N dose. Similar to the trend with respect to green fodder, dry fodder yield was significantly higher in fodder maize. Fodder sorghum grown with 100 per cent RDN yielded equally well. This is in conformity with the findings of Chaudhary *et al*. (2014) who recorded a higher yield from fodder maize owing to its taller stature, higher leaf area and wider stem diameter compared to other cereal (sorghum, pearl millet, teosinte) and leguminous fodders (lucern, fodder cowpea, cluster bean). Boosting of dry fodder yield of fodder sorghum, with increased application of N was observed by Chaudhary *et al*. (2018).

5.1.4 Quality Parameters

Higher crude protein content and lower crude fibre are the desirable traits of fodder crops. Crude protein content was significantly higher and crude fibre content significantly less in fodder cowpea and rice bean, especially when supplied with 100 per cent RDN. Enhanced crude protein content with higher dose of N was observed by Tariq *et al*. (1998), Bhavya *et al*. (2014) and Balai *et al*. (2017). Baran *et al*. (1987) noted a reduced crude fibre content under increased level of N application. While there are reports of increase in crude fibre content with increased levels of N application in different crops [Ayub *et al*. (1999) ; Chaudhary *et al*. (2018)]. Baran *et al*. (1987) recorded a reduced crude fibre content under increased level of N application.

5.1.5 Weeds in Summer Season

5.1.5.1 Weed Composition

The weeds comprised of grasses, sedges and broad leaved weeds. As the experimental field was a summer fallow of double cropped rice field, several weeds commonly noticed in rice were present in the fodder crops raised during summer. Rice plants which grew from the previous crop was also a major weed.

Among grasses, rice (*Oryza sativa),* blood grass (*Isachne miliacea)* and barnyard grass (*Echinocloa crusgalli)* were the major species observed.

Sedges comprised of umbrella sedge (*Cyperus difformis),* yellow nut sedge (*Cyperus iria),* globe finger rush (*Fimbristylis miliacea)* and oval leaf pondweed (*Monochoria vaginalis).*

Among broad leaved weeds, penny wort (*Centella asiatica),* false daisy (*Eclipta postrata),* small flowered lindernia (*Lindernia parviflora),* perennial water primrose (*Ludwigia perennis),* Indian madder (*Oldenlandia umbellata),* stone breaker (*Phyllanthus niruri),* sweet broom weed (*Scoparia dulcis)* and wedgewort (*Sphenoclea zeylanica)* were dominant.

5.1.5.2 Weed Population or Absolute Density

At 20 DAS, sedges dominated in majority of the treatments. There was no particular trend with regard to weed population in the different treatments.

At 40 DAS, grasses dominated followed by sedges and broad leaved weeds. At this stage also, there was no particular trend with respect to weed population between treatments. Both at 20 and 40 DAS, the variations in weed population had no specific relation with varying doses of N. In general, total weed population was more in the fallow plot.

The weed dry matter production was significantly more in the fallow plot. There was no specific trend in weed dry matter production at 20 DAS. However, at 40 DAS weed dry matter production was relatively less in fodder cowpea. There was no marked variation in the weed dry matter production with varying doses of N. Weed smothering efficiency was relatively greater in all the fodder crops except fodder cowpea at 20 DAS. However, at 40 DAS, the WSE in rice bean, fodder maize and fodder sorghum declined, while in fodder cowpea it increased. The enhanced canopy of fodder cowpea, especially at higher doses of N (75 and 100 % RDN) at 40 DAS, might have restricted the weed growth, thereby resulting in the higher WSE.

5.1.6 Chemical Analysis

5.1.6.1 Nutrient Uptake by Crop

The N uptake was significantly higher in fodder maize which was on par with fodder sorghum with 100 per cent RDN. The P uptake by fodder crops was significantly higher in fodder maize. K uptake was significantly more and on par in fodder maize and fodder sorghum, irrespective of the varying dose of N. Fodder cowpea with 100 and 75 per cent RDN was also on par. The higher nutrient uptake in fodder maize and fodder sorghum is commensurate with the higher dry matter production (yield) of the crops. A higher nutrient uptake (N, P and K) with higher dose of N was reported in fodder crops by Ali (2015).

5.1.6.2 Nutrient Removal by Weeds

N removal at 20 and 40 DAS was significantly more in fallow plot. At 20 DAS, N removal did not show any definite trend. At 40 DAS, N removal by weeds was significantly less in fodder cowpea.

P removal by weeds at 20 DAS did not reveal any definite trend. At 40 DAS, P removal was significantly less in fodder cowpea.

K removal at 20 DAS did not exhibit any specific pattern. At 40 DAS, K removal was significantly less in fodder cowpea especially at 100 and 75 per cent RDN. It was observed that, nutrient removal by weeds increased with weed dry

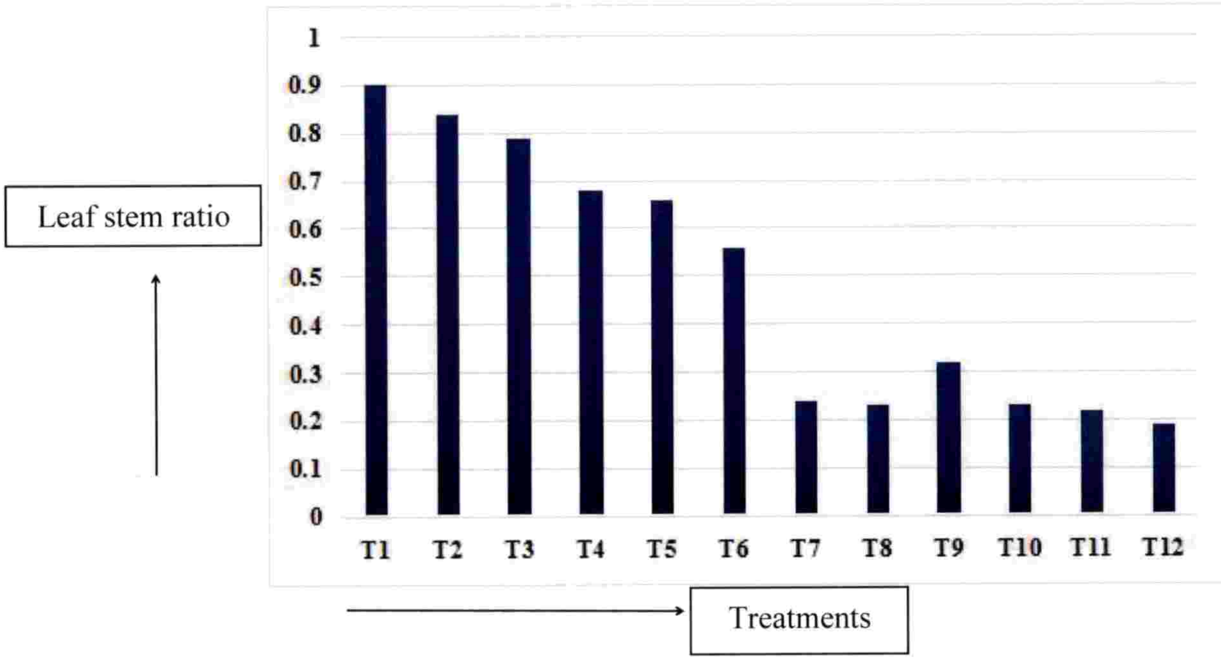

Fig. 3 Effect of treatments on leaf stem ratio of fodder crops

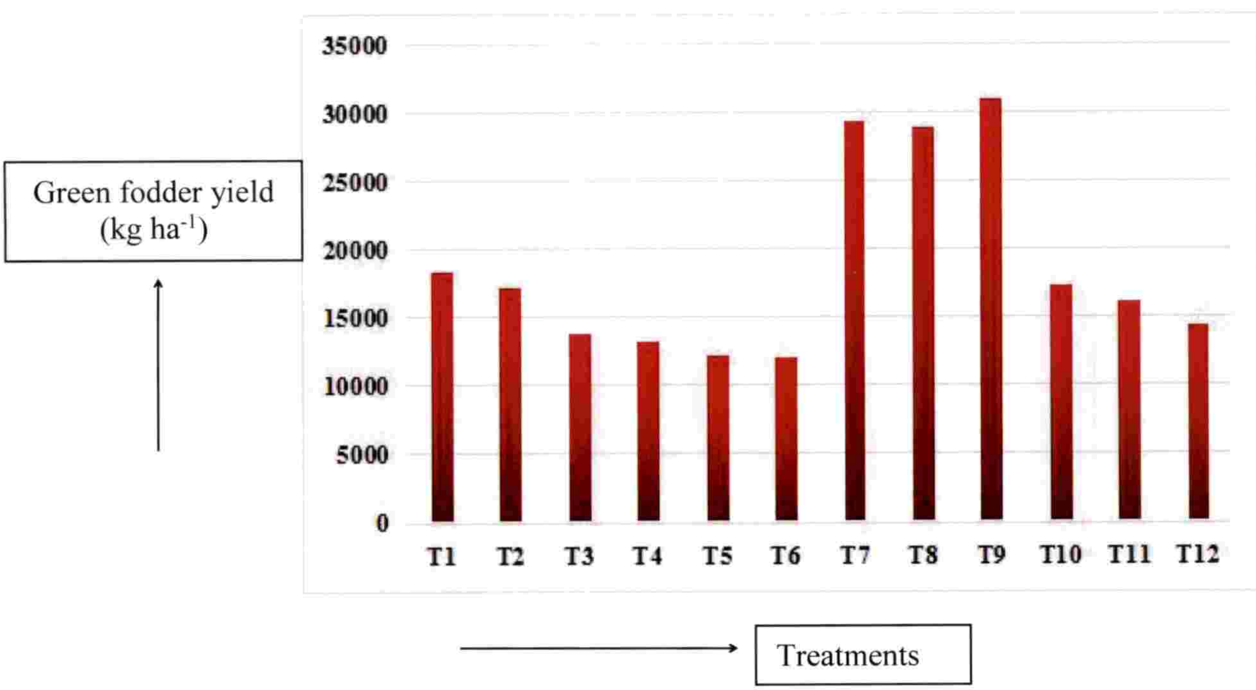

Fig. 4 Effect of treatments on green fodder yield of fodder crops

matter production. The findings are in accordance with Singh *et al.* (2013) who recorded that higher weed dry matter production resulted in higher nutrient removal.

The higher WSE of fodder cowpea during the later stages resulted in lesser dry matter production and consequently lesser removal of nutrients by weeds.

5.1.6.3 Available nutrient status of soil after summer fodder crop

The available N status was significantly higher in rice bean, fodder cowpea and fodder sorghum, both at 100 and 75 per cent RDN. Available P was significantly higher in rice bean, fodder cowpea and fodder sorghum. Available K status did not exhibit any specific pattern in relation to different fodder crops or varying doses of nitrogen.

Fodder maize produced higher dry matter and thereby, removed more nutrients, especially N and P as evident from results of the study. This might be the reason for the lower available N and P status in plots where fodder maize was grown.

The effect of leguminous fodder crops on soil available N status was not distinct probably due to the fact that the soil analyzed was collected immediately after the harvest of the leguminous fodders. Decomposition of the root biomass and nodules and release of N might have occurred only later on.

5.1.7 Economic Analysis of Fodder Crop Cultivation in Summer

Net income was significantly higher from fodder maize, irrespective of the N dose and was on par with fodder cowpea grown with 100 and 75 per cent RDN, when compared to other fodder crops. The higher yield obtained from fodder maize and fodder cowpea generated more returns and hence, greater net income. However, significantly higher B:C ratio was recorded in fodder cowpea grown with 100 and 75 per cent RDN. Though the net income from fodder maize was on par with fodder cowpea, the lower cost of cultivation for fodder cowpea resulted

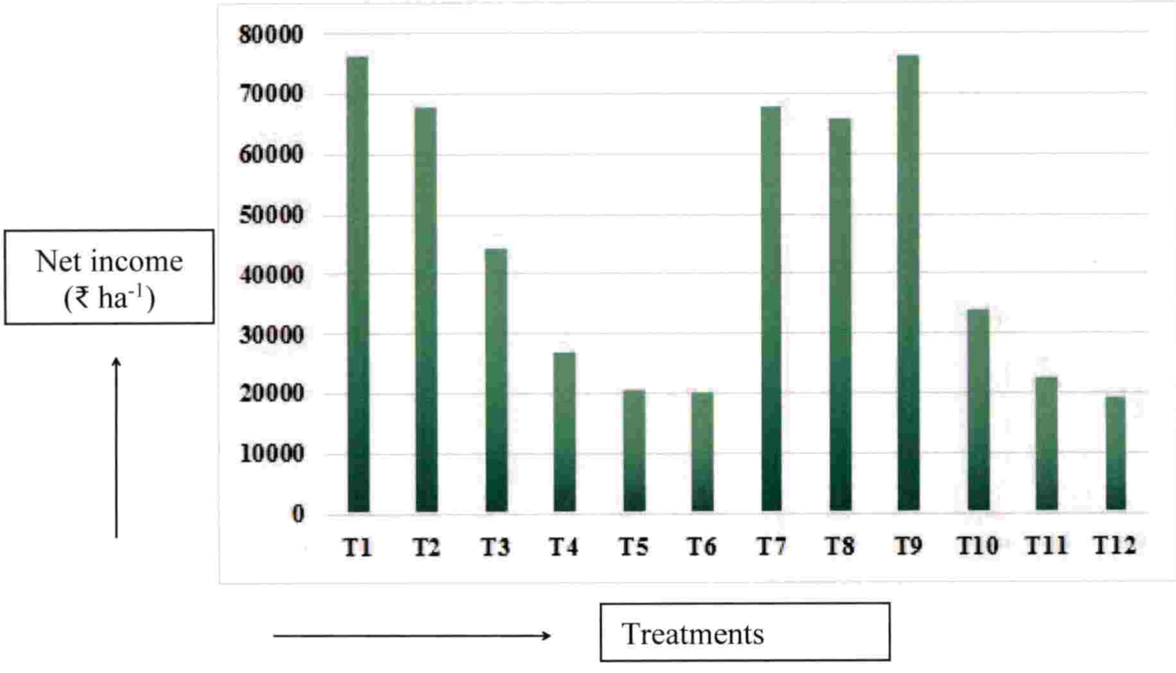

Fig. 5 Effect of treatments on net income of fodder crop cultivation

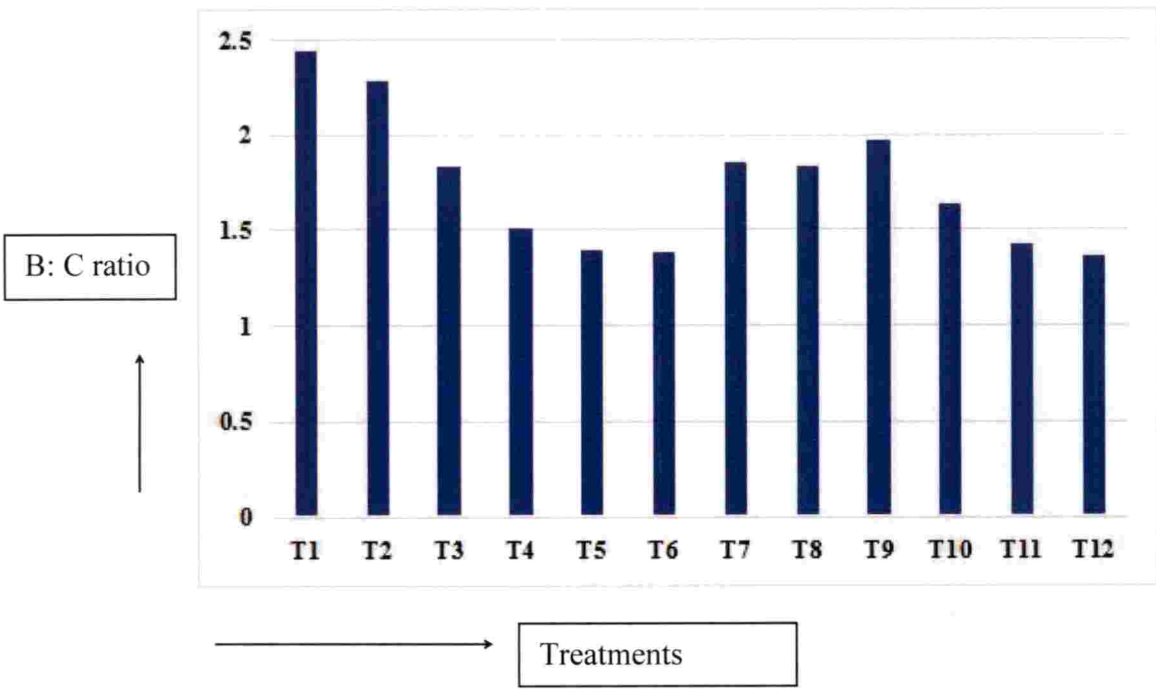

Fig. 6 Effect of treatments on B: C ratio of fodder crop cultivation

in the higher B:C ratio. Fodder maize requires more organic manure (25 t ha^{-1}) compared to fodder cowpea (12.5 t ha^{-1}), which is a prime factor contributing to the difference in cost of cultivation. Moreover, fodder cowpea being a leguminous fodder, has a higher crude protein and fetches a higher price per kilogram *ie*. ₹ 7 kg^{-1}, while for fodder maize it is only ₹ 5 kg^{-1}. It is notable that fodder cowpea has a duration of only 55 days while fodder maize takes 60 days to yield.

5.1.8 Nitrogen Balance Sheet after Summer Crop

The balance sheet of N after summer crop showed a negative balance of N in all the treatments. The N uptake by fodder crops and N removal by weeds along with losses of N in different forms, such as leaching and volatile losses might have resulted in negative balance of N in all the treatments. The positive effect of the leguminous crops by way of N fixation is not likely to reflect in the soil available N status after the summer crop, as the soil samples analyzed were collected immediately after harvesting of the summer crop.

5.2 SUCCEEDING RICE CROP DURING *VIRIPPU,* 2018-19

The *virippu* rice crop was raised with the primary objective of assessing the residual effect on the growth and yield, if any, of the preceding fodder crops and the varying doses of N supplied to them.

With respect to growth and yield of the rice crop, plant height alone exhibited a significant difference between the treatments at 20 and 40 DAS and at harvest. But, there was no specific pattern in the observed differences in plant height with regard to the preceding crops or varying doses of nitrogen.

It can be inferred that, despite two of the fodder crops raised during summer being legumes, the expected legume effect was not evident in growth or yield of rice. It is also interesting that reducing the level of N to the crops raised during summer did not have any adverse effect on the *virippu* rice crop. The experiment was undertaken in a field with a history of rice-rice-fallow sequence for the past several years. The stubbles of the first and second crop were regularly incorporated in the soil. Moreover, the weeds of the summer fallow were also recycled. This might have resulted in a stabilized nutrient cycle and helped to override the adverse effect expected out of a reduction in N dose for the summer crop. This is evident from the absence of significant difference in OC and available N, P and K status of the soil after *virippu* rice crop, despite differences observed in N, P and K removal by rice crop.

The present study revealed that, among the different fodder crops tested, fodder maize performed better in the summer rice fallows with higher green fodder yield. However, with respect to net income it was comparable with fodder cowpea at 100 and 75 per cent RDN. Fodder cowpea (100 and 75% RDN) recorded higher B: C ratio. Considering the shorter duration, better quality fodder and higher B:C ratio, fodder cowpea was the best fodder crop for summer rice fallows. Yield, net income and B: C ratio of rice bean, fodder maize and fodder sorghum under varying doses of N was comparable, indicating the adequacy of 50 per cent RDN. Further, reducing the RDN for the summer crops did not have any adverse effect on the productivity and economics of the succeeding *virippu* rice. Neither negative nor positive residual effects due to the inclusion of fodder crops during summer or owing to reduction of N dose for the summer crops were observed in the succeeding *virippu* rice crop. It is to be noted that the *virippu* rice crop was supplied with the recommended organic manure and nutrients.

SUMMARY

6. SUMMARY

The study entitled "Productivity enhancement of rice based cropping system with fodder crops" was undertaken during 2017-2019 with the objectives of evaluating the suitability of different fodder crops in summer fallow of double cropped lowland rice field under varying N regimes and to assess its residual effect on the succeeding *virippu* rice crop.

The research work was carried out as two experiments, at IFSRS, Karamana, Thiruvananthapuram. The experiment was laid out in RBD with thirteen treatments replicated thrice, during summer 2017-18 and *virippu* 2018-19 seasons. In Experiment I, four fodder crops were raised during summer 2017-18 under varying nitrogen regimes. The treatments were T_1 (fodder cowpea with 100 % recommended dose of nitrogen [RDN]), T_2 (fodder cowpea with 75 % RDN), T_3 (fodder cowpea with 50 % RDN), T_4 (rice bean with 100 % RDN), T_5 (rice bean with 75 % RDN), T_6 (rice bean with 50 % RDN), T_7 (fodder maize with 100 % RDN), T_8 (fodder maize with 75 % RDN), T_9 (fodder maize with 50 % RDN), T_{10} (fodder sorghum with 100 % RDN), T_{11} (fodder sorghum with 75 % RDN), T_{12} (fodder sorghum with 50 % RDN) and T_{13} (fallow during summer). In Experiment II, first crop of rice (*virippu*) was raised in the same plots during 2018-19 to assess the residual effect of the fodder crops on rice. The varieties of fodder cowpea, rice bean, fodder maize, fodder sorghum and rice used were CO-9, Bidhan-2, African tall, CO (FS) 31 and Uma, respectively.

6.1 SUMMER FODDER CROPS

Regarding growth attributes of summer fodder crops, the height of different fodder crops differed significantly at 30 and 60 DAS. Fodder maize and fodder sorghum were taller compared to other fodder crops. At 60 DAS, fodder maize plants with 100 per cent RDN was significantly taller. With respect to physiological parameters, LAI differed significantly between fodder crops only at 20 DAS. LAI was significantly higher in fodder maize, which was comparable with fodder cowpea at 100 per cent RDN. Significantly higher CGR was observed in fodder maize during the period from 1 to 20 DAS. However, from 20 to 40 DAS, fodder cowpea with 100 per cent RDN, fodder maize with 75 per cent RDN and fodder sorghum with 100 per cent RDN had significantly higher and comparable CGR. Significantly higher NAR was observed in fodder sorghum during 1 to 20 DAS, irrespective of the N dose. However, during 20 to 40 DAS, NAR in fodder sorghum and fodder cowpea was significantly higher and on par irrespective of N dose. Fodder maize with 75 per cent RDN was also on par. At 20 DAS, significantly higher SCMR was recorded in fodder cowpea which was on par with fodder maize with 50 per cent RDN. At 40 DAS, significantly higher SCMR was recorded in fodder cowpea which was on par with fodder maize with 100 per cent recommended dose of nitrogen.

The yield attributes and yield differed significantly between the treatments. Significantly higher leaf: stem ratio was recorded in fodder cowpea which was comparable with rice bean with 100 per cent RDN. Among the fodder crops, green fodder yield was significantly more in fodder maize irrespective of N dose. Dry fodder yield was significantly more in fodder maize irrespective of the N dose and exhibited a trend similar with respect to green fodder yield. Fodder sorghum grown with 100 per cent RDN yielded equally well.

In case of quality parameters, among the fodder crops, fodder cowpea with 100 per cent RDN, had significantly higher crude protein, which was on par with 75 per cent RDN in fodder cowpea and rice bean with 100 per cent RDN. Crude fibre content was significantly lower in rice bean and fodder cowpea with 100 per cent RDN, which were on par.

As the experimental field was summer fallow of double cropped rice field, several weeds commonly noticed in rice were present in the fodder crops. Rice plants which grew from the previous crop was a major weed. Among grasses rice (*Oryza sativa),* blood grass (*Isachne miliacea)* and barnyard grass (*Echinocloa crusgalli)* species were observed. Sedges comprised of umbrella sedge (*Cyperus difformis),* yellow nut sedge (*Cyperus iria),* globe finger rush (*Fimbristylis miliacea)* and oval leaf pondweed (*Monochoria vaginalis).* Among broad leaved weeds, penny wort (*Centella asiatica),* false daisy (*Eclipta postrata),* small flowered lindernia (*Lindernia parviflora),* perennial water primrose (*Ludwigia perennis),* Indian madder (*Oldenlandia umbellata),* stone breaker (*Phyllanthus niruri),* sweet broom weed (*Scoparia dulcis)* and wedgewort (*Sphenoclea zeylanica)* were dominant.

At 20 DAS, in general, among the weeds present, sedges dominated in majority of the treatments. There was no particular trend with regard to weed population in the different treatments. The absolute density of grasses was significantly less in fodder maize with 100 per cent RDN, which was on par with other treatments of fodder maize, fodder cowpea with 100 and 75 per cent RDN, rice bean with 100 and 50 per cent RDN, fodder sorghum with 100 and 50 per cent RDN and fallow treatment. The absolute density of sedges was significantly low in rice bean with 75 per cent RDN which was on par with other treatments of rice bean, fodder cowpea with 100 per cent RDN, fodder maize with 100 and 50 per cent RDN and the fallow treatment. The absolute density of broad leaved weeds was significantly low in rice bean with 75 per cent RDN which was on par with other treatments of rice bean, fodder cowpea with 50 per cent RDN, fodder maize 100 and 75 per cent RDN and all the treatments fodder sorghum. The total absolute density was significantly less in fodder maize with 100 per cent RDN which was on par with rice bean with 100 and 50 per cent RDN, fodder sorghum with 100 and 75 per cent recommended dose of nitrogen.

At 40 DAS, in general, among the weeds present, grasses dominated, followed by sedges and broad leaved weeds. The absolute density of grasses was significantly less in fodder sorghum with 50 per cent RDN, which was comparable with other treatments of fodder sorghum, all treatments of fodder cowpea, rice bean with 100 and 50 per cent RDN, fodder maize with 50 per cent RDN. The population of sedges was significantly less in fodder sorghum with 50 per cent RDN, which was comparable with fodder cowpea with 100 per cent RDN, all treatments of rice bean and fodder sorghum 100 per cent RDN. The absolute density of broad leaved weeds was significantly less in fodder sorghum, with 50 per cent RDN, which was on par with all the treatments of fodder cowpea and rice bean with 100 per cent RDN. The total absolute density of weeds was significantly less in fodder sorghum with 50 per cent RDN, which was on par with rice bean with 100 per cent RDN. However, total weed population was more in the fallow plot.

At 20 DAS, the dry matter of weeds was significantly less in fodder maize with 100 per cent RDN, which was on par with all other treatments except fallow treatment. But, at 40 DAS the dry matter production of weeds was significantly less in fodder cowpea (100 and 75 % RDN). There was no marked variation in the weed dry matter production with varying doses of nitrogen.

Regarding weed smothering efficiency, at 20 DAS, the WSE was significantly higher in rice bean with 50 per cent RDN, which was on par with all other treatments, except in fodder cowpea with 50 per cent RDN and rice bean with 75 per cent RDN. However, at 40 DAS, the WSE was significantly higher in fodder cowpea with 100 and 75 per cent recommended dose of nitrogen.

The nutrient uptake by both fodder crops and weeds were significantly influenced by the treatments. The N uptake by fodder crops was significantly higher in fodder maize which was on par with fodder sorghum with 100 per cent RDN. The P uptake by fodder crops was significantly higher in fodder maize. The K uptake by fodder crops was significantly more in fodder maize, which was on par with fodder sorghum and fodder cowpea with 100 and 75 per cent recommended dose of nitrogen.

With regard to nutrient removal by weeds, at 20 DAS, the N removal was significantly low in fodder cowpea with 75 per cent RDN, which was on par with all other treatments except, fodder cowpea with 100 per cent RDN, fodder maize with 50 per cent RDN and the fallow treatment. But at 40 DAS, N removal by weeds was significantly less in fodder cowpea. The P removal by weeds, at 20 DAS, was significantly less in fodder maize with 100 per cent RDN, which was comparable with 75 per cent RDN, fodder cowpea (75 and 50% RDN), all the treatments of rice bean and fodder sorghum (75 and 50% RDN). However, at 40

DAS, significantly less P removal by weeds was in fodder cowpea with 100 per cent RDN, which was on par with other treatments of fodder cowpea and fodder maize with 100 per cent RDN. The K removal by weeds, at 20 DAS, was significantly less in fodder sorghum with 50 per cent RDN which was comparable with other treatments of fodder sorghum, fodder cowpea with 75 and 50 % RDN, rice bean with 50 per cent RDN, fodder maize with 75 per cent RDN. At 40 DAS, significantly less K removal by weeds was in fodder cowpea (100 and 75 % RDN).

There was no significant difference between the treatments in soil organic carbon status after summer crop. Available N, P and K status of soil after the summer crop differed significantly between treatments. Available N was significantly more in rice bean with 100 per cent RDN which was on par with 75 per cent RDN, fodder cowpea (100 and 75 % RDN), fodder sorghum (100 and 75 % RDN). Available P was significantly high in rice bean with 100 per cent RDN, which was on par with 75 % RDN, fodder cowpea (100 and 50 % RDN), all the treatments of fodder maize and fodder sorghum. Available K was significantly the maximum in fodder maize with 50 per cent RDN, which was on par with fodder maize with 75 per cent RDN, rice bean with 50 per cent RDN and fodder sorghum with 50 per cent RDN. There was no significant difference between treatment and control.

Net income was significantly higher from fodder maize irrespective of the N dose and was on par with fodder cowpea grown with 100 and 75 per cent RDN, when compared to other fodder crops. The higher yield obtained from fodder maize and fodder cowpea generated more returns and hence, greater net income. However, significantly higher B: C ratio was recorded in fodder cowpea grown with 100 and 75 per cent recommended dose of nitrogen.

The balance sheet of N after summer crop showed a negative balance of N in all the treatments. The N uptake by fodder crops and N removal by weeds along with losses of N in different forms, such as leaching and volatile losses might have resulted in negative balance of N in all the treatments.

6.2 SUCCEEDING RICE CROP DURING *VIRIPPU,* 2018-19

Significantly taller plants at 20 DAT was recorded in rice crop which succeeded, fodder sorghum with 50 per cent RDN, which was on par with fodder sorghum with 75 per cent RDN, all the treatments of rice bean and fodder maize with 75 and 50 per cent RDN. At 40 DAT, significantly taller plants of rice crop was observed which succeeded fodder cowpea with 50 per cent RDN, which was on par with all other treatments except fodder cowpea with 75 per cent RDN. At harvest, significantly taller plants were observed in rice crop that followed fodder sorghum with 100 per cent RDN, which was on par with 75 per cent RDN, rice bean with 100 and 50 per cent RDN, fodder maize with 100 and 75 per cent RDN and the fallow treatment.

There was no significant difference between the treatments with regard to tillers m^{-2} both at 20 and 40 DAS and also yield attributes and yield such as, productive tillers m^{-2}, thousand grain weight, grain yield, straw yield and harvest index.

The nutrient uptake by *virippu* rice crop differed between the treatments. Nitrogen uptake by rice crops was significantly higher in plots which succeeded fodder sorghum and was comparable with fodder cowpea with 100 and 50 per cent RDN and fodder maize with 100 per cent RDN. In case of P uptake by rice, P uptake was significantly higher in plots which followed rice bean with 100 per cent RDN compared to all other treatments. The K uptake was significantly higher by rice crop which succeeded fodder sorghum treatments which was on par with fodder cowpea and fodder maize with 100 per cent recommended dose of nitrogen.

The OC and available N, P and K status of soil after *virippu* rice crop did not differ significantly between the treatments. The gross income, net income and BC ratio did not differ significantly between the treatments.

The present study revealed that, among the different fodder crops tested, fodder maize performed better in the summer rice fallows with higher green fodder yield. However, with respect to net income it was comparable with fodder cowpea at 100 per cent and 75 per cent RDN. Fodder cowpea (100 and 75% RDN) recorded higher B: C ratio. Considering the shorter duration, better quality fodder and higher B:C ratio, fodder cowpea was the best fodder crop for summer rice fallows. Yield, net income and B: C ratio of rice bean, fodder maize and fodder sorghum under varying doses of N was comparable, indicating the adequacy of 50 per cent RDN. Further, reducing the RDN for the summer crops did not have any adverse effect on the productivity and economics of the succeeding *virippu* rice. Neither negative nor positive residual effects due to the inclusion of fodder crops during summer or owing to reduction of N dose for the summer crops were observed in the succeeding *virippu* rice crop. It is to be noted that the *virippu* rice crop was supplied with the recommended dose of organic manure and nutrients.

Future line of work:

1. Evaluate the performance of *virippu* rice under reduced (75 and 50 %) RDN which succeeds summer fodder crops, in the rice based cropping system.
2. Explore the possibility of growing different other climate resilient crops in summer fallow of double cropped rice field.

REFERENCES

REFERENCES

Abayomi, Y. A., Ajibade, T. V., Sammuel, O. F. and Sa'adudeen, B. F. 2008. Growth and yield responses of cowpea (*Vigna unguicufata* (L.) Walp)genotypes to nitrogen fertilizer (NPK) application in the southern Guinea savanna zone of Nigeria. *Asian J. Plant Sci.* 7(2): 170-176.

Afzal, M., Ahmad, A and Ahmad, Au. H. 2012. Effect of Nitrogen on Growth and Yield of Sorghum Forage (*Sorghum Bicolor* (L.) Moench Cv.) under Three Cuttings System. Available: https://www.researchgate.net/publication. [8 January 2019].

Akbar, M. A., Islam, M. S., Bhuiya, M. S. U., Islam M. S. and Hossain, M. A. 2000. Integration of Fodder Legumes into Rice-based Cropping Systems in Bangladesh : Production of Lathyrus Sativus and Its Use as a Supplement to Straw-based Rations of Dairy Cows. *Asian-Aust. J. Anim. Sci.* 13(A): 526-528.

Ali, H. Q. Z., Choudhary, F. A., Hayat, S., Iqbal, R, Khaliq, T. and Ahmad, A. 2019. Viable alternatives to cotton-wheat crop rotation for semi-arid climatic conditions. *J. of Dev. and Agric. Econ.* 11(3): 57-62.

Ali, Q. 2015. Yield maximization of fodder bajra and fodder sorghum in summer rice fallows. M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissure, 93p.

AOAC [Association of Official Agricultural Chemists]. 1975. Official and Tentative methods of Analysis. Association of Official Agricultural Chemists, Washington, D. C., 350p.

Ayub, M., A. Tanveer, K. Mahmud, A. Ali and M. Azam, 1999. Effect of nitrogen and phosphorus on the fodder yield and quality of two sorghum cultivars (*Sorghum bicolor* L.). *Pak. J. Biol. Sci.* 2:247-250.

Ayub, M., Tahir, M., Nadeem, M. A., Zubair, M., Tariq, M., and Ibrahim, M. 2010. Effect of nitrogen applications on growth, forage yield and quality of three cluster bean varieties. *Pak. J. Life Soc. Sci.* 8(2): 111-116.

Balai, R. C., Meena L. R., and Sharma S. C. 2017. Effect of different levels of nitrogen and phosphorus on cowpea [*Vigna unguiculata* (L.) Walp] under rainfed conditions of Rajasthan. *J. Agri. Ecology* 3: 19-24.

Balasubramanian, V., Raghauram, N., Abrol, Y. P., Sachdev, M. S., Pathak, H. and Singh, B. 2010. Reactive nitrogen: Good, Bad and Ugly. Comprehensive Status Report, SCON-ING, New Delhi: 52p.

Balyan, J. S. 1997. Production potential and nitrogen uptake by succeeding wheat under different cropping sequences. *Indian J. Agron.* 42(2): 250-252.

Baran, M., 1987. Effects of nitrogen application on the production and nutritive value of maize and soybean mixture. Plant Nohespodarstov, 37: 613-624.

Behera, J., Mohanty, P. K., Lokose, R.Y. P., and Mishra. A. 2017. Response of promising ricebean [Vignaumbellata [(Thunb.) Ohwi & Ohashi] genotypes in different levels of nitrogen. *Int. J. Sci. Res.* 6(9): 65-69.

Bhavya, M. R., Palled, Y. B., Pushpalatha, Ullasa, M. Y., and Nagaraj, R. 2014. Influence of seed rate and fertilizer levels on dry matter distribution and dry matter yield of fodder cowpea (cv. Swad). *Trends Biosci.* 7:1516-1521.

Bouyoucos, C. J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* 54: 464-465.

Brady, N. C. 1984. The Nature and Properties of Soils. 9th Edition. Macmillan Publishing Company. New York. 750 p.

Carangal, V. R., Rebancos, E. T., Jr., Armada, E. C and Tengco, P. L. 1994. Green manure production systems for Asian Rice Lands. International rice research institute, Los Banos, Philippines. 132p.

Cerny, J., J. Balik, M. Kulhanek, F. Vasak, L. Peklova, O. Sedlar. 2012. The effect of mineral N fertilizer and sewage sludge on yield and nitrogen efficiency of silage maize. *Plant Soil Environ.* 58: 76-83.

Chaudhary, D.P., Jat, S.L., Kumar, R., Kumar, A. and Kumar, B. (2014). Fodder Quality of Maize: Its Preservation. Chapter from book Maize: Nutrition Dynamics and Novel Uses (pp.153-160).

Chaudhary, J. D., Pavaya, R.P.,Malav, J. K., Dipika, G., Chaudhary, N., Kuniya, N. K., Vina, A., Patel, I. M. and Jat, J. R. 2018. Effect of nitrogen and potassium on yield, nutrient content and uptake by forage sorghum (*Sorghum bicolor* (L.) Moench) on loamy sand. *International J. of Chemical Studies* 2018; 6 (2) : 761-765.

Cochran, W. G. and Cox, G. M. 1965. Experimental Designs. John Willey and Sons Inc., New York, 182p.

Dahipahle, A. V., Kumar, S., Sharma, N., Singh, H., Kashyap., S. and Meena H. 2017. Rice Bean - A Multipurpose, Underutilized, Potential Nutritive Fodder Legume - A Review. *J. of Pure and Appl. Microbiol.* 11(1):433-439.

Donald, C. M. and Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron.* 28: 361-405.

Dubey, R., Sharma, R. S. and Dubey, D.P. 2014. Effect of organic, inorganic and integrated nutrient management on crop productivity, water productivity and soil properties under various rice-based cropping systems in Madhya Pradesh, India. *Int. J. Curr. Microbiol. App. Sci.* 3(2): 381-389.

Dwivedi, B. S., Shukla, A. K., Singh, V. K., and Yadav, R. L. 2001. Results of participatory diagnosis of constraints and opportunities (PDCO) based trails from the state of Uttar Pradesh. In: Subba Rao, A., Srivastava, S. (Eds.), *Development of Farmers Resource- Based Integrated Plant Nutrient Supply Systems: Experience* of a *FAO-ICAR-IFFCO Collaboartive Project and AICRP on Soil Test Crop Response Correlation.* IISS, Bhopal, India, pp. 50-75.

FIB [Farm Information Bureau]. 2019. *Farm guide* 2019. Farm Information Bureau, Thiruvananthapuram.[on-line]. Available: http://spb.kerala.gov.in/ [5 July 2018].

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M. (2011). Solutions for a cultivated planet. *Nature* 478, 337–342.

Fray, P. K. and Olson, W. A. 1978. Techniques for separating weed seed from soil. *Weed Sci.* 26 (7): 530-533.

Gaurav, S. K., Verma, R. S., Meena, A.C., Maurya and Kumar. S. 2018. Nutrients Uptake and Available Nutrients Status in Soil as Influenced by Sowing Methods and Herbicides in Kharif Maize. *Int. J. of Agric. Environ and Biotechnol* 11(1): 17-24.

Ghosh ,P. K., Bandyopadhyay ,K. K., Wanjari , R. H., Manna , M. C., Misra ,M. Mohaty, A. K. and Rao, A. S. 2007. Legume effect for enhancing productivity and nutrient use-efficiency in major cropping systems–An Indian Perspective: A Review. *J. of Sustain. Agric.* 30(1): 98p.

GOI [Government of India]. 2017. Livestock Censuses, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture & Farmers Welfare. [on-line]. Available: http://www.dahd.nic.in/ [5 Dec. 2018].

GOK [Government of Kerala]. 2015. Economic Review 2015. [on-line]. Available: https://kerala.gov.in/ [10 Jan. 2019].

Gomez, K. A. 1972. *Techniques for Field Experiments with Rice*. IRRI, Los Banos, Philippines. 49p.

Gregory, F. G. 1926. The effect of climatic conditions on the growth of barley. Ann. Bot. 10: 11-26.

Haque, I. 1992. Use of legume biological nitrogen fixation in crop/livestock production system. In: Biological Nitrogen Fixation and Sustainability of Tropical Agriculture, (Eds. K. Mulongoy, M. Gueye and D.S.C. Spencer). John Willey & Sons, New York. pp. 423-437.

Hasan, M. R., Akbar, M. A., Khandaker, Z. H., and Rahman, M. M. 2010. Effect of nitrogen fertilizer on yield contributing characters, biomass yield and nutritive value of cowpea forage. *Bang. J. Anim. Sci.* 39(2): 83-88.

Jackson, M. L. 1973. *Soil Chemical Analysis* (2nd Ed.). Prentice Hall of India, New Delhi, 498p.

Jadav, A.S. (1989). Nutrient balance with reference to fertilizer management under wheat based cropping system. *J. Maharastra Agric.Univ*. 14 (3) :288-291.

Jha, S. K. and Tiwari, N. 2018. Evaluation of intensive fodder cropping systems for round the year green fodder production in Chhattisgarh. *Forage Res*., 44 (2) : pp. 115-118.

John, J., Rajasekharan, P., Rajasree, G., and Bindu, P. 2014. *Cropping Systems in Kerala*. State Planning Board, Thiruvananthapuram, Kerala, 46p.

Kar, G., Singh, R., Verma, H. N. 2004. Alternative cropping strategies for assured and efficient crop production in upland rainfed rice areas of eastern India based on rainfall analysis. *Agric. Water Manag.* 67: 47-62.

KAU (Kerala Agricultural University) 2016. Package of Practices Recommendations: Crops (15th Ed.). Kerala Agricultural University, Thrissur, 393p.

Khadkam, R. and Paudel, M.N. 2010. Inclusion of grain legumes in rice based systems in the mid-hills of central Nepal. *Agron. J. Nepal* 1: 61-66.

Khan, A., Munsif, F., Akhtar, K., Afridi, M. Z., Ahmad, Z., and Fahad, S. 2014. Response of fodder maize to various levels of nitrogen and phosphorus. *American J. of Plant Sci.* 5(15): 2323-2329.

Kropff, M. J., and Laar, H. H. V. 1993. Modeling crop-weed interactions. CAB International, Wallingford, UK. 305p.

Kumar, A. and Elamathi, S. 2007. Effect of nitrogen levels and rhizobium application methods on yield attributes, yield and economics of black gram (*Vigna mungo* L.). *Int. J. Agric. Sci.* 3(1): 179-180.

Kumar, A. and Murthy, N. 2017. Integrated weed management in rice bean. *Indian J. of Weed Sci.* 49(2): 182–183.

Kumar, R., Singh, M., Meena, B. S., Ram, H., Parihar, C, M., Kumar, S., Yadav, M. R., Meena, R. K., Kumar, U. and Meena, V. K. 2017. Yield of fodder maize (*Zea mays*) and its chemical composition under varying plant densities and nutrient management. *Indian J. of Agric. Sci.* 87 (8): 1013–7.

Kumari, K. 2017. Yield, quality and nutrient uptake of rabi fodder crops in response to zinc. *An. of Plant and Soil Res.* 19(2): 219 - 222.

Ladha, J. K., Kundu, D. K., Coppenolle, M. G. A., Peoples, M. B., Carangal, V. R., and Dart. P. J. 1996. Legume productivity and soil nitrogen dynamics in lowland rice based cropping systems. *Soil Sci. Soc. of America J.* 60:183-192.

Iqbal, K., Tanveer, A., Ali, A., Ayub, M., and Tahir, M. 1998. Growth and yield response of rice bean (*Vigna umbellata*) fodder to different levels of N and P. *Pakist. J. Biol. Sci.* 1(3): 212-214.

Madankumar, M. 2017. Crop productivity and weed dynamics in rice based farming systems. M.Sc. thesis, Kerala Agricultural University, Thrissur, 125p.

Mahajan, G. and Sardana, V. 2003. Nutrient uptake by wheat and phalaris minor as influenced by weed management practices. Agric. Sci. Digest. 23:195 - 198.

Mahdi, S.S., Hasan, B. and Singh, L. 2012. Influence of seed rate, nitrogen and zinc on fodder maize (*Zea mays*) in temperate conditions of western Himalayas. *Indian J. Agron.* 57: 85-88.

Maloth, S. and Prasad, R. 1976. Relative efficiency of rock phosphate and superphosphate for cowpea (*Vigna sinensis* Savi) fodder. *Plant Soil* 45(1): 295–300.

Mani, V. S. and Gautham, K. G. 1973. Chemical weed control- effective and economical. *Indian Farming.* 22: 21-22.

Maranville, J. W., Pandey, R. K. and Sirifi, S. 2002. Comparison of nitrogen use efficiency of a newly developed sorghum hybrid and two improved cultivars in the Sahel of West Africa. *Commun. in Soil Sci. and Plant Anal.* 33(9):1519-1536.

Meena, L. R. and Chand, R. 2014. Response of fodder cowpea to varying levels of nitrogen and phosphorus under rainfed conditions of Rajasthan. *Indian J. Small Rumin.* 20(2): 121-123.

Meena, M. S. and Singh K. M. 2014. Fodder production scenario and strategies for revitalizing fodder production technologies [on-line]. Available: http://mpra.ub.uni-muenchen.de/ [12 Dec. 2018].

Menon, M. V. 1987. Potential and prospects of fodder legumes in rice fallows. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 144p.

Moorthy, B. T. S and Mitra., B. N. 1991. Influence on weed management practices on the performance of upland rice. *Thailand J. Agric. Sci.* 24: 1-19.

Mridha, M. A. J. 1987. Effect of the rate of green manuring on growth, yield and nitrogen uptake of BR3 rice. M.Sc. Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh. 132p.

Mwangi, D.M., Romney, D., Stanal, S., Battenweek, I. and Mwendia, S.W. 2006. Strategies for feeding small holder dairy cattle in intensive maize production systems and implications for Integrated Pest Management. Proceedings of the 7th KARI biennial scientific conference, 13-17 November 2004, KARI HQs, Nairibi, Kenya. pp:23-27.

Nirmal, S.S., Dudhade, D.D., Solanke, A.V., Gadakh, S.R., Bhakare , B.D., Hasure, R.R. and Gore, S.B. 2015. Effect of nitrogen levels on growth and yield of forage sorghum [*Sorghum bicolor* (l.) moench] varieties. *Int. J. of Sci. Environ. and Technol.* 5(5):2999 – 3004.

Njarui, D.M.G., Keating, B.A., Jones, R.K. and Beattie, W.M. (2004). Evaluation of forage legumes in the semi-arid region of Eastern Kenya. II Persistence and dry matter production of selected forage legume. *Trop. and Sub Trop. Agrosystems,* 4 : 57-68.

Palaniappan, S. P. 1985. Cropping systems in the Tropics. Principles and Management. Wiley Eastern Ltd. 209p.

Panda, N. K. 2015. Production potential of rice - fodder cropping sequence under various rice cultivation methods. M. Sc. Thesis, Orissa University of Agriculture and Technology, Bhubaneswar, 78p.

Pandya, C. B. and Bhatt V. R. 1999. Effect of different nutrient levels on yield and nutrient content of fodder cowpea. *Legume Res.* 30(3): 218- 220.

Patidar, S. 2013. Effect of different phosphorous levels on forage yield of promising varieties of rice bean [*Vigna umbellata* (Thonb.)]. M. Sc. (Ag) thesis. Jawaharlal Nehru Krishi Viswa Vidyalaya, Jabalpur. 129p.

Philips, E. A. 1959. *Methods of Vegetation Study-Ecology Workbook.* Henry Holt and Company, 144p.

Qamar, Z. and Malik, M. A. 1999. Growth and seed yield and protein contents of rice bean (Vigna umbellata) in relation to nitrogen and phosphorous nutrition. *Int. J. Agri. Biol.* 4: 76-80.

Rahman, M. M. 1994. Nitrogen use efficiency and recovery from N fertilizer under rice-based cropping systems. *Aust. J. of Crop Sci.* 3(6):336-351.

Rajasree, G. 1994. Herbage production of leguminous crops in summer rice fallows.M.Sc. (Ag) thesis,Kerala Agricultural University, Thrissur, 174p.

Rajasree, G. and Pillai, G. R. 2001. Performance of fodder legumes under lime and phosphorus nutrition in summer rice fallows. *J. Trop. Agric.* 39:67-70.

Rakesh, K. 2016. Fodder Production (Status, constraints, strategies) [on-line]. Available:https://www.biotecharticles.com/Agriculture-Article/Fodder-Production-Sta- tus-constraints-strategies-3563.html [15 Dec. 2017].

Ramachandra, C., Syed, M. A., Janardhan, G., and Murthy, P. 2007. Production potential and economics of rice-based cropping systems in hill zone of Karnataka, India. *Int. J. Agric. Sci.* 3(2): 127-129.

Ramachandrappa,B.K.,Thimmegowda, M.N., Kumar,H.S. R., Dhanpal,G.N., G.N. Anitha,M., Savitha, M.S., Babu,P.N. S. and Gopinath. K. A. 2017. Productivity and Economics of Fodder Crops-Onion (*Allium cepa* L.) Double Cropping System as Influenced by Varieties and Fertilizer Levels in Onion. *Indian J. Dryland Agric. Res. And Dev.* 32 (1): 51-55.

Rathod, B. G. S. and Somasundaram, E. 2017. Effect of organic rice to weed management practices on yield parameters and microbial population grown under lowland condition. *Int. J. Curr. Microbiol. App. Sci.* 6(7): 2154-2162.

Reddy, S. B. 2013. Irrigation and tillage practices for fodder maize (*Zea mays* L.) in rice fallows. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 146p.

Rola, J. and H. Rola, 1990. Control of triazine-resistant weeds in maize in Southwest Poland. Zeitschrift fure Pflanzenkrankheiten und Pflanzenschutz, 12: 509-514.

Sanodiya, P., Jha, A. K. and Shrivastava, A. 2013. Effect of integrated weed management on seed yield of fodder maize. *Indian Journal of Weed Science.* 45 (3): 214–216.

Sattell, R. R., Dick, R., Ingham, R., Karow, and McGrath, D. 1998. Sudangrass and sorghum-sudangrass hybrids. Oregon Cover Crops, Extension and Experiment Station, Oregon State University. Corvallis.192p.

Seufert, V., Ramankutty, N., and Foley, J. A. 2012. Comparing the yields of organic and conventional agriculture. *Nature*. 485: 229–232.

Shukla, D. K., Pratap, T., and Prasad. B. 2014. Standardization of organic manures levels for better growth, yield and economics of rice bean (*Vigna umbellata L.*) under central Himalaya. *J. Hill Agric.* 5(1): 57-60.

Simpson, J. E., Adair, C. H., Kohler, G. O., Dawson, E. N., Debald, H. A., Kester, E. B. and Klick, J. T. 1965. Quality evaluation studies of foreign and domestic rice. *Tech. Bull.* No.1331. Services, U.S.D.A., pp.1-86.

Singh, A. K., Tripathi, P. N., and Singh, R. 2007. Effect of Rhizobium inoculation, nitrogen and phosphorus levels on growth, yield and quality of kharif cowpea [*Vigna unguiculata* (L.) Walp.]. *Crop Res.* 33(3): 71-73.

Singh, A., Singh, R. K., Kumar, P., and Singh, S. 2013. Growth, weed control and yield of direct seeded rice as influenced by different herbicides. *Indian J. Weed Sci.* 45(4): 235-238.

Singh, D. and Chauhan, V. 2017. Fodder yield, quality and nutrients uptake potential of different types of sorghum (*Sorghum bicolor*) varieties in central Gujarat. *Forage Res.* 43 (2) : pp. 121-128.

Singh, K. A., Khan, M. A., Singh, K. M., and Subash, N. 2011. *Forages and Fodder.* Daya Publishing House, Delhi, 366p.

Singh, S. S., Kumar, N., Praharaj, C. S. and Singh, N. P. 2016. Agro-technologies for pulses in rice- fallows. ICAR [Indian Council of Agricultural Research], Kanpur.36p.

Singh, V. K. and Sharma, B. B. 2002. Economic evaluation of rice (*Oryza sativa*)-based cropping sequences in the foothills of Himalayas. *Indian J of Agron.* 47(1): 12-19.

Smith, S. I., and A.N. Sharpley. 1990. Soil nitrogen mineralization in the presence of surface and incorporated crop residues. *Agron. J.* 82: 112-116.

Subbaiah, B. V. and Asija, G. L. 1956. A rapid procedure for determination of available nitrogen in soil. *Curr. Sci.* 25: 259 -260.

Sultana, M. N., Khan, M. J., Khandaker, Z. H., and Uddin, M. M. 2005. Effects of rhizobium inoculums and nitrogen fertilizer on biomass production of cowpea forage at different stages of maturity. *Bangladesh J. Agric. Univ.* 3(2): 249-255.

Sunil, K. and Faruqui, S. A., 2009. Production potential and economic viability of food forage based cropping system under irrigated condition. *Indian J. of Agron.* 54(1).

Tariq, M., Zubair, M. and Ibrahim, M. 1998. Effect of fertilizer applications on growth, forage yield and quality of cluster bean. *Pakistan. J. Life Soc. Sci.* 1(2): 101-106.

Timsina, J., Jat, M. L., and Majumdar, K. 2010. Rice-maize systems of South Asia: Current status, future prospects and research priorities for nutrient management. *Plant Soil.* 335: 65-82.

Toaima, S. E. A., Lamlom, M. M.,Wahab, A. T. I. and Wahab, S. I. A. 2014. Allelopathic effects of sorghum and sudan grass on some following winter field crops. *Int. J. of Plant & Soil Sci.* 3(6): 599-622.

Ullah, M. I., Khakwani, A. A., Sadiq, M., Awan, I., Munir, M. and Ghazanfarullah 2015. *Sarhad J. of Agric.* 31(1):1-80.

Varughese, K., Jacob J., Rani, B., and Vijayan, M. 2007. Scope of crop diversification in paddy fields. In: *Papers on special session: Paddy cultivation in Kerala,* 19th Kerala Science Congress, 29-31 January 2007, Kannur. Kerala State Council for Science, Technology and Environment, Government of Kerala, pp.59-70.

Vijayabaskaran, S. and Kathiresan, R. M. 1993. Integrated weed management in rice-cotton cropping system. In: *Proceedings of international symposium on integrated weed management for sustainable agriculture.* HAU, Hisar, India. P. 62.

Watson, D. J. 1947. Comparative physiological studies in the growth of field crops. I: Variation in assimilation rate and leaf area between species and varieties and within and between years. *Ann. Bot.* 11:41 - 76.

Xiao, H. L., Peng, S. L., Mo, J. M. and Chen, Z. Q. 2007. Relationships between the allelopathy and nutrients content in plant and soil. *Allelopathy J.* 19(2):297-310.

APPENDICES

Appendix I a.

Weather data during summer crop period (February to May 2018)

Standard week	Month and date	Temperature °C		Relative humidity (%)	Rain fall (mm)
		Maximum	Minimum		
8	21 Feb- 25 Feb	31.40	24.12	78.00	
9	26 Feb – Mar 4	32.42	24.34	73.42	
10	Mar 5 - 11	32.71	24.14	77.64	
11	Mar12-18	31.92	24.47	78.35	04.4
12	Mar 19- 25	32.64	25.08	79.14	
13	Mar 26- Apr 1	32.92	25.60	77.57	
14	Apr 2-8	33.50	25.78	77.14	00.2
15	Apr 9-15	32.71	25.07	82.21	22.6
16	Apr 16-22	32.64	26.28	84.71	08.4
17	Apr 23-29	33.14	26.57	80.50	03.8
18	Apr 30- May 6	33.50	23.53	76.28	02.6
19	May 7-13	32.14	25.07	85.07	88.6

Appendix I b.

Weather data during *viruppu* crop period (February to June to October 2018)

Standard week	Month and date	Temperature °C		Relative humidity (%)	Rain fall (mm)
		Maximum	Minimum		
24	Jun11- 17	30.35	24.5	85.92	47
25	Jun 18-24	30.21	24.28	85.14	69
26	Jun 25-Jul 1	30.78	24	80.5	31.2
27	Jul 2-8	30.78	24.28	78	7.2
28	Jul 9-15	29.57	20.07	75.07	98.28
29	Jul 16-22	30.42	23.78	80.21	44.7
30	Jul 23-29	30.71	24.5	79.21	7.8
31	Jul 30-Aug 5	30.00	24.21	89.5	4.6
32	Aug 6-12	29.64	20.64	90.14	117.4
33	Aug 13-19	28.28	22.85	93.85	188.8
34	Aug 20-26	31.00	24.42	84.28	
35	Aug 27-Sep 2	30.85	24.28	84	
36	Sep 3-9	31.28	23.92	93.71	
37	Sep 10- 16	31.92	24.35	80.42	
38	Sep 17- 23	31.57	24.5	85.28	8.3
39	Sep 24-30	32.21	24.57	83.71	91.6
40	Oct 1-7	30.21	25	91	75.4
41	Oct 8-14	30.57	24.64	90	25.2
42	Oct 15-21	31.25	23.85	88.57	82
43	Oct 22-28	31.07	24.28	91.28	

Appendix II

Sale prices of fodder crops (2018-19)

Sl. No.	Fodder crops	Price (₹ kg^{-1})
1.	Fodder cowpea	7
2.	Rice bean	6
3.	Fodder maize	5
4.	Fodder sorghum	5

PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH FODDER CROPS

BINDHYA.B.N

(2017-11-133)

Abstract of the thesis
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Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM- 695 522
KERALA, INDIA
2019

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ABSTRACT

The study entitled "Productivity enhancement of rice based cropping system with fodder crops" was undertaken during 2017-2019 with the objectives to evaluate the suitability of different fodder crops in summer fallow of double cropped lowland rice fields under varying nitrogen regimes and to assess its residual effect on the succeeding *virippu* rice crop.

The research work was carried out as two experiments, at the IFSRS, Karamana, Thiruvananthapuram. The experiment was laid out in RBD with 13 treatments replicated thrice, during summer 2017-18 and *virippu* 2018-19 seasons. In Experiment I, four fodder crops were raised during summer 2017-18 under varying nitrogen regimes. In Experiment II, first crop of rice (*virippu*) was raised in same plots during 2018-19 to assess the residual effect of the fodder crops on rice.

In Experiment I, the treatments were T_1 [fodder cowpea (FC) with 100 % recommended dose of nitrogen (RDN)], T_2 (FC with 75 % RDN), T_3 (FC with 50 % RDN), T_4 [rice bean (RB) with 100 % RDN], T_5 (RB with 75 % RDN), T_6 (RB with 50 % RDN), T_7 [fodder maize (FM) with 100 % RDN)], T_8 (FM with 75 % RDN), T_9 (FM with 50 % RDN), T_{10} [(fodder sorghum (FS) with 100 % RDN)], T_{11} (FS with 75 % RDN), T_{12} (FS with 50 % RDN) and T_{13} (fallow during summer). The varieties of FC, RB, FM, FS and rice used were CO-9, Bidhan-2, African tall, CO FS-31 and Uma respectively.

Regarding physiological parameters, at 20 days after sowing (DAS), LAI was significantly higher in FM, which was on par with FC (100% RDN). CGR (1 to 20 DAS) was significantly higher in FM. However, for 20 to 40 DAS, FC (100% RDN) was significantly higher, which was on par with FM (75% RDN) and FS (100 % RDN). NAR (1 to 20 DAS) was significantly higher in FS (100 % RDN) which was on par with other treatments of FS (75 and 50% RDN) and RB (50% RDN). NAR (20 to 40 DAS) was significantly higher in FS with 100% RDN which was comparable with FS with 50% RDN. SCMR was significantly higher in FC both at 20 and 40 DAS.

Leaf: stem ratio was significantly higher in FC. FM produced significantly higher green fodder yield and dry fodder yield at all levels of nitrogen.

Crude protein content was significantly more in FC (100 % RDN) and was comparable with FC (75 % RDN) and RB (100 % RDN). Crude fibre was significantly less in FC (100 % RDN) and RB (100 % RDN).

At 20 DAS, weed smothering efficiency was significantly higher in RB (50% and 100 % RDN) which was on par with FC (100 and 75% RDN) and all the treatments of FM and FS. However, at 40 DAS, significantly higher weed smothering efficiency was in fodder cowpea (100 and 75% RDN).

Net income was significantly higher in FM (50% RDN) which was on par with other treatments of FM (100 and 75% RDN) and FC (100 and 75% RDN). However, in case of B:C ratio, FC (100 and 75%) was significantly superior.

The N balance sheet after summer crop was negative for all the treatments.

In *viruppu* rice crop, except plant height, all the growth and yield attributes, net income and B: C ratio was observed to be unaffected by the preceding summer crops.

The present study revealed that, among the different fodder crops tested, fodder maize performed better in the summer rice fallows with higher green fodder yield. However, with respect to net income it was comparable with fodder cowpea at 100 per cent and 75 per cent RDN. Fodder cowpea (100 and 75% RDN) recorded higher B: C ratio. Considering the shorter duration, better quality fodder and higher B: C ratio, fodder cowpea was assessed as the best fodder crop for the summer rice fallows. Yield, net income and B: C ratio of rice bean, fodder maize and fodder sorghum under varying doses of N were comparable, indicating the adequacy of 50 per cent RDN. Further, reducing the RDN for the summer crops did not have any adverse effect on the productivity and economics of the succeeding *virippu* rice.

സംക്ഷിപ്തം

"തീറ്റപുല്ലുകൾ ഉൾപ്പെടുത്തി നെലധിഷ്ഠിത വിള സമ്പ്രദായത്തിലെ ഉല്പാദനക്ഷമത മെച്ചപ്പെടുത്തൽ " എന്ന വിഷയത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. വിരിപ്പും മുണ്ടകനും നെൽകൃഷിക്ക് ശേഷമുള്ള വേനല്ക്കാല ഒഴിവ് നിലത്തിലെ നിർദേശിക്കപ്പെട്ട തോതിൽ നിന്നും വ്യതസ്ത അളവുകളിൽ (100, 75, 50 ശതമാനം) പാക്യജനകം വളമായി പ്രയോഗിച്ച് കൃഷി ചെയുന്ന വിവിധ തീറ്റപ്പുല്ലുകളുടെ അനുയോജ്യതയും തുടർന്നുള്ള വിരിപ്പ് നെൽകൃഷിയിൽ അതിൻറ്റെ അവശേഷിക്കുന്ന പ്രഭാവവും വിലയിരുത്തുകയായിരുന്നു പഠനലക്ഷ്യം.

തീറ്റപ്പുല്ലുകളിലെ, സി ഒ 9 എന്ന പയറിനം, ബിധാൻ 2 എന്ന അരിപ്പയറിനം, ആഫ്രിക്കൻ ടോൾ എന്ന ചോളയിനം, സി ഒ (എഫ് സ്) 31 എന്ന മണി-ച്ചോളായിനം എന്നിവ വേനൽക്കാലത്ത് കൃഷി ചെയ്തു. ഉമ എന്ന നെല്ലിനം തുടർന്നുള്ള വിരിപ്പുക്കാലത്ത് കൃഷി ചെയ്തു.

ചോളമാണ് വിളവ് അധികം നല്കിയത്. എന്നാൽ, വരുമാനത്തിൻറ്റെ കാര്യത്തിൽ പയറായിരുന്നു ലാഭകരം. നെൽകൃഷിയിൽ ശ്രദ്ധേയമായ മാറ്റങ്ങളൊന്നും കണ്ടില്ല. തീറ്റപ്പുല്ലുകളിൽ കുറഞ്ഞ അളവിലുള്ള (50 ശതമാനം) പാക്യജനക പ്രയോഗം മതിയാകുമെന്നും അത് തുടർന്നുള്ള നെല്ലിൻറ്റെ വിളവിനെ പ്രതികൂലമായി ബാധിക്കില്ലെന്നും പഠനത്തിൽ കണ്ടെത്തി.