PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH PULSES

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(2017-11-101)

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DECLARATION

I hereby declare that this thesis entitled **'Productivity enhancement of rice based cropping system with pulses'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **'Productivity enhancement of rice based cropping system with pulses'** is a record of research work done independently by **Mr. Adarsh S. (2017-11-101)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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5

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Dedicated to

PAPPA and AMMA

CONTENTS

9

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS & SYMBOLS

%	-	Per cent
&	-	And
BCR	-	Benefit-cost ratio
CD		Critical difference
CGR	-	Crop Growth Rate
cm	-	Centimeter
cm^{-2}	-	Per centimeter square
DAS	-	Days after sowing
DAT	-	Days after transplanting
EC	-	Electrical conductivity
FIB	-	Farm Information Bureau
Fig	-	Figure
FYM	-	Farmyard manure
g	-	Gram
g cc^{-1}	-	Gram per cubic centimeter
ha	-	Hectare
K	-	Potassium
K_2O	-	Potassium dioxide
KAU	-	Kerala Agricultural University
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
LAI	-	Leaf Area Index
M	-	Meter
m^{-2}	-	Per meter square
Mm	-	Milli meter
N	-	Nitrogen
NAR	-	Net Assimilation Rate
NS	-	Not significant
°C	-	Degree Celsius
°E	-	Degree East
°N	-	Degree North
P	-	Phosphorus

pH	-	Power of Hydrogen (pouvoir hydrogene)
POP	-	Package of Practices
P_2O_5	-	Phosphorous pentoxide
R	-	Replication
RARS	-	Regional Agricultural Research Station
RDN	-	Recommended dose of nitrogen
₹	-	Rupee
₹ ha^{-1}	-	Rupee per hectare
SCMR	-	SPAD Chlorophyll meter reading
Sem	-	Standard error of mean
T	-	Treatment
t	-	Tones
t ha^{-1}	-	Tones per hectare
USDA	-	United States Department of Agriculture
var.	-	Variety

15

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for the largest number of people on earth. Nearly, 90 per cent of worldwide cultivation is contributed by irrigated, rainfed and deep water systems, which totals about an area of 167 m ha and producing 759.6 m t of rice (FAO, 2018). Asia contributes about 686 m t to global share of rice from 149 m ha area (Bandumula, 2018). India has rice cultivation on 102 m ha area giving a production of 110 m t of rice (DAC & FW, 2018). Kerala has a rice production of 0.43 m t from an area of 0.17 m ha (FIB, 2019).

In Kerala, the performance of the rice crop in recent years is dismal regardless of its importance in agrarian economy. In northern Kerala, rice-rice-fallow is the major rice based cropping system, especially in the districts of Kasaragod, Kannur, Kozhikode (John *et al.*, 2014). Several farmers have been opting for crops of their choice and are converting paddy fields for other purposes. The greatest challenge in rice cultivation is to make it a remunerative venture by inclusion of different crops in rice based cropping systems.

Utilisation of summer fallows for raising different crops increases system productivity (Varughese *et al.,* 2007). Selection of the summer fallow crop should be done after considering various crop parameters like growth, rooting pattern, duration, and other factors like economics of cultivation and available nutrients left in rhizosphere for succeeding crop. Pulse crops are potential candidates for considering for summer rice fallows as they satisfy these criteria. They fix atmospheric nitrogen (Pillai *et al.*, 2007; Porpavai *et al.*, 2011) and enhance the physical, chemical and biological properties of soil. They have a prominent role in human nutrition also. They are very good sources of protein with low glycaemic index, low gluten content and even acts as a functional food (Rao, 2002). The World Health Organisation recommends 80 g pulses man^{-1} day^{-1}. The Indian Council of Medical Research (ICMR) recommends 40 g pulses man^{-1} day^{-1}. However, the actual availability ranges from 30 – 35 g pulses man^{-1} day^{-1}.

17

The total area under pulses in Kerala during 2015-16 was 3764 ha with a production of 4263 m t and productivity of 1133 kg ha^{-1} (FIB, 2019). Cowpea, green gram, black gram and red gram are the important pulse crops traditionally grown in Kerala. Due to various socio-economic reasons, the scope for bringing additional area exclusively for pulses cultivation is limited and no area is specifically earmarked for cultivation of pulses in Kerala. Cultivation of pulses in rice fallows, is the only opportunity for increasing the area and production of pulses. Pulses can be cultivated in summer fallows due to its drought tolerant property which helps it to grow on marginal lands, wastelands, summer fallows of cereals and areas of rainfed agriculture. Their short duration help them to be fit in the gap between main crops (FAO, 2016).

Introduction of pulse crop in the lowland summer rice fallows can augment the pulse production and also enhance the productivity of the rice based cropping system thereby enhancing the nutritional status of the system (Khadkam and Paudel, 2010). The nitrogenous fertilizers applied to the first and second rice crop along with the incorporated rice stubbles might have a positive residual effect and hence, there is a prospect for reducing the nitrogen requirement of the pulse crops raised during summer. Besides, the raising of pulses during summer is likely to improve productivity of the succeeding *virippu* rice crop (Pratibha *et al.*, 1997; Mishra *et al.*, 2013). Pulses were found to increase the net returns and benefit cost ratio of the system (Nayak, 2005).

Though the performance of different pulses raised as sole crops has been studied, a cropping system based investigation has not been undertaken. In this context, the present investigation entitled "Productivity enhancement of rice based cropping system with pulses" is proposed with the aim of evaluating the following objectives.

i. To find the suitability of common pulses in summer fallow of double cropped lowland rice fields under varying nitrogen regimes

ii. To determine the residual effect of the pulses on the succeeding *virippu* rice crop.

Review of literature

2. REVIEW OF LITERATURE

2.1 Introduction

The productivity of rice, a major food crop of India is reduced (Yadav *et al.*, 1998) owing to decline in soil fertility and increase in multiple nutrient deficiency (Fujisaka *et al.*, 1994; Singh and Singh., 1995). Continuous intensive agriculture of a high yielding variety of cereal leads to exhaustion of soil nutrients (John *et al*, 2001). Inclusion of pulses in cereal based cropping systems was found beneficial (Kumpawat, 2001) since the scope of summer rice cultivation in lowlands is restricted due to water availability. Hence, cropping systems with short duration and crops requiring less water is likely to assure increased production and income.

In northern Kerala, rice-rice-fallow is the major rice based cropping system, especially in the districts of Kasaragod, Kannur, Kozhikode (John *et al.*, 2014). Prathibha *et al.* (1997) recorded that rice-rice-black gram sequence registered higher production efficiency. Black gram and red gram were found to be more suitable in paddy fallows due to their yielding ability, higher net returns and high benefit cost ratio (Nayak, 2005). Pillai *et al.* (2007) concluded that including legumes *viz.* cowpea and groundnut in the rice based cropping system resulted in positive balance of nitrogen in the soil.

The literature falling within the scope of the investigation is reviewed in this chapter. Research information on other related crops and cropping systems are reviewed, where pertinent literature is lacking.

2.2 Pulses in rice based cropping systems

Pulses are important components of rice based cropping systems (Byth *et al.*, 1987). Sequential cropping with residue incorporation of green gram, cowpea, black gram and pigeon pea in rice fallows provided more available soil nutrients and increased system productivity of rice (Kulkarni and Pandey, 1988).

Cowpea, green gram and black gram were found suitable in summer rice fallows (Prasad, 1985; Singh, 1988; Alam, 1989). Pulses are grown in rice based cropping systems of tropics as a source of protein, fodder and green manure (Buresh and De Datta, 1991). Cowpea, green gram, black gram and red gram were found suitable in summer rice fallows (Pande *et al.,* 2012).

2.3 Performance of pulse crops in sequential cropping system

Pulses performed significantly in terms of growth and yield when cultivated in summer rice fallows (Tuteja, 2006; Kar and Kumar, 2009). The growth and dry matter accumulation of pulses improved when cultivated in rice fallows (Miah *et al*., 2009; Jat *et al.*, 2012). The yield, growth, dry matter production, system productivity, net return and economics of pulse cultivation was increased when cultivated in summer rice fallows, where preceding rice residues were incorporated (Behera *et al.,* 2014).

2.3.1 Growth attributes of pulse crops

The increase in growth characters of pulses was due to residual effect of preceding rice (Siag and Prakash, 2007; Ghosh *et al.,* 2012; Ali, 2014; Behera *et al.,* 2014). The plant height and number of branches of pulses were found higher in minimum tillage soils (Banjara *et al.*, 2017).

2.3.2 Physiological parameters of pulse crops

Cowpea showed higher dry matter production than green gram in rice fallows on summer (Mutnal *et al.*, 1994). Meena *et al.* (2015) reported that the dry weight of pulses was maximum in undisturbed soils. The dry weight of chick pea was found higher in minimum tillage soils (Banjara *et al.*, 2017). The increase in leaf area index, dry matter and other physiological characters were due to residual effect of preceding rice (Siag and Prakash, 2007; Ghosh *et al.*, 2012; Ali, 2014; Behera *et al.*, 2014).

2.3.3 Yield of pulse crops

The grain yield of green gram increased in nutrient managed soils than non-fertilised on fallows of rice cultivated areas (Lakshmi *et al*., 2012). Nayak *et al.* (2005) reported that when pulses were cultivated in summer rice fallows the crop equivalent yield in terms of rice was highest (3639 kg ha^{-1}) for red gram and black gram compared to cultivation of pulses in upland.

The increase in yield and yield attributes of pulses were due to residual effect of preceding rice (Siag and Prakash, 2007; Ghosh *et al.*, 2012; Ali, 2014; Behera *et al.*, 2014). The number of pods per plant and grain yield of lentil increased when it was cultivated on rice fallows (Singh *et al.*, 2015).

The yield of lentil increased when it was grown on double cropped rice fallows during summer with rice residue as mulch (Shylla *et al.*, 2016). The number of pods per plant and seed yield of chick pea were higher under minimum tilled soils (Banjara *et al.*, 2017). The number of pods per plant and grain weight increased as the amount of nutrients in the preceding crop increased (Tripathi *et al.*, 2009; Singh *et al.*, 2013; Jagannath *et al.*, 2017).

2.3.4 Weed flora in pulses

Dicotyledonous weeds dominated in summer season cultivated cowpea (Mathew and Sreenivasan, 1998). The major weeds in cowpea raised in summer were *Dactyloctenium aegyptium*, *Eleusine indica*, *Gnaphalium indicum*, *Cyperus rotundus*, *Echinochloa crusgalli* and *Sorghum halepense* (Tripathi and Govindra Singh, 2001).

Digitaria sanguinalis, *Cyperus amuricus*, *Portulaca oleracea*, *Amaranthus retroflexus* were also reported in cowpea grown during summer fallow (Lee Kwang Hoe, 2007). *Cyperus rotundus*, *Eluesine indica*, *Euphorbia hirta* and

22

Mollugo sp. were reported in green gram and black gram intercropping system (Kumar *et al.*, 2000; Reddy *et al.*, 2000).

2.3.5 Nutrients removed during pulse cultivation

2.3.5.1. Nutrient uptake by pulses

Kumari and Ushakumari (2002) reported that cowpea plant exported 53.42 kg N, 7.26 kg P_2O_5 and 23.78 kg K_2O ha^{-1}, when grown according to KAU POP recommendations.

Cowpea contains 0.37 % P in plant, when cultivated as per KAU POP (Meena and Hameed, 2002).

Pillai *et al* (2007) reported that cowpea removed 32.5 kg ha^{-1} nitrogen when cultivated as per KAU POP recommendation.

Pulses grown in summer rice fallows have higher N, P and K content, which may be due to the availability of these nutrients from the residues of rice incorporated (Singh *et al.*, 2013; Jagannath *et al.*, 2017).

2.3.5.2 Nutrients removed by weeds

Weeds removed 79 kg N, 19 kg P_2O_5 and 79 kg K_2O, when green gram was cultivated in summer fallow (Kundra *et al.*, 1991).

Kaur *et al.* (2010) found that weeds removed 68 kg N, 19 kg P_2O_5 and 77 kg K_2O when green gram was cultivated in summer fallow.

The nutrient removal of weeds was reported significantly superior by Shalini and Singh (2014) amounting to 11 kg N, 1.2 kg P_2O_5 and 12 kg K_2O, when dwarf field pea was cultivated in summer fallow.

About 15 kg N, 2 kg P_2O_5 and 11 kg K_2O were removed by weeds when cowpea was cultivated in summer fallow (Kujur *et al.*, 2015).

2.3.6 Residual effect of pulses on succeeding rice

2.3.6.1 Growth characters

The residue incorporation of pulses grown in summer fallows caused higher plant height and no. of tillers in rice (Jacob, 1994). The growth characters of boro rice increased when green manuring was done on transplanted aman rice and the residues incorporated to subsequent boro rice (Pramanik, 2006). The growth and yield parameters of rice increased when pulses were grown in summer fallows and residues incorporated to following rice (Yadav *et al.*, 2018).

2.3.6.2 Pulses on rice productivity

Rekhi and Meelu (1983) reported that addition of green gram residues cultivated in summer increased rice yield by 0.9 t ha^{-1} and supplied 100 kg N ha^{-1}. Rice yield subsequently cultivated after green gram cultivated in summer fallows was increased (Anil *et al.*, 1988).

Grain and straw yield of rice increased when legumes were cultivated as preceding crops (De *et al.*, 1983). Cowpea (bush type) residue was found to increase succeeding rice yield (John *et al.*, 1989, 1992; Palaniappan and Siddeswaran, 1990; Meelu *et al.*, 1992; Kumar *et al.*, 1993; Padhi, 1993; Jacob, 1994).

Silsbury (1990) reported that the rice yield increased by 10 per cent by incorporating pulse residues cultivated in summer fallows. Haulm incorporation of cowpea and black gram improved rice productivity by 10.4 per cent (Siddeswaran, 1992). Addition of crop residues provided more nutrition to rice crop causing high yield (Mahapatra *et al.*, 2002).

Cultivating pulse crops in summer rice fallows improved succeeding rice yield (Wu and Yan, 1992; Ali, 1993; Hegade and Dwivedi, 1993; Dogbe, 1998; Rahman *et al.*, 1998; Menon *et al.*, 1999; Singh and Verma, 1999; and Phogat *et al.*, 2004). Mishra *et al.* (2013) reported that rice productivity was enhanced by 17 per cent by including of pulses in summer fallows than monocropping.

2.3.7 Pulses on soil fertility

Integration of legumes in the systems could enrich soil (Khadkam and Paudel, 2010). The soil chemical properties were found to improve in cereal based cropping system, including pulses cultivated in summer rice fallows (Alam *et al.*, 2014).

Cropping systems including legumes uptake less K from soil (George and Prasad, 1989). Inclusion of cowpea, green gram, black gram and pigeon pea in cropping systems reduced fertiliser N need in succeeding cereals (Faroda and Singh, 1983). The increase in soil N is due to lower soil N uptake by pulses, carry over of N from legume residues and fixing of atmospheric N by legumes (Mongia *et al.*, 1989; Danso and Papastylianou, 1992).

Total N content in soil was high when preceding crop was legume (Mandal *et al.*, 1992; Sidhu and Sur, 1993). Cowpea showed higher nitrogen fixation than green gram when raised in rice fallows during summer (Mutnal *et al.*, 1994). Reddy *et al* (1994) reported that cultivating pulses before cereals lowered the C:N ratio of soils. Addition of cowpea residue added 76.8 N kg ha^{-1} to soil (Reddy *et al.*, 1995).

Positive balance of soil N was found when cowpea was cultivated in rice-wheat-pulse cropping system (Singh *et al.*, 1996). The N content was higher in soils where cowpea had been cultivated and residues were incorporated in summer rice fallows (Jacob, 1994; Mahapatra *et al.*, 2002). Gangwar and Ram (2005) reported that the soil N content increased when green gram and black gram were cultivated in summer rice fallows.

The P and K content in soil was higher when cowpea was cultivated in summer fallows and residue incorporated to the next rice crop (Jacob, 1994; Mahapatra *et al.*, 2002). Paikaray *et al.* (2002) reported a positive P and K balance in soil, where cowpea was cultivated in summer rice fallows. Gangwar and Ram (2005) reported that the soil P and soil K content increased when green gram and black gram were cultivated as crops during summer rice fallows.

25

2.3.8 Economics of pulse cultivation

The B : C ratio was of rice-rice-cowpea system was remarkable when considered as system (Jacob, 1994). Kumar *et al.* (1993) reported rice – rice – cowpea system fetched ₹. 10,336 ha^{-1}. Nayak *et al.* (2005) reported that net returns from black gram and red gram was ₹. 12213 ha^{-1} and ₹. 11823 ha^{-1} respectively in rice-rice-pulse system which was significantly higher than sole cropping of pulses. The highest benefit cost ratio was noticed in rice-rice-green gram system with incorporated rice residues and 75 per cent of recommended dose of fertiliser (Lakshmi *et al.*, 2012).

Integration of legumes in the systems would be beneficial to farmers because of better nutritional status and attractive price in the market (Khadkam and Paudel, 2010). The increase in profit with pulse cultivation was due to residual effect of preceding rice stubbles incorporated, thus causing more nutrient uptake of pulse crops (Siag and Prakash, 2007; Ghosh *et al.,* 2012; Ali, 2014; Behera *et al.,* 2014). The number of pods per plant and seed yield of chick pea was higher in minimum tilled soils (Banjara *et al.*, 2017).

2.4 Nitrogen nutrition on rice

2.4.1 Growth parameters of rice

Nitrogen plays an important role in all plant tissues by forming constituent of proteins, enzymes, hormones, vitamins and chlorophyll (Balasubramaniyan and Palaniappan, 2005) and plant growth was negatively affected in its absence (Reddy and Reddy, 2005). The N application increased plant height of rice (Maqsood *et al.,* 2005; Manzoor *e al.,* 2006; Awan *et al.,* 2011).

The plant height and number of tillers m^{-2} in rice increased with increase in N application (Sharief *et al.*, 2006). The number of tillers increased with N fertilization up to 120 kg N ha^{-1} (Anil *et al.,* 2014; Bai *et al.,* 2014) and to 150 kg N ha^{-1} (Zaidi and Tripathi, 2007). The plant height was increased when N dose was increased from 120 to 160 kg ha^{-1} and applied in splits (Hebbal, 2015; Singh *et al.*, 2015; Anusha, 2016).

2.4.2 Yield and yield attributes of rice

Higher yield and yield attributes were observed by increasing N level up to 100 kg ha^{-1} (Sharma and Tomar, 1997). Ramamoorthy *et al.* (1997) reported that grain yield increased significantly on increasing N application of N up to 200 kg ha^{-1}.

Singh *et al.* (2000) and Sharief *et al.* (2006) observed an increase in grain and straw yield of rice, when N application was increased from 0 to 120 kg ha^{-1}.

The yield was found to increase when the amount of N added was increased (Quyen and Sharma, 2003). Application of 125 kg N ha^{-1} enhanced no. of tillers m^{-2}, 1000 grain weight and yield of crop (Maqsood *et al*, 2005). Srinivasan *et al.* (2007) confirmed the increased yield of rice when N was increased up to 150 kg N ha^{-1}.

The grain and straw yield of rice increased, when N was added up to 150 kg N ha^{-1} (Zaidi and Tripathi, 2007). The economic yield increased by 62 per cent, when N was added from 0 to 120 kg ha^{-1} (Singh *et al.*, 2007).

The increased application of nitrogen improved the thousand grain weight in rice (Awan *et al.*, 2011). The duration to remain green depends on the amount of N available to the crop, which ultimately leads to production of more yield (Fageria and Moreira, 2011).

The productive tillers m^{-2}, thousand grain weight, grain yield and straw yield increased by increasing nitrogen fertilisation (Srivastava *et al.*, 2014; Jagannath *et al.*, 2017).

The harvest index of rice was highest when addition of N was increased (Hebbal *et al.*, 2017). The harvest index was 0.42, when N was applied at 120 kg ha^{-1} (Rawal *et al.*, 2017).

27

2.4.3 Nutrient uptake by rice

Narang *et al.* (1990) reported that rice yielding 9.5 t ha^{-1} took up 198 kg N, 31 kg P_2O_5 and 230 kg K_2O ha^{-1}. Varughese (2006) reported that rice removed 92.8 kg N, 13.9 kg P_2O_5 and 109.5 kg K_2O ha^{-1}, when cultivated as per KAU POP recommendation.

Application of N up to 90 kg ha^{-1} improved the nutrient uptake and dry matter accumulation of rice (Naseer and Bali, 2007). Increased levels of N from 50 to 150 kg N ha^{-1} improved thousand grain weight, no. of effective tillers and yield of rice (Pandey *et al.,* 2008). Pooniya and Shivay (2011) and Sharma *et al.* (2015) reported maximum uptake of nutrients in rice grown with fertilisers, FYM and residues of legumes.

2.4.4 Soil Nutrient Status

The availability of nitrogen in soil increased when crop residues of pulses grown in summer fallows and inorganic fertilisers were applied (Shukla *et al.,* 2001; Deshpande and Devasenapathy, 2010).

Increase of N was 0.12 %, when N fertiliser was added in the crop residue incorporated area (Ali, 1993). Soil nutrient status of N, P and K were higher in plots where recommended dose of fertiliser was added and legume residues were incorporated (Yang *et al*., 2004; Sharma *et al*., 2015)

2.4.5 Economics of rice cultivation

Baksh *et al.* (2011) reported that split application of N improved the gross income, net income and benefit cost ratio of cultivation. Gupta *et al.* (2011) reported that split application of N at the rate of 120 kg ha^{-1} improved the economics of cultivation. Split application of N at the rate of 125 kg ha^{-1} improved the economics of the system (Hebbal, 2015). Baksh *et al.* (2017) reported that application of N at the rate of 80 kg ha^{-1} improved the economics of cultivation.

The foregoing review indicates that pulse crops can restore soil fertility decline and enrich soils with N and organic matter, thereby improving the yield of subsequent crop. Pulse crops grown in summer rice fallows had beneficial residual effects on the yield of following cereal crop. The significant influence of legumes on succeeding crops has been illustrated by several authors.

Though the performance of different pulses raised as sole crops and its residual effect on succeeding rice crop have been studied, for which reviews are available, a cropping system based investigation has not been undertaken so far. Review on pulses under varied nitrogen levels in rice based cropping system is meagre. There is also a dearth of information on the residual effect of the pulses on a succeeding rice crop.

Therefore, the present study is imperative to fulfil the objectives of evaluation of the suitability of common pulses in summer fallow of double cropped lowland rice fields under varying nitrogen regimes and assessment of the residual effect of pulses on the succeeding *virippu* rice crop.

Materials and methods

3. MATERIALS AND METHODS

The investigation entitled "Productivity enhancement of rice based cropping system with pulses" was undertaken with the objectives of assessing the suitability of different pulse crops in summer fallow of double cropped lowland rice fields, under varying nitrogen levels, and its residual effect on the succeeding *virippu* rice crop. The experiment was conducted during February 2018 to October 2018, in double cropped lowland rice fields at Regional Agricultural Research Station (RARS), Pilicode, Kasaragod. The details of materials used and methods adopted for the study are described in this chapter.

3.1 EXPERIMENTAL SITE

The experimental field is the double cropped lowland rice field located at 12°12'209'' N to 12°15'397" N latitude and 75°7'025" E to 75°10'580'' E longitude at an altitude of 6 m above mean sea level. The geographical location of the experimental plot is shown in Fig. 1. The images used for showing geographical location are acknowledged in the reference section (Google image, 2019 a, b, c, d).

3.1.1 Climate

A warm humid tropical climate prevails over the experimental site. The data on weather parameters (rainfall, maximum temperature, minimum temperature, relative humidity) during the cropping period were collected from agrometeorological field unit (AMFU) at RARS, Pilicode which acts as the nodal observatory for northern zone under Kerala Agricultural University. The details of weather parameters are summarized in Appendix 1 & 2 and depicted graphically in Fig. 2a and 2b. The rainfall received during the period of experiment of summer fallow crop extended from 24th February to 25th May 2018 was 80.2 mm, while that during the first crop season (*virippu* rice) from 1st June to 10th October 2018 is found

31

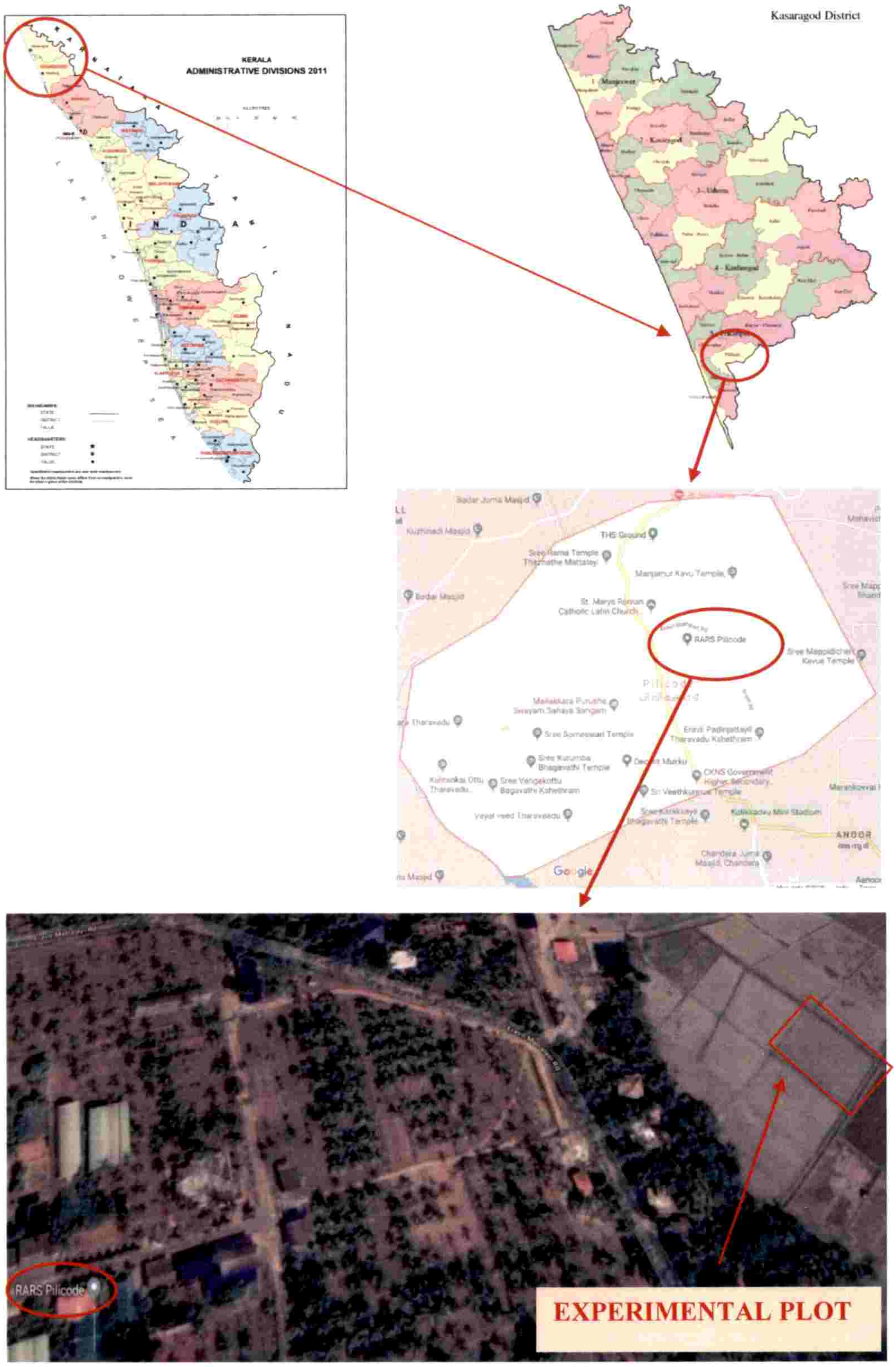

Fig. 1. Geographical location of the experimental plot

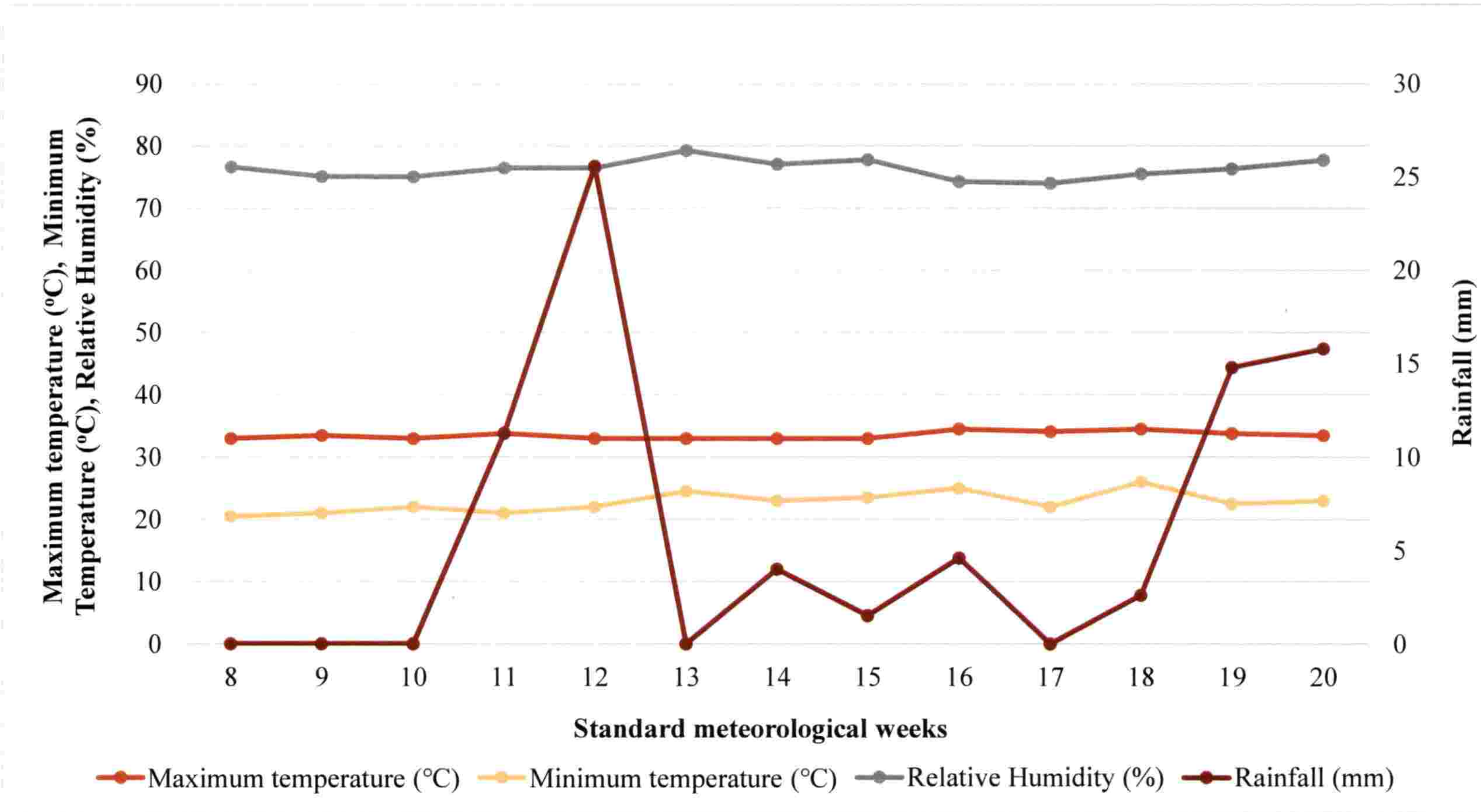

Fig. 2a. Weather data during summer crop period (February to May 2018)

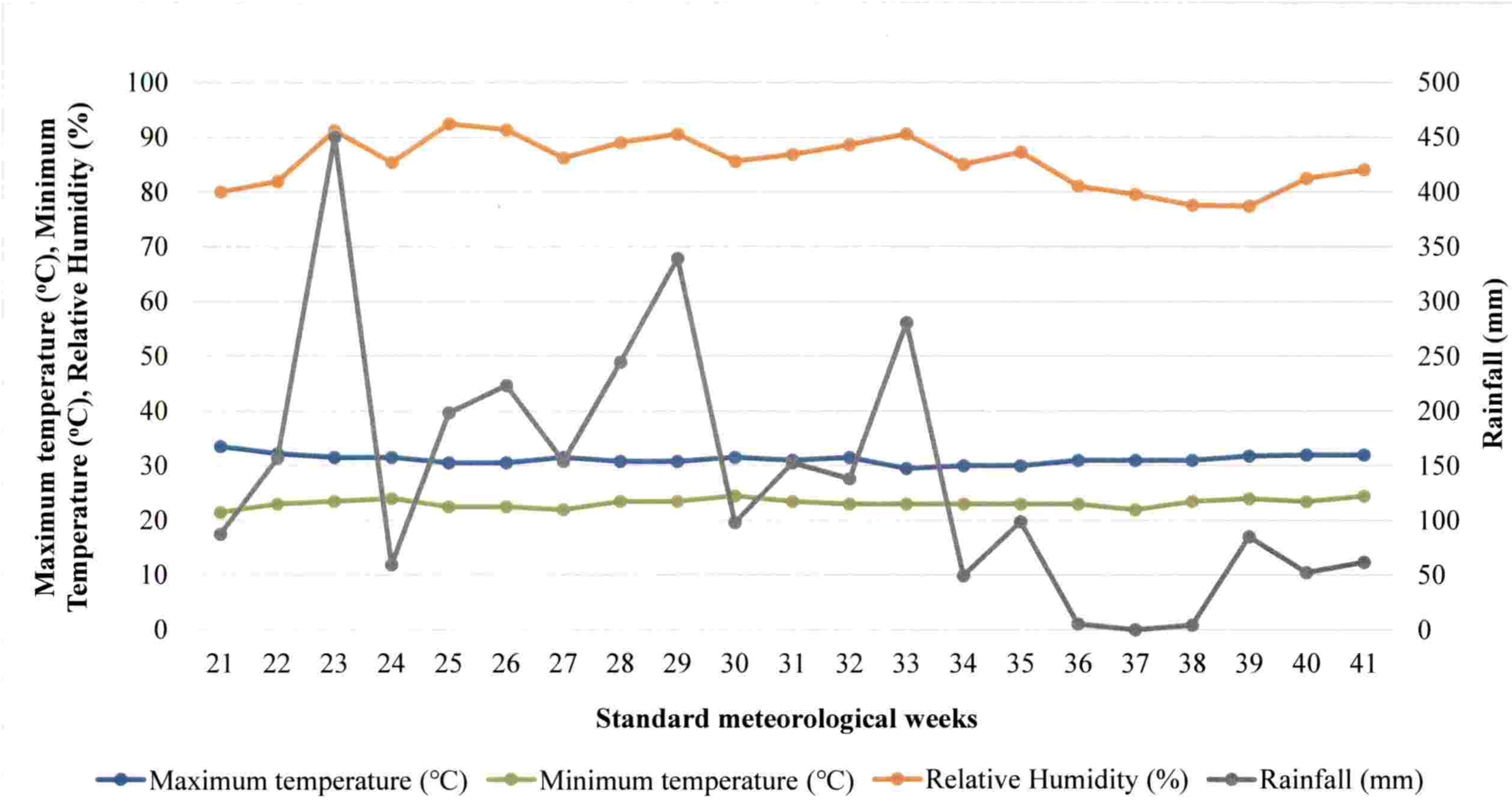

Fig. 2b. Weather data during *virippu* crop period (June to October 2018)

as 2862.1 mm. During summer crop, the maximum and minimum temperature varied between 33°C and 34.5°C and 20.5°C and 26°C respectively. During first crop season, the maximum and minimum temperature varied between 29.5°C and 32.2°C and 22°C and 24.5°C respectively.

3.1.2 Cropping Season

The experiment was conducted in two seasons of 2018 *i.e.* with summer fallow pulse crops (24th February– 24th May, 2018) *viz*., cowpea, green gram, red gram and black gram followed by the v*irippu* rice (var. Uma) (1st June-10th October 2018).

3.1.3 Soil

Composite soil samples were collected from 15 cm depth from the site before the experiment and analysed for the physico-chemical properties, and are abridged in Tables 1 and 2. The soil properties were rated as per the classification given in the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2016). The soil of the experimental site, which falls under the order Ultisol (FAO, 1974), was sandy clay loam in texture, extremely acidic in pH and, high in available nitrogen, available phosphorus and available potassium. The bulk density of the soil, estimated by undisturbed core sample (Black *et al*., 1965), was 1.31 Mg m^{-3} while the particle density, estimated by pycnometer method (Black *et al*., 1965), was 2.35 Mg m^{-3} .

Table 1. Mechanical composition of soil of the experimental site

Sl. No.	Fraction	Content (%)	Method
1.	Fine sand	27.6	International Pipette Method (Piper, 1967)
2.	Coarse sand	27.4	
3.	Silt	22.6	
4.	Clay	22.4	
Soil texture: Sandy clay loam (USDA textural triangle, (USDA, 1999))			

3.1.4 Cropping History of Experimental Plot

The experiment was conducted in the lowland rice field of RARS, Pilicode, where the cropping sequence rice-rice-fallow was followed.

Table 2. Chemical properties of soil of the experimental site and the analytical methods adopted

Sl. No.	Property	Value	Rating	Method
1.	pH (1:2.5)	4.33	Extremely acid	pH meter (Jackson, 1973)
2.	Electrical Conductivity ($dS\ m^{-1}$) (1:2.5)	0.05	Suitable for all crops	Conductivity meter (Jackson, 1973)
3.	Organic carbon (%)	0.65	Medium	Wet digestion method (Walkley and Black, 1934)
4.	Available nitrogen ($kg\ ha^{-1}$)	564.48	High	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available phosphorus ($kg\ ha^{-1}$)	86.76	High	Bray No.1 extraction and spectrophotometry (Jackson, 1973)
6.	Available potassium ($kg\ ha^{-1}$)	371.84	High	Ammonium acetate method (Jackson, 1973)

3.2 MATERIALS

3.2.1 Crops and Variety

3.2.1.1 Cowpea

The variety used was PGCP 6, released from Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. It is an early maturing (65-70 days), bush type (50-55 cm tall), high yielding variety of cowpea developed from IT98K-889-1 following pure line selection. It is resistant to yellow mosaic virus and bacterial blight. The seeds are kidney to oval in shape with brown colour. It contains 27 per cent protein. The seeds were obtained from RARS, Pattambi.

3.2.1.2 Black gram

The variety used was Co 6, released from Tamil Nadu Agricultural University (TNAU), Coimbatore. It is a derivative of the cross between MGG 336 and COGG 902, has high protein content (25.2 %), high seed weight and exhibits synchronized maturity. The seeds of the variety were obtained from RARS, Pattambi.

3.2.1.3 Green gram

The variety used was Co 8, released from TNAU, Coimbatore. It is a cross between COGG 923 x VC 6040A. It attains 50-55 cm height, with 60 days duration and broad pubescent leaves and pods having green smooth surface. The seeds were obtained from RARS, Pattambi

3.2.1.4 Red gram

The variety used was APK 1, released from TNAU, Coimbatore. It is a pure line selection from ICPL 87101 released in 1999, and has a duration of 95-105 days. It is erect and determinate in growth with deep red coloured standard petal and greenish purple streaks coloured pods with reddish brown seeds. The seeds were procured from Regional Research Station (RRS), Aruppokotai, TNAU, since specific recommendations were not available for red gram.

3.2.1.5 Rice

The variety used was Uma (Mo 16), released from the Rice Research Station, Moncompu of Kerala Agricultural University. It is of medium duration (115-120 days), medium tillering, non-lodging and resistant to brown plant hopper. The seeds were obtained from RARS, Pilicode.

3.2.2 Manures and Fertilizers

Farmyard manure (0.69% N, 0.13% P_2O_5 and 0.22% K_2O respectively) was used for both experiments. Straight fertilizers *viz*., urea (46% N), rock phosphate (18% P_2O_5) and muriate of potash (60% K_2O) were used as a source of nitrogen (N), phosphorus (P) and potassium (K) respectively for all crops. The dose of fertilisers was as recommended in the Package of practices recommendations of Kerala Agricultural University (KAU, 2016) for cowpea, black gram and green gram. The recommended dose of fertiliser applied for red gram was according to the information received from Regional Research Station, Aruppokotai, TNAU.

3.3 METHODS

3.3.1. Experimental Design and Layout

The experiment was laid out in randomised block design and the layout plan is presented in Fig. 3.

Design	: Randomised Block Design
Treatments	: 13
Replication	: 3
Plot size	: 5 m x 4 m
Spacing	: 30 cm x 15 cm (Cowpea)
	25 cm x 15 cm (Green gram, Black gram)
	60 cm x 15 cm (Red gram)
	20 cm x 15 cm (Rice)

Experiment 1 (Summer 2018)

Treatments : 13

T_1 Cowpea with 100 per cent N of RD*

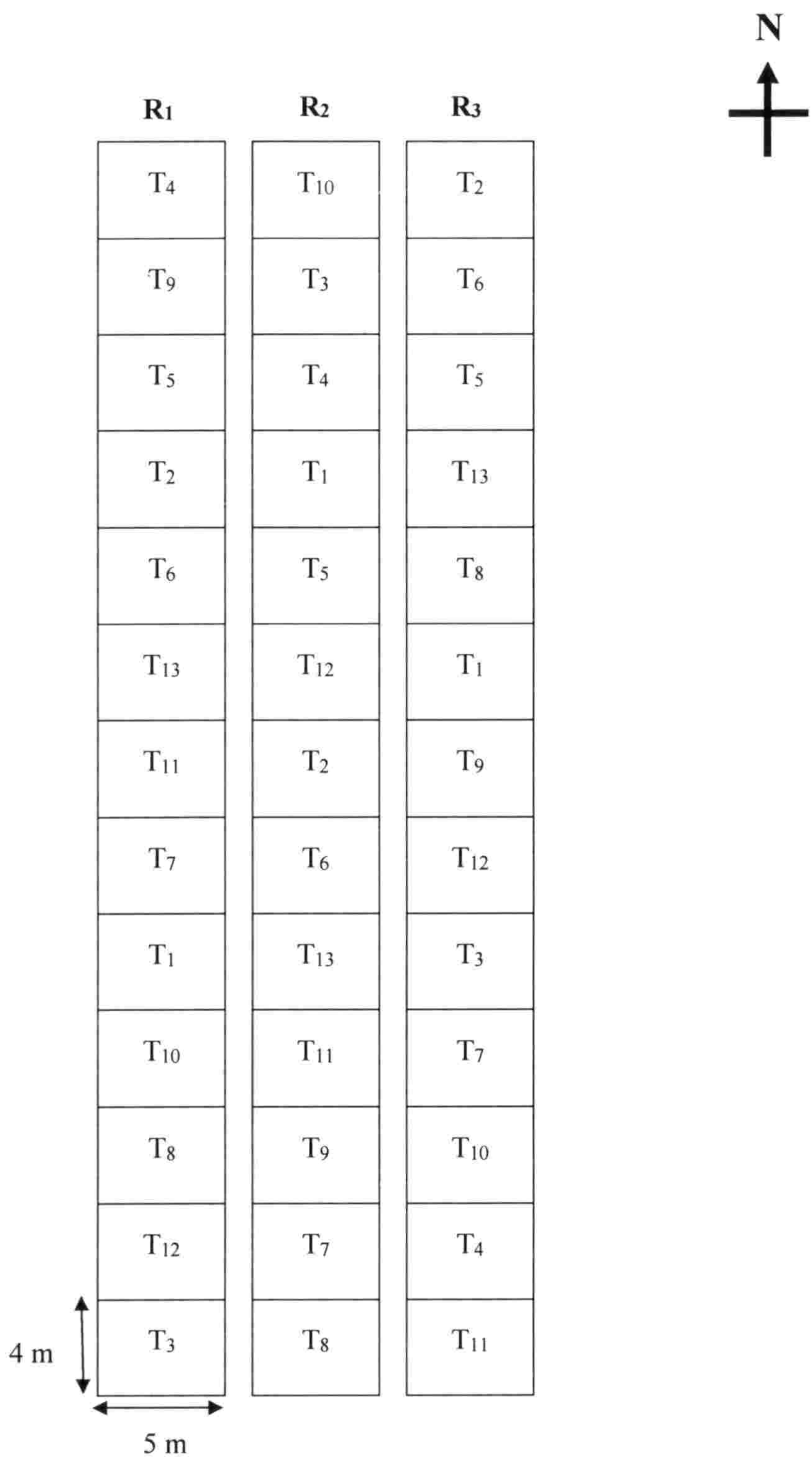

Fig 3. Layout of the experimental plot

T_2 Cowpea with 75 per cent N of RD*

T_3 Cowpea with 50 per cent N of RD*

T_4 Black gram with 100 per cent N of RD*

T_5 Black gram with 75 per cent N of RD*

T_6 Black gram with 50 per cent N of RD*

T_7 Green gram with 100 per cent N of RD*

T_8 Green gram with 75 per cent N of RD*

T_9 Green gram with 50 per cent N of RD*

T_{10} Red gram with 100 per cent N of RD**

T_{11} Red gram with 75 per cent N of RD**

T_{12} Red gram with 50 per cent N of RD**

T_{13} Control (fallow during summer)

*RD: Recommended dose as per Package of Practices Recommendations of Kerala Agricultural University (KAU, 2016) for cowpea, green gram and black gram.
**RD: Recommended dose as per information received from Regional Research Station, Aruppokotai, TNAU.

Experiment 2 (*Virippu* 2018)

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

3.3.2 Crop Management

3.3.2.1 Summer crop

3.3.2.1.1 Land preparation

After harvest of *mundakan* rice crop of 2017-18, weeds were removed, stubbles of previous rice crop were incorporated by ploughing. The field was modified to flat beds of 5 m length and 4 m width with an interbed distance of 30 cm raised to prevent mixing of soil nutrients as rectangular basin suited to check basin system of irrigation. The experimental plot was separated from the main pathways/bunds with a distance of 60 cm on all sides. The land was perfectly levelled and brought to a fine tilth.

3.3.2.1.2 Application of lime, manures and fertilizers

Lime, FYM (farmyard manure), N, P and K were applied as per the Package of practice recommendations (KAU, 2016) and for red gram it was given according to RRS, Aruppokotai, TNAU as shown in Table 3.

Table 3. Details of lime, FYM and nutrients supplied for the different pulses

Crops	Lime (kg ha^{-1})	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Cowpea	250	20	20*	30	10
Black gram	250	20	20*	30	30
Green gram	250	20	20*	30	30
Red gram	250	12.5	20*	50	25

*The N dose given for treatments with 100% N of RD, will be 15 kg N ha^{-1} and 10 kg N ha^{-1} for treatments with 75% N of RD and 50% N of RD respectively.

3.3.2.1.3 Seeds and sowing

Pulses were line sown on 24th February 2018. The seed rate and spacing at which pulse crops were sown are given in Table 4.

3.3.2.1.4 Irrigation

Need based irrigation was given with sprinkler irrigation.

Table 4. Details of seed rate and spacing at which pulse crops were sown

Sl. No.	Pulse Crop	Seed rate (kg ha^{-1})	Spacing
1.	Cowpea	60	30 cm x 15 cm
2.	Black gram	25	25 cm x 15 cm
3.	Green gram	25	25 cm x 15 cm
4.	Red gram	25	60 cm x 15 cm

3.3.2.1.5. Gap filling

Gap filling was done for pulses one week after planting.

3.3.2.1.6 Weeding

Weeding was done at 20 and 40 DAS, with hoe, for pulses completely, except in the 2 m^2 area per plot set apart for observations on weeds.

3.3.2.1.7 Harvesting

First harvesting of cowpea, green gram and black gram was done at 26th April 2018, when the mature pods started to dry. On 30th April 2018, second harvesting was done. First harvesting was done by picking the dried pods with hands and the second harvesting was done by uprooting the whole plant. After drying, pods were threshed by beating with sticks and the seeds separated. Red gram was harvested on 15th June 2018.

3.3.2.2 First crop / virippu rice of 2018-19

3.3.2.2.1 Land preparation: Nursery

Wet nursery method was adopted for raising seedlings. The nursery area was ploughed, levelled and beds of 15 cm height, 1-1.5 m width and 10 m length were prepared with drainage channels between beds. Farmyard manure was applied @ 1 kg m^{-2} and incorporated manually. Pregerminated seeds were sown on beds.

3.3.2.2.2 Land preparation: Main field

After harvest of summer crop, the crop residues were manually chopped and incorporated in the soil. The plots were puddled separately without disturbing the bunds in between during first week of June 2018. The dimensions of the plots were same as that of summer crop.

3.3.2.2.3 Application of lime, manures and fertilizers

Lime, FYM, N, P and K were applied as per the package of practices recommendations for medium duration variety of rice (KAU, 2016). FYM was applied 2 weeks before transplanting of rice at the rate of 5 t ha^{-1} and incorporated manually. Full dose of P and half dose of N and K were applied as basal dose and remaining half of N and K was given at panicle initiation (KAU, 2016).

3.3.2.2.4 Transplanting

Seedlings aged 21 days were transplanted to plots at a spacing of 20 cm x 15 cm at the rate of 2-3 seedlings per hill.

3.3.2.2.5 Water management

The water level was maintained at 2 cm at transplanting and was increased to 5 cm after one week of transplanting. Subsequently, a water level of 5 cm was maintained in the plots. The field was drained two weeks before harvest.

3.3.2.2.6 Weeding

Weeding was done at 20 and 40 DAT completely.

3.3.2.2.7 Harvesting

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

3.4 OBSERVATIONS ON CROPS

3.4.1 Pulses

Sampling Procedure

Observations on pulses were taken from five plants per plot from tagged plants at monthly intervals for growth attributes, at harvest for yield and yield attributes, at 20 and 40 DAS for physiological parameters. Observations on weeds were taken at 20 and 40 DAS from 2 m^2 area per plot earmarked for this, such that separate 1 m^2 area will be used for taking observations at 20 DAS and 40 DAS. Soil samples were collected from the root zone of observational plants and quartering method was used to draw soil sample per plot.

3.4.1.1 Growth Attributes

3.4.1.1.1 Height of the plant

The plant height was measured from ground level to the growing tip of the main stem and expressed in cm.

3.4.1.1.2 Number of branches per plant

The number of branches per plant was recorded and the mean was worked out.

3.4.1.2 Yield and Yield Attributes

3.4.1.2.1 Number of pods per plant

The number of pods per plant was recorded and mean was worked out.

3.4.1.2.2 Grain Weight

The grain weight per plot was found and expressed in kg ha^{-1}.

3.4.1.3 Physiological Parameters

3.4.1.3.1 Leaf area index (LAI)

Leaf area index (LAI) was worked out using the formula suggested by Watson (1947).

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

3.4.1.3.2 Crop growth rate (CGR)

The crop growth rate (CGR) was calculated using the formula suggested by Watson (1947) and expressed in g m^{-2} per day.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

45

where,

W_1 : Initial dry weight of plant (g)

W_2 : Final dry weight of plant (g)

t_1 : Initial time (day)

t_2 : Final time (day)

P : Land area occupied by plant (m^2)

3.4.1.3.3 Net assimilation rate (NAR)

The net assimilation rate (NAR) was calculated by the formula given by Gregory (1926) and expressed in g cm^{-2} per day.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1}$$

where,

A_1 : Total leaf area at t_1 (cm^2)

A_2 : Total leaf area at t_2 (cm^2)

W_1 : Initial dry weight of plant (g)

W_2 : Final dry weight of plant (g)

t_1 : Initial time (day)

t_2 : Final time (day)

3.4.1.3.4 SCMR (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 observation was taken during morning (between 09.00 a.m. to 11.00 a.m.). The third apical leaf of pulse crop was selected for the measurement.

46

3.4.2 Rice

Sampling Procedure

Observations on rice were taken from five hills per plot from tagged plants. Growth attributes were recorded at 20 and 40 DAT and at harvest, while yield attributes were assessed at harvest. Soil samples were collected from the root zone of the observational plants and quartering method was followed to obtain soil sample per plot.

3.4.2.1 Growth Attributes

3.4.2.1.1 Height of the plant

The height of the plant was measured from the ground level to the tip of the longest leaf and expressed in cm.

3.4.2.1.2 Number of tillers m^{-2}

Number of tillers were counted and expressed as number of tillers m^{-2}.

3.4.2.2 Yield and Yield Attributes

3.4.2.2.1 Productive tillers m^{-2}

The number of productive tillers at harvest was recorded and expressed as number of productive tillers m^{-2}.

3.4.2.2.2 Thousand grain weight

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

3.4.2.2.3 Grain yield

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

3.4.2.2.4 Straw yield

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

3.4.2.2.5 Harvest index (HI)

The ratio of grain yield to biological yield (grain + straw) was used for calculating the harvest index using the formula suggested by Donald and Hamblin (1976).

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

3.5 OBSERVATION ON WEEDS

The observations on weeds were taken using a quadrat of 1 m x 1 m which was placed randomly in each plot of summer crop. Observations were taken at 20 and 40 DAS.

3.5.1 Weed composition

Weeds from sampled area were identified and grouped into grasses, broad-leaved weeds and sedges.

3.5.2. Dry matter production

48

Dry matter of the weeds was estimated by sampling of weeds from 1 m^2 area. Weeds were uprooted from each plot with minimum damage to roots and dried under shade and then oven dried at 70 ± 5°C till consecutive weights and expressed as g m^{-2}.

3.5.3 Weed smothering efficiency (WSE)

Weed smothering efficiency is the modified weed control effeciency for intercropping situations (Mani *et al.,* 1973). It is calculated by the formula given below and expressed in per cent (%).

$$WSE = \frac{WdwC - WdwT}{WdwC} \times 100$$

where,

WdwC: Weed dry weight in control (g m^{-2})

WdwT: Weed dry weight in treated plot (g m^{-2})

3.5.4 Absolute density/Weed population

The weed population was estimated by counting the number of weeds in each category *i.e.*, grasses, broad-leaved weeds and sedges and expressed in number m^{-2}.

3.6 CHEMICAL ANALYSIS

3.6.1 Plant Analysis

The samples were dried to constant weight in an electric hot air oven at 70 ± 5°C, ground into fine powder and used for chemical analysis. Uptake of nutrients by crops was calculated from the values of dry matter content and per cent nutrient content of crop . The nutrient removal by weeds were calculated from the per cent nutrient content of weeds and dry matter content of weeds. The procedures adopted for the chemical analysis are furnished in Table 5.

3.6.1.1 Nutrient removal

The nutrient uptake by crops (at harvest), and nutrient removal by weeds during summer crop (at 20 and 40 DAS) was calculated using the formula given below and expressed as kg ha^{-1}.

Table 5. Plant nutrient content estimation

Nutrient	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)

$$\text{Nutrient Uptake by Crop or Nutrient Removal by Weed} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter (kg ha}^{-1})}{100}$$

3.6.2 Soil Analysis

A composite soil sample was collected from the experimental site before the summer crop. Soil samples were drawn from each plot separately after the summer and *virippu* crops and analysed for the following chemical properties.

3.6.2.1 Available N

Available nitrogen of the soil was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

3.6.2.2 Available P

Available phosphorus was determined by Bray I (0.03 N ammonium fluoride in 0.025 N hydrochloric acid) method as described by Jackson (1973) and estimated using spectrophotometer and expressed in kg ha^{-1}.

3.6.2.3 Available K

Available potassium was determined by neutral normal ammonium acetate extract method and estimated using Flame photometer (Jackson, 1973) and expressed in kg ha^{-1}.

3.7 ECONOMIC ANALYSIS

For economic analysis the following parameters were worked out.

3.7.1 Gross Income

Gross income was calculated by multiplying the marketable yield with market price of the produce and expressed in ₹ ha^{-1}.

3.7.2 Net Income

Net income was calculated by subtracting cost of cultivation from gross income and expressed in ₹ ha^{-1}.

3.7.3 Benefit Cost Ratio (BCR)

BCR was worked out as the ratio of gross income to cost of cultivation.

$$\text{BCR} = \frac{\text{Gross income (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.8 STATISTICAL ANALYSIS

The data generated from the experiment was analysed by following the techniques of Analysis of Variance (ANOVA) for Randomized Block Design (Cochran and Cox, 1965). Wherever significant differences among treatments were observed, CD (critical difference) values at 5 per cent level of significance were calculated for comparison of means.

Plate 1. General view of experimental field during summer crop

Plate 2. Destructive sampling of summer crops for observations

Plate 3. General view of nursery for *virippu* crop

Plate 4. General view of experimental field during *virippu*

Plate 5. General view of the field during *virippu* (from north)

Results

4. RESULTS

The present investigation entitled "Productivity enhancement of rice-based cropping system with pulses" was undertaken with the objective of studying the suitability of different pulse crops in summer fallow of double cropped lowland rice fields, under varying nitrogen levels and assessing its residual effect on succeeding *virippu* rice crop. The data generated from the study was statistically analysed and presented in this chapter.

4.1 SUMMER CROP (2017-18)

4.1.1 Growth Attributes

4.1.1.1 Plant height

The data on plant height of pulses are presented in Table 6. At 30 DAS, plants were significantly taller in T_1 and on par with T_3 in cowpea, in T_4 in black gram, in T_8 and T_9 for green gram and on par in all treatments of red gram. At 60 DAS, plants were significantly taller in T_8 and T_9 for green gram and were on par in all treatments of cowpea, black gram, and red gram.

4.1.1.2 Number of branches per plant

The data on number of branches per plant are furnished in Table 6. At 30 DAS, the number of branches per plant was significantly superior in T_4 in black gram and was on par in all treatments of cowpea, green gram, and red gram.

At 60 DAS, in cowpea, the number of branches per plant was significantly higher and on par with T_1 and T_2, whereas in green gram, black gram and red gram, it was on par with all treatments.

Table 6. Effect of treatments on growth attributes of summer crop

Treatments	Plant height (cm)		Number of branches per plant	
	30 DAS	60 DAS	30 DAS	60 DAS
T_1: Cowpea with 100 % N	29.13	38.73	7.33	9.40
T_2: Cowpea with 75 % N	25.20	36.20	6.00	9.93
T_3 : Cowpea with 50 % N	28.07	34.73	6.00	6.60
Sem (±)	0.27	0.40	0.12	0.13
CD (0.05)	3.11	NS	NS	1.47
T_4: Black gram with 100 % N	23.83	34.40	5.67	7.53
T_5: Black gram with 75 % N	17.93	33.20	4.33	7.80
T_6: Black gram with 50 % N	19.63	31.73	4.67	7.00
Sem (±)	0.32	0.33	0.05	0.15
CD (0.05)	3.65	NS	0.60	NS
T_7: Green gram with 100 % N	16.70	26.53	4.33	5.47
T_8: Green gram with 75 % N	23.67	32.47	5.00	5.87
T_9: Green gram with 50 % N	22.70	33.80	4.67	5.07
Sem (±)	0.24	0.27	0.04	0.08
CD (0.05)	2.76	3.12	NS	NS
T_{10}: Red gram with 100 % N	29.63	71.33	4.00	9.00
T_{11}: Red gram with 75 % N	28.27	73.33	4.00	9.22
T_{12}: Red gram with 50 % N	30.50	79.53	4.00	9.55
Sem (±)	0.20	0.93	0.07	0.41
CD (0.05)	NS	NS	NS	NS

4.1.2 Physiological parameters

4.1.2.1 Leaf area index (LAI)

The data on LAI are presented in Table 7. At 20 DAS, the LAI of treatments T_1 and T_3 in cowpea was significantly higher and on par. The N treatments in black gram, green gram and red gram were on par. A similar trend was observed at 40 DAS. Among the pulse crops, cowpea had significantly higher LAI.

4.1.2.2 Crop growth rate (CGR)

The data on crop growth rate are presented in Table 7. At 20 DAS, CGR was highest in T_3 in cowpea and the N treatments in black gram, green gram and red gram were on par. At 40 DAS, the CGR of the various N management treatments in cowpea, black gram, green gram and red gram were not significantly different. However, red gram had higher CGR followed by cowpea.

4.1.2.3 Net assimilation rate (NAR)

The data on NAR are presented in Table 7. At 20 DAS, NAR of the different treatments in cowpea, black gram, green gram and red gram were on par. A similar trend was noticed at 40 DAS also. Red gram had significantly higher NAR among the pulse crops, both at 20 and 40 DAS.

4.1.2.4 SPAD chlorophyll meter reading (SCMR)

The data on SCMR are presented in Table 7. At 20 DAS, SCMR of the treatments in cowpea, black gram, green gram and red gram were on par. SCMR was significantly higher and on par in cowpea and red gram than black gram and green gram. At 40 DAS, SCMR had a trend similar to that observed at 20 DAS. However, at this stage SCMR was significantly higher with cowpea among the pulse crops.

4.1.3 Yield and Yield Attributes

4.1.3.1 Number of pods per plant

The data on number of pods per plant are presented in Table 8. The number of pods per plant in the different N management treatments in cowpea, black gram, green gram and red gram were on par. Among the pulse crops, significantly more pods were produced in red gram.

Table 7. Effect of treatments on physiological parameters of summer crop

Treatments	Leaf area index		Crop growth rate (g m^{-2} per day)		Net assimilation rate (g cm^{-2} per day)		SPAD chlorophyll meter reading	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Cowpea with 100 % N	0.291	1.160	1.18	4.00	1.40×10^{-3} (0.037)	0.28×10^{-3} (0.016)	43.36	58.69
T_2: Cowpea with 75 % N	0.212	0.858	0.89	3.03	1.40×10^{-3} (0.037)	0.28×10^{-3} (0.016)	44.64	60.62
T_3 : Cowpea with 50 % N	0.362	1.288	1.44	4.57	1.41×10^{-3} (0.037)	0.26×10^{-3} (0.015)	44.39	59.24
T_4: Black gram with 100 % N	0.035	0.209	0.35	1.69	2.58×10^{-3} (0.050)	0.70×10^{-3} (0.026)	35.32	41.44
T_5: Black gram with 75 % N	0.046	0.247	0.29	2.01	1.95×10^{-3} (0.043)	0.70×10^{-3} (0.025)	34.82	39.39
T_6: Black gram with 50 % N	0.036	0.214	0.33	1.62	2.34×10^{-3} (0.048)	0.62×10^{-3} (0.024)	32.19	39.69
T_7: Green gram with 100 % N	0.102	0.390	0.57	1.82	1.67×10^{-3} (0.040)	0.35×10^{-3} (0.018)	34.56	42.86
T_8: Green gram with 75 % N	0.056	0.472	0.33	2.51	1.63×10^{-3} (0.040)	0.54×10^{-3} (0.023)	30.04	38.35
T_9: Green gram with 50 % N	0.065	0.477	0.40	2.73	1.75×10^{-3} (0.041)	0.54×10^{-3} (0.023)	29.56	39.52
T_{10}: Red gram with 100 % N	0.075	0.499	3.73	11.19	14.69×10^{-3} (0.120)	2.29×10^{-3} (0.047)	44.60	44.68
T_{11}: Red gram with 75 % N	0.066	0.675	3.67	11.02	16.78×10^{-3} (0.128)	1.89×10^{-3} (0.043)	46.59	45.54
T_{12}: Red gram with 50 % N	0.073	0.623	3.76	11.20	15.20×10^{-3} (0.122)	2.18×10^{-3} (0.045)	44.84	44.08
Sem (±)	0.026	0.130	0.10	0.75	0.005	0.003	1.81	1.64
CD (0.05)	0.077	0.381	0.31	2.21	0.015	0.009	5.32	4.81

Figures in parentheses denote transformed (square root) values

4.1.3.2 Grain weight

The grain yield (weight) of the N management treatments in black gram, green gram and red gram were not significantly different (Table 8). However, cowpea grain yield in T_3 was significantly higher than T_2. Among the pulse crops, yield of red gram was significantly more than black gram and green gram, while it was on par with cowpea.

Table 8. Effect of treatments on yield attributes and grain weight (yield) of summer crops

Treatments	Number of pods per plant	Grain weight (kg ha^{-1})
T_1: Cowpea with 100 % N	22.8 (4.73)	1268.31
T_2: Cowpea with 75 % N	15.8 (3.97)	1094.24
T_3: Cowpea with 50 % N	27.4 (5.22)	1681.16
T_4: Black gram with 100 % N	22.4 (4.71)	418.13
T_5: Black gram with 75 % N	21.8 (4.63)	409.64
T_6: Black gram with 50 % N	25.4 (4.89)	521.55
T_7: Green gram with 100 % N	15.6 (3.91)	336.83
T_8: Green gram with 75 % N	35.2 (5.89)	842.48
T_9: Green gram with 50 % N	33.2 (5.72)	753.21
T_{10}: Red gram with 100 % N	140.3 (11.77)	1497.78
T_{11}: Red gram with 75 % N	151.7 (12.02)	1852.08
T_{12}: Red gram with 50 % N	178.3 (13.20)	1903.36
Sem (±)	0.71	179.67
CD (0.05)	2.10	526.99

Figures in parentheses denote transformed (square root) values

4.1.4 Observation on Weeds

4.1.4.1 Weed composition

The data of weed composition during summer season at 20 and 40 DAS are furnished in Tables 9 and 10 respectively. The weeds comprised of grasses *viz., Oryza sativa* and *Eleusine indica,* sedge *viz., Cyperus rotundus* and broadleaved weeds viz. *Boerhavia diffusa, Mollugo* sp. and *Euphorbia hirta.*

At 20 DAS, there was no significant difference between treatments in the population of *Oryza sativa, Cyperus rotundus, Mollugo* sp. and *Euphorbia hirta*. The population of *Eleusine indica* was highest in T_3, which was on par with T_6, T_9 and T_{12}. The population of *Boerhavia diffusa* was highest in T_{13}, which was on par with all the treatments, except T_{10}, T_{11} and T_{12}, where the population was significantly less. At 40 DAS, there was no significant difference in the population of different weeds between treatments. But, the weed *Mullogo* sp. was absent in majority of the treatments (except T_1, T_3 and T_7), while certain broad-leaved weeds *viz. Euphorbia hirta* (T_8), *Cleome rutidospermum* (T_2, T_3, T_7, T_{13}) and *Oldenlandia umbellata* (T_8, T_9) appeared newly in certain treatments.

4.1.4.2 Absolute density (Weed population)

The data on absolute density of weeds are given in Table 11. There was no significant difference among treatments in the population of grasses and sedges at 20 and 40 DAS. With regard to broad-leaved weeds, at 20 DAS, the population was significantly less in T_{10}, T_{11} and T_{12}. However, at 40 DAS, all treatments had no difference with respect to broad-leaved weeds.

4.1.4.3 Dry matter production

The data on dry matter production of weeds is presented in Table 12. At 20 DAS, the dry matter of weeds was significantly higher in T_{13}, T_8 and T_3. At 40 DAS, the dry weight of weeds was significantly more in T_{13}, T_4 and T_9.

4.1.4.4 Weed smothering efficiency / Weed control efficiency

The data on weed smothering efficiency is furnished in Table 12. At 20 DAS, there was no significant difference in weed smothering efficiency. At 40 DAS, the highest weed smothering efficiency was recorded in T_6, which was on par with T_2, T_5, T_7, T_{10}, T_{11} and T_{12}.

62

Table 9. Effect of treatments on composition of weeds during summer crop at 20 DAS, number m^{-2}

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	Sem (±)	CD (0.05)
Grasses															
Oryza sativa	65.9 (9.0)	48.2 (8.3)	81.8 (11.6)	40.3 (8.8)	107.2 (12.4)	125.1 (12.1)	66.2 (8.9)	71.0 (10.0)	71.6 (8.1)	51.2 (8.3)	69.9 (9.0)	76.0 (10.3)	49.3 (9.7)	1.3	NS
Eleusine indica	17.6 (4.1)	14.6 (3.8)	47.6 (6.7)	14.0 (3.7)	16.3 (4.0)	40.0 (6.3)	21.0 (4.5)	20.6 (4.4)	43.6 (6.1)	15.6 (3.9)	18.7 (4.3)	39.0 (5.6)	18.3 (4.2)	0.6	1.9
Sub total	**83.5**	**62.8**	**129.4**	**54.3**	**123.5**	**165.1**	**87.2**	**91.6**	**115.2**	**66.8**	**88.6**	**115.0**	**67.6**		
Sedge															
Cyperus rotundus	206.0 (13.7)	224.0 (14.9)	241.6 (13.5)	212.3 (14.0)	201.0 (13.9)	44.6 (6.4)	62.3 (7.54)	240.3 (14.4)	86.0 (8.5)	123.3 (10.8)	87.0 (7.84)	29.3 (5.05)	179.0 (13.1)	2.72	NS
Broad-leaved weeds															
Boerhavia diffusa	548.3 (23.0)	714.0 (26.0)	429.3 (20.6)	575.0 (23.9)	603.0 (24.5)	479.3 (21.7)	409.6 (19.9)	450.6 (21.2)	526.3 (22.8)	304.0 (16.2)	266.3 (15.6)	249.6 (15.4)	774.0 (27.2)	2.52	7.36
Mollugo sp.	14.3	14.0	14.0	6.3	18.6	15.3	16.3	19.0	14.6	18.3	15.6	17.0	19.3	1.83	NS
Euphorbia hirta	18.3	15.6	16.7	20.6	14.3	18.6	23.0	18.6	20.6	17.3	21.3	19.0	21.0	2.32	NS
Sub total	**580.9**	**743.6**	**460.0**	**601.9**	**635.9**	**513.2**	**448.9**	**488.2**	**561.5**	**339.6**	**303.2**	**285.6**	**814.3**		

Figures in parentheses denote transformed (square root) values

63

Table 10. Effect of treatments on composition of weeds during summer crop at 40 DAS, number m^{-2}

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{11}	T_{11}	T_{12}	T_{13}	Sem (±)	CD (0.05)
Grasses															
Oryza sativa	102.6 (10.0)	109.3 (10.2)	152.0 (11.6)	89.3 (8.8)	102.6 (10.0)	52.0 (7.1)	158.6 (12.5)	96.0 (7.6)	177.3 (12.9)	121.3 (10.9)	178.7 (12.8)	126.7 (9.3)	89.3 (9.3)	2.5	NS
Eleusine indica	6.6 (1.9)	20.0 (3.8)	20.0 (3.8)	13.3 (3.2)	20.0 (3.8)	6.6 (1.9)	6.6 (1.9)	20.0 (3.0)	0 (0.7)	0 (0.7)	26.6 (5.1)	6.6 (1.9)	0 (0.7)	1.3	NS
Subtotal	**109.2**	**129.3**	**172.0**	**102.6**	**122.6**	**58.6**	**165.2**	**116.0**	**177.3**	**121.3**	**205.3**	**133.3**	**89.3**		
Sedge															
Cyperus rotundus	372.0 (18.5)	241.3 (14.7)	392.0 (18.3)	221.3 (13.7)	228.0 (14.8)	64.0 (6.6)	64.0 (6.7)	234.6 (14.9)	360.0 (18.5)	290.6 (16.1)	121.3 (10.8)	133.3 (8.9)	145.3 (10.5)	3.5	NS
Broad-leaved weeds															
Boerhavia diffusa	510.6 (19.9)	460.0 (21.3)	422.6 (20.3)	536.0 (22.8)	529.3 (22.2)	302.6 (17.2)	441.3 (20.9)	366.7 (19.1)	421.3 (20.4)	486.6 (21.1)	360.0 (17.9)	158.6 (12.2)	868.0 (29.4)	2.7	NS
Mollugo sp.	6.7 (1.9)	0 (0.7)	13.3 (2.5)	0 (0.7)	0 (0.7)	0 (0.7)	13.3 (3.2)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0.7	NS
Euphorbia hirta	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	6.6 (1.9)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0.3	NS
Cleome rutidospermum	0 (0.7)	32.0 (3.7)	13.3 (2.5)	0 (0.7)	0 (0.7)	0 (0.7)	26.7 (4.3)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	6.6 (1.9)	1.2	NS
Oldenlandia umbellata	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	6.7 (1.9)	6.7 (1.9)	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)	0.5	NS
Sub total	**517.3**	**492.0**	**449.2**	**536.0**	**529.3**	**302.6**	**481.3**	**380.0**	**428.0**	**486.6**	**360.0**	**158.6**	**874.6**		

Figures in parentheses denote transformed (square root) values

Table 11. Effect of treatments on absolute density of weeds during summer crop, number m^{-2}

Treatments	Grasses		Sedges		Broad-leaved weeds	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Cowpea with 100 % N	83.5 (9.1)	109.2 (10.0)	206.0 (13.7)	372.0 (18.5)	581.0 (23.7)	517.3 (22.7)
T_2: Cowpea with 75 % N	62.8 (7.9)	129.3 (11.1)	224.0 (14.9)	241.3 (14.7)	743.6 (26.6)	492.0 (22.1)
T_3: Cowpea with 50 % N	129.4 (11.3)	172.6 (13.1)	241.6 (13.5)	392.0 (18.3)	460.0 (21.3)	449.2 (21.1)
T_4: Black gram with 100 % N	54.3 (7.3)	102.6 (9.4)	212.3 (14.0)	221.3 (13.7)	612.0 (24.6)	536.0 (23.1)
T_5: Black gram with 75 % N	123.3 (11.1)	122.6 (11.1)	201.0 (13.9)	228.0 (14.8)	636.0 (25.1)	529.3 (23.0)
T_6: Black gram with 50 % N	165.1 (12.8)	58.6 (7.6)	44.6 (6.4)	64.0 (6.6)	513.3 (22.5)	302.6 (17.3)
T_7: Green gram with 100 % N	87.2 (9.3)	165.2 (12.8)	62.3 (7.5)	64.0 (6.7)	449.0 (20.9)	481.3 (21.9)
T_8: Green gram with 75 % N	91.6 (9.5)	116.0 (10.7)	240.3 (14.4)	234.6 (14.9)	488.3 (22.0)	380.0 (19.4)
T_9: Green gram with 50 % N	115.6 (10.7)	177.3 (13.3)	86.0 (8.5)	360.0 (18.5)	561.6 (23.6)	428.0 (20.6)
T_{10}: Red gram with 100 % N	66.8 (8.1)	121.3 (11.0)	123.3 (10.3)	290.6 (18.3)	339.6 (17.3)	486.6 (22.0)
T_{11}: Red gram with 75 % N	88.6 (9.4)	205.3 (14.3)	87.0 (7.8)	121.3 (10.8)	303.3 (16.9)	360.0 (18.9)
T_{12}: Red gram with 50 % N	115.0 (10.7)	133.3 (11.5)	29.3 (5.0)	133.3 (8.9)	285.6 (16.5)	158.6 (12.5)
T_{13}: Control (Fallow during summer)	67.6 (8.2)	89.3 (9.4)	179.0 (13.1)	145.3 (10.5)	814.3 (27.9)	874.6 (29.5)
Sem (±)	1.10	2.30	2.70	3.50	2.40	2.80
CD (0.05)	NS	NS	NS	NS	7.11	NS

Figures in parentheses denote transformed (square root) values

65

Table 12. Effect of treatments on dry matter production and smothering efficiency of weeds during summer crop

Treatments	Dry matter production (g m^{-2})		Weed smothering efficiency (%)	
	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Cowpea with 100 % N	30.80 (3.28)	81.84	70.27	58.33
T_2: Cowpea with 75 % N	35.62 (3.55)	112.46	65.43	42.94
T_3: Cowpea with 50 % N	47.39 (3.76)	131.81	53.48	33.07
T_4: Black gram with 100 % N	43.65 (3.70)	182.56	56.99	7.17
T_5: Black gram with 75 % N	34.13 (3.50)	103.76	66.30	47.15
T_6: Black gram with 50 % N	21.62 (3.04)	61.56	78.99	68.82
T_7: Green gram with 100 % N	22.78 (3.09)	69.72	77.33	64.39
T_8: Green gram with 75 % N	61.44 (4.06)	119.88	38.75	39.65
T_9: Green gram with 50 % N	35.63 (3.38)	156.71	65.15	20.10
T_{10}: Red gram with 100 % N	26.44 (3.21)	108.53	74.12	44.79
T_{11}: Red gram with 75 % N	37.01 (3.32)	100.80	63.65	48.14
T_{12}: Red gram with 50 % N	17.80 (2.75)	66.94	82.99	66.07
T_{13}: Control (Fallow during summer)	102.45 (4.62)	197.54	0*	0*
Sem (±)	0.29	16.89	10.65	8.82
CD (0.05)	0.86	49.32	NS	25.89

Figures in parentheses denote transformed (log) values

* Values were not used for statistical analysis

66

4.1.5 Chemical Analysis

4.1.5.1 Nutrient uptake (assimilation) by crop (N, P, K)

The N and P uptake were on par in all treatments of black gram and red gram. In cowpea, T_1 and T_3 were on par, while in green gram T_8 and T_9 were on par. Among the pulses, N and P uptake was significantly higher in red gram. Regarding K, the uptake was on par in all treatments of black gram, green gram and red gram. However, in cowpea, the K uptake was more in T_3. Among the pulses, K uptake was more in red gram and on par with T_3 of cowpea (Table 13).

Table 13. Effect of treatments on nutrient uptake (assimilation) (N, P, K) of summer crop at harvest, kg ha^{-1}

Treatments	N	P	K
T_1: Cowpea with 100 % N	46.2	7.3	15.1
T_2: Cowpea with 75 % N	35.3	5.5	15.9
T_3 : Cowpea with 50 % N	60.0	9.9	25.0
T_4: Black gram with 100 % N	25.1	2.6	6.0
T_5: Black gram with 75 % N	25.3	2.6	5.9
T_6: Black gram with 50 % N	23.2	3.1	6.7
T_7: Green gram with 100 % N	18.5	1.7	4.9
T_8: Green gram with 75 % N	52.6	4.6	10.5
T_9: Green gram with 50 % N	42.9	4.4	10.9
T_{10}: Red gram with 100 % N	82.0	8.0	24.5
T_{11}: Red gram with 75 % N	72.9	10.6	24.7
T_{12}: Red gram with 50 % N	96.8	10.6	28.8
Sem (±)	6.8	0.9	2.4
CD (0.05)	20.1	2.9	7.1

4.1.5.2 Nutrient removal (N, P, K) by weeds

The data of nutrient removal by crops is furnished in Table 14. At 20 DAS, the removal of N by weeds was significantly more in T_{13} while it was on par in all other treatments. The removal of P and K did not differ significantly among treatments. At 40 DAS, N removal was significantly higher in T_{13}, which was on par with T_4 and T_9. The removal of P exhibited a trend similar to that of N. The K removal did not differ significantly between treatments.

Table 14. Effect of treatments on nutrient removal (N, P, K) by weeds at during summer crop, kg ha^{-1}

Treatments	N		P		K	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Cowpea with 100 % N	6.66 (1.79)	15.50	0.78	2.50	3.51	11.00 (2.30)
T_2: Cowpea with 75 % N	7.39 (1.99)	16.70	0.55	2.20	2.50	10.90 (2.20)
T_3: Cowpea with 50 % N	8.54 (2.13)	22.50	1.14	3.20	5.07	11.00 (2.30)
T_4: Black gram with 100 % N	9.37 (2.00)	29.70	0.73	5.50	2.93	18.60 (2.70)
T_5: Black gram with 75 % N	7.40 (1.99)	15.90	0.87	2.80	3.55	11.90 (2.30)
T_6: Black gram with 50 % N	7.09 (1.94)	12.40	0.64	1.10	2.89	6.90 (1.90)
T_7: Green gram with 100 % N	6.06 (1.74)	12.80	0.62	1.20	3.38	7.00 (1.90)
T_8: Green gram with 75 % N	17.39 (2.82)	17.00	1.43	3.30	5.62	14.10 (2.60)
T_9: Green gram with 50 % N	8.25 (2.00)	26.80	0.89	3.90	3.61	13.50 (2.50)
T_{10}: Red gram with 100 % N	7.77 (1.99)	24.70	0.59	2.40	2.94	14.50 (2.60)
T_{11}: Red gram with 75 % N	9.92 (2.01)	20.20	1.07	2.40	3.05	12.80 (2.40)
T_{12}: Red gram with 50 % N	6.03 (1.64)	14.30	0.45	2.10	2.43	9.10 (2.20)
T_{13}: Control (Fallow during summer)	134.89 (4.06)	36.00	1.92	6.00	9.13	21.70 (2.90)
Sem (±)	0.37	3.70	0.33	0.70	1.26	0.24
CD (0.05)	1.09	11.00	NS	2.10	NS	NS

Figures in parentheses denote transformed (log) values

4.1.5.3 Available status of soil (N, P, K) after crop

The available N, P and K status of soil after the summer crop did not differ significantly among the treatments (Table 15).

Table 15. Effect of treatments on available N, P and K status of soil after summer crop, kg ha^{-1}

Treatments	N	P	K
T_1: Cowpea with 100 % N	422.30	93.40	59.54 (4.08)
T_2: Cowpea with 75 % N	397.70	111.80	135.18 (4.74)
T_3: Cowpea with 50 % N	459.90	103.80	79.40 (4.36)
T_4: Black gram with 100 % N	468.30	96.70	110.58 (4.68)
T_5: Black gram with 75 % N	472.40	82.50	97.06 (4.56)
T_6: Black gram with 50 % N	355.40	92.00	306.58 (5.68)
T_7: Green gram with 100 % N	430.60	122.80	88.40 (4.47)
T_8: Green gram with 75 % N	363.70	76.50	146.01 (4.70)
T_9: Green gram with 50 % N	401.40	82.80	95.12 (4.45)
T_{10}: Red gram with 100 % N	443.20	61.50	113.86 (4.72)
T_{11}: Red gram with 75 % N	397.20	76.50	86.35 (4.44)
T_{12}: Red gram with 50 % N	363.70	88.00	127.19 (4.71)
T_{13}: Control (Fallow during summer)	447.40	105.30	101.39 (4.59)
Sem (±)	33.15	16.80	0.26
CD (0.05)	NS	NS	NS

Figures in parentheses denote transformed (log) values

4.1.6 Economic Analysis

The data on gross income, net income and benefit cost (B:C) ratio of the summer crops is presented in Table 16. Among the pulse crops, gross income was significantly higher in all treatments in red gram, which was on par with T_3 in cowpea

Net income was significantly higher in T_{11} and T_{12}, which was on par with T_3 in cowpea . The B:C ratio was significantly higher in T_{12}, which was on par, T_{11}, T_3, T_{10} and T_1.

Table 16. Effect of treatments on economics of summer crop

Treatments	Gross Return (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C ratio
T_1: Cowpea with 100 % N	91318.3	25819.3	1.39
T_2: Cowpea with 75 % N	78785.7	13352.7	1.20
T_3: Cowpea with 50 % N	121043.5	55676.5	1.85
T_4: Black gram with 100 % N	28432.9	-32566.1	0.46
T_5: Black gram with 75 % N	27855.3	-33077.7	0.45
T_6: Black gram with 50 % N	35465.2	-25401.7	0.58
T_7: Green gram with 100 % N	29640.7	-33608.2	0.46
T_8: Green gram with 75 % N	74138.7	10955.7	1.17
T_9: Green gram with 50 % N	66282.9	3165.9	1.05
T_{10}: Red gram with 100 % N	119822.9	38323.8	1.47
T_{11}: Red gram with 75 % N	148166.7	66733.6	1.81
T_{12}: Red gram with 50 % N	152269.2	70902.2	1.87
Sem (±)	13827.8	13827.8	0.18
CD (0.05)	40558	40558	0.55

Price list

Cowpea	- ₹ 72 kg^{-1}
Black gram	- ₹ 68 kg^{-1}
Green gram	- ₹ 88 kg^{-1}
Red gram	- ₹ 80 kg^{-1}
Labour charge	- ₹ 741/-

4.2 *VIRIPPU* CROP (2018-19)

4.2.1 Growth and growth attributes

4.2.1.1 Plant height

The data on plant height is presented in Table 17. The plant height did not differ among treatments at 20 and 40 DAT, and harvest.

4.2.2.2 Tillers m^{-2}

The data on tillers m^{-2} is given in Table 17. The tillers m^{-2} did not differ significantly among the treatments at 20 and 40 DAT, and harvest.

4.2.2 Yield and yield attributes

4.2.2.1 Productive tillers m^{-2}

The data on number of productive tillers m^{-2} is furnished in Table 18. The number of productive tillers m^{-2} did not differ among the treatments.

4.2.2.2 Thousand grain weight

The data on thousand grain weight is presented in Table 18. The thousand grain weight was significantly more in T_1, which was on par with T_7. The treatments T_6 and T_{12}, which were on par, recorded the lowest grain weight.

4.2.2.3 Grain yield, straw yield and harvest index

There was no significant difference among the treatments in grain yield, straw yield and harvest index as shown in Table 18.

Table 17. Effect of treatments on growth attributes of *virippu* crop

Treatments	Plant height (cm)			Tillers m^{-2}		
	20 DAT	40 DAT	at harvest	20 DAT	40 DAT	at harvest
T_1: Cowpea with 100 % N	40.9	63.9	98.0	224.4	355.0	258.5
T_2: Cowpea with 75 % N	43.2	68.2	106.0	209.0	409.4	319.0
T_3: Cowpea with 50 % N	44.4	66.3	101.8	228.8	383.3	264.0
T_4: Black gram with 100 % N	45.5	69.2	108.8	209.0	372.4	286.0
T_5: Black gram with 75 % N	44.3	66.5	96.3	200.2	363.7	280.5
T_6: Black gram with 50 % N	43.5	69.1	107.1	250.8	455.2	269.5
T_7: Green gram with 100 % N	42.9	66.2	99.5	187.0	365.9	341.0
T_8: Green gram with 75 % N	44.8	69.6	100.5	244.2	348.4	242.0
T_9: Green gram with 50 % N	42.6	71.4	105.5	239.8	409.4	297.0
T_{10}: Red gram with 100 % N	44.0	69.6	100.6	277.2	422.5	308.0
T_{11}: Red gram with 75 % N	41.2	67.4	100.1	217.8	429.0	324.5
T_{12}: Red gram with 50 % N	43.5	68.2	100.0	215.6	383.3	247.5
T_{13}: Control (Fallow during summer)	41.9	67.0	101.6	198.0	426.8	319.0
Sem (±)	1.6	2.4	3.9	27.4	33.2	46.3
CD (0.05)	NS	NS	NS	NS	NS	NS

Table 18. Effect of treatments on yield and yield attributes at harvest of *virippu* crop

Treatments	Productive tillers m^{-2}	Thousand grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
T_1: Cowpea with 100 % N	193.8	27.02	4318.3	8581.7	0.33
T_2: Cowpea with 75 % N	239.2	25.67	4520.0	9793.3	0.32
T_3 : Cowpea with 50 % N	198.0	24.31	4761.6	7586.7	0.38
T_4: Black gram with 100 % N	214.5	25.72	4991.6	9068.2	0.35
T_5: Black gram with 75 % N	210.3	25.25	4198.3	9090.0	0.31
T_6: Black gram with 50 % N	202.1	23.48	5006.6	8888.3	0.36
T_7: Green gram with 100 % N	255.7	26.91	4513.3	8540.0	0.34
T_8: Green gram with 75 % N	181.5	25.56	4665.0	8366.7	0.35
T_9: Green gram with 50 % N	222.7	24.20	4481.6	10332.0	0.30
T_{10}: Red gram with 100 % N	185.6	25.62	3780.0	8135.0	0.31
T_{11}: Red gram with 75 % N	255.7	25.14	5035.0	10237.0	0.33
T_{12}: Red gram with 50 % N	185.6	23.37	4821.6	11037.0	0.30
T_{13}: Control (Fallow during summer)	239.2	24.09	4458.3	8458.3	0.35
Sem (±)	34.7	0.06	485.2	1033.4	0.02
CD (0.05)	NS	0.19	NS	NS	NS

73

4.2.3 Chemical analysis

4.2.3.1 Nutrient uptake (assimilation) (N, P, K) of crop

The data on nutrient uptake of crop are presented in Table 19. The differences in uptake of N among the treatments were significant, while that of P and K were non-significant. The N uptake was highest in T_{11} and was on par with T_{12}, T_5, T_6 and T_9.

Table 19. Effect of treatments on nutrient uptake (assimilation) (N, P, and K) during *virippu* crop, kg ha^{-1}

Treatments	N	P	K
T_1: Cowpea with 100 % N	221.7	38.6	192.3
T_2: Cowpea with 75 % N	206.5	38.6	192.3
T_3: Cowpea with 50 % N	211.7	41.0	142.0
T_4: Black gram with 100 % N	213.1	38.8	210.1
T_5: Black gram with 75 % N	289.3	41.9	146.2
T_6: Black gram with 50 % N	305.7	42.5	172.8
T_7: Green gram with 100 % N	239.1	41.9	176.9
T_8: Green gram with 75 % N	235.5	33.8	137.4
T_9: Green gram with 50 % N	252.5	45.7	207.9
T_{10}: Red gram with 100 % N	189.2	56.5	163.8
T_{11}: Red gram with 75 % N	321.3	50.3	208.6
T_{12}: Red gram with 50 % N	303.6	48.8	268.9
T_{13}:Control (Fallow during summer)	234.1	37.6	174.9
Sem (±)	25.8	6.5	26.0
CD (0.05)	75.4	NS	NS

74

4.2.3.2 Available N, P, K status of soil

The available N, P and K status of soil after *virippu* crop are presented in Table 20. The available N, P and K status of soil after *virippu* crop did not differ significantly among the treatments.

Table 20. Effect of treatments on available N, P and K status of soil after *virippu* crop, kg ha^{-1}

Treatments	N	P	K
T_1: Cowpea with 100 % N	317.70	8.03 (2.07)	200.85 (5.14)
T_2: Cowpea with 75 % N	296.80	7.15 (1.96)	242.10 (5.21)
T_3: Cowpea with 50 % N	338.60	9.61 (2.16)	147.09 (4.98)
T_4: Black gram with 100 % N	146.30	10.84 (2.29)	391.25 (5.79)
T_5: Black gram with 75 % N	263.40	16.49 (2.74)	224.37 (5.21)
T_6: Black gram with 50 % N	326.10	11.66 (2.39)	164.64 (5.09)
T_7: Green gram with 100 % N	342.80	22.40 (2.97)	245.28 (5.44)
T_8: Green gram with 75 % N	330.30	8.11 (2.07)	233.89 (5.41)
T_9: Green gram with 50 % N	326.10	15.33 (2.65)	254.98 (5.41)
T_{10}: Red gram with 100 % N	309.40	17.81 (2.60)	349.62 (5.32)
T_{11}: Red gram with 75 % N	317.70	19.89 (2.69)	206.08 (5.21)
T_{12}: Red gram with 50 % N	317.70	9.79 (2.25)	221.76 (5.34)
T_{13}:Control (Fallow during summer)	313.60	25.03 (2.91)	212.42 (5.13)
Sem (±)	46.50	0.28	0.29
CD (0.05)	NS	NS	NS

Figures in parentheses denote transformed (log) values

4.2.4 Economic analysis

The economic analysis is presented in Table 21. There was no significant difference in gross income, net income and BC ratio among the treatments. However, though not significant, relatively higher gross and net return were obtained in T_{11} (red gram with 75% RDN) followed by T_{12}.

Table 21. Effect of treatments on economics of *virippu* crop

Treatments	Gross Return (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C ratio
T_1: Cowpea with 100 % N	172458.3	76979.33	1.80
T_2: Cowpea with 75 % N	184566.6	89087.67	1.93
T_3: Cowpea with 50 % N	180783.3	85304.33	1.89
T_4: Black gram with 100 % N	195090.8	99611.83	2.04
T_5: Black gram with 75 % N	171400.0	75921.00	1.79
T_6: Black gram with 50 % N	194641.6	99162.67	2.03
T_7: Green gram with 100 % N	178100.0	82621.00	1.86
T_8: Green gram with 75 % N	181788.3	86304.33	1.90
T_9: Green gram with 50 % N	186108.3	90629.33	1.94
T_{10}: Red gram with 100 % N	154075.0	58596.00	1.61
T_{11}: Red gram with 75 % N	202233.3	106754.3	2.11
T_{12}: Red gram with 50 % N	199833.3	104354.3	2.09
T_{13}: Control (Fallow during summer)	176041.6	80562.67	1.84
Sem (±)	16869.5	16869.56	0.17
CD (0.05)	NS	NS	NS

<u>Price list</u>

Rice - ₹ 30 kg^{-1}

Straw - ₹ 5 kg^{-1}

Labour charge - ₹ 741/-

Discussion

5. DISCUSSION

The present investigation "Productivity enhancement of rice-based cropping system with pulses" was undertaken with the objective of studying the suitability of different pulse crops in summer fallow of double cropped lowland rice fields, under varying nitrogen levels and assess its residual effect on succeeding *virippu* rice crop. The results obtained from the study are discussed in this chapter.

5.1 SUMMER CROP

5.1.1 Growth Attributes

The influence of varying levels of N on plant height was evident in cowpea, black gram and green gram at 30 DAS. However, at 60 DAS there was significant difference in the plant height only in green gram with the highest at 75 and 50 per cent RDN, while in the others, it was not significant. Hence it is evident that lowering the N dose by 50 per cent did not adversely affect plant height.

Number of branches per plant differed significantly among treatments in black gram only at 30 DAS. However, at 60 DAS, differences between treatments were notable only in cowpea, where decreased number of branches was observed at 50 per cent RDN. Hence reduction in RDN by 50 per cent reflected in the branch growth of cowpea only.

It can be inferred regarding growth that reducing the fertiliser dose of N, did not adversely affect except in case of branch growth of cowpea. The growth of different crops cannot be compared owing to the specific morphological characters of each pulse crop.

5.1.2 Physiological Parameters

The influence on LAI was obvious only in cowpea both at 20 DAS and 40 DAS whereas other pulses showed no significant difference among the treatments.

The higher and on par LAI in cowpea at 100 and 50 per cent did not have any adverse effect.

CGR was significantly more at red gram at 20 and 40 DAS, when compared to other pulses. At 20 DAS, CGR in cowpea was second highest but it was on par with black gram and green gram at 40 DAS. The CGR did not differ with varying levels of N in all the pulses at 40 DAS. The CGR did not differ with varying levels of N in all the pulses at 40 DAS.

NAR was recorded significantly higher in red gram among the pulses. The varying levels of N caused no appreciable difference in NAR of pulses at 20 and 40 DAS. The SCMR was highest in red gram followed by cowpea at 20 DAS but at 40 DAS cowpea had the highest SCMR.

This shows that the physiological parameters were not detrimentally affected when the RDN was reduced to 50 per cent.

5.1.3 Yield and Yield Parameters

The highest number of pods per plant was recorded in red gram and it was not influenced by the varying levels of N. All the other pulses produced similar number of pods with no appreciable difference between levels of nitrogen

The highest grain yield was obtained from red gram (irrespective of N level) and was on par with grain yield of cowpea at 50 per cent RDN (Fig. 4). The reduced yield for black gram and green gram might be due to the sudden change in temperature, relative humidity besides the irregular rainfall that occurred during the pod filling stage. Reducing the level of N did not result in a yield in a remarkable yield decline in any of the pulses.

It is notable that the reduction in number of branches with reducing N level in cowpea did not bring out a similar effect in the yield. The higher grain yield obtained from red gram can be attributed to higher number of pods per plant, NAR and CGR.

Considering the history of the experimental site, it is clear that the residues of the first and second crop of rice may have contributed adequate nutrients for the third crop. Moreover, the FYM added at the rate of 5 t ha^{-1} to the two crops also might have served as a source of nutrients especially N for the pulses raised in the same land during summer thereby negating the influence of varying N levels. This in line with the findings of the literature reviewed (Lakshmi *et al.*, 2012; Siag and Prakash, 2007; Ghosh *et al.,* 2012; Ali, 2014; Behera *et al.,* 2014).

5.1.4 Weed growth

5.1.4.1 Weed composition

The major weeds during summer season were observed and classified into grasses, sedges and broad-leaved weeds. The major grasses were *Oryza sativa* and *Eleusine indica*; while sedge was *Cyperus rotundus* and the broad-leaved weeds were *Boerhavia diffusa*, *Mollugo* sp., *Euphorbia hirta, Cleome rutidospermum* and *Oldenlandia umbellata.*

At 20 DAS among grasses, *Oryza sativa* dominated but the population did not differ significantly among the treatments. However, the population of *Eleusine indica* was highest in cowpea at 50 per cent RDN, which was on par with black gram, green gram and red gram at 50 per cent RDN. There was no significant difference in the population of sedge among the treatments. Among broad-leaved weeds, *Boerhavia diffusa* predominated and alone differed significantly between treatments. The population of *Boerhavia diffusa* was highest in fallow and was on par with all treatments, except red gram. The differential weed growth observed may be due to the different growth habit of the crop during the initial stages and the associated land management practices adopted.

5.1.4.2 Absolute density (Weed population)

Both at 20 and 40 DAS, broad-leaved weeds predominated over sedges and grasses. There was no significant variation in the population of grasses and sedge at 20 and 40 DAS. Broad-leaved weeds were significantly less in red gram with higher doses of N at 20 DAS only, but at 40 DAS the population was on par in all treatments. It is also revealed that there was no remarkable difference in the population of the different categories of weeds among different levels of N in the various pulse crops.

5.1.4. Dry matter production

The weed dry matter production was influenced by varying levels of N only in green gram and cowpea. At 20 DAS, the dry matter of weeds was significantly higher in control fallow, green gram with 75 per cent of RDN and in cowpea with 50 per cent of RDN. At 40 DAS, the dry weight of weeds was significantly more in control fallow, black gram with 100 per cent N and in 50 per cent applied green gram. In general, weed dry matter was more in the plot left as fallow. Evidently there was no specific trend with regard to effect of treatments on dry matter production of weeds under varying levels of N.

Weed smothering efficiency had not been influenced by varying levels of N at 20 DAS. At 40 DAS, the highest weed smothering efficiency was recorded in black gram with 50 per cent of RDN, which was on par with cowpea with 75 per cent RDN, black gram with 75 per cent RDN, green gram with 100 and 75 per cent of N of RDN, and in all N levels in red gram. It is to be noted that the weed smothering efficiency at 40 DAS was significant in those treatments, which was not significant when dry matter production was considered at 20 and 40 DAS (except in green gram with 50% RDN at 20 DAS), which justifies the weed smothering efficiency of crop. This might be due to the weed smothering effect based on crop weed competition in aspects like canopy cover and nutrient uptake by crops.

5.1.5 Chemical Analysis

The uptake of N, P and K by crops were maximum in red gram, which was a consequence of higher yield and dry matter of the crop. Similar trend was observed in other crops. The removal of N by weeds alone was significant with the highest in the fallow; which was due to the highest weed dry matter production in the treatment. At 20 and 40 DAS, the removal of N and P followed the same trend. The available status of N, P and K after the first crop did not vary significantly among the treatments. This lack of difference among the treatments may be due to the fact that soil samples were collected immediately after the harvest of pulse crops, following which the decomposition of root nodules and release of nutrients might have occurred.

5.1.6 Economic Analysis

The net income was significant in red gram at lower doses of N (75 and 50 % RDN), which was on par with cowpea with lowest N dose (50 % RDN). Based on the net return and B:C ratio, it can be concluded that the most remunerative pulses are red gram and cowpea. The varying nitrogen doses were not critical in influencing the net returns from any pulse crop. However, cowpea has a shorter duration (65 days), compared to red gram (110 days) and a similar yield and net income. Hence, cowpea can be adjudged as more suitable among the pulses investigated.

5.2 *VIRIPPU* CROP (2018-19)

The rice crop raised during *virippu* subsequent to the different pulse crops under various treatments during summer showed no variation in growth. No difference was noticed in the number of productive tillers m^{-2} also. Though the thousand grain weight was more in rice succeeding cowpea (100 % RDN) and green gram (100 % RDN), it did not reflect in the grain yield (Fig. 4), straw yield or harvest index, which were on par among all treatments. With respect to uptake of nutrients (N, P, K) the difference was noticed between treatments in N uptake alone.

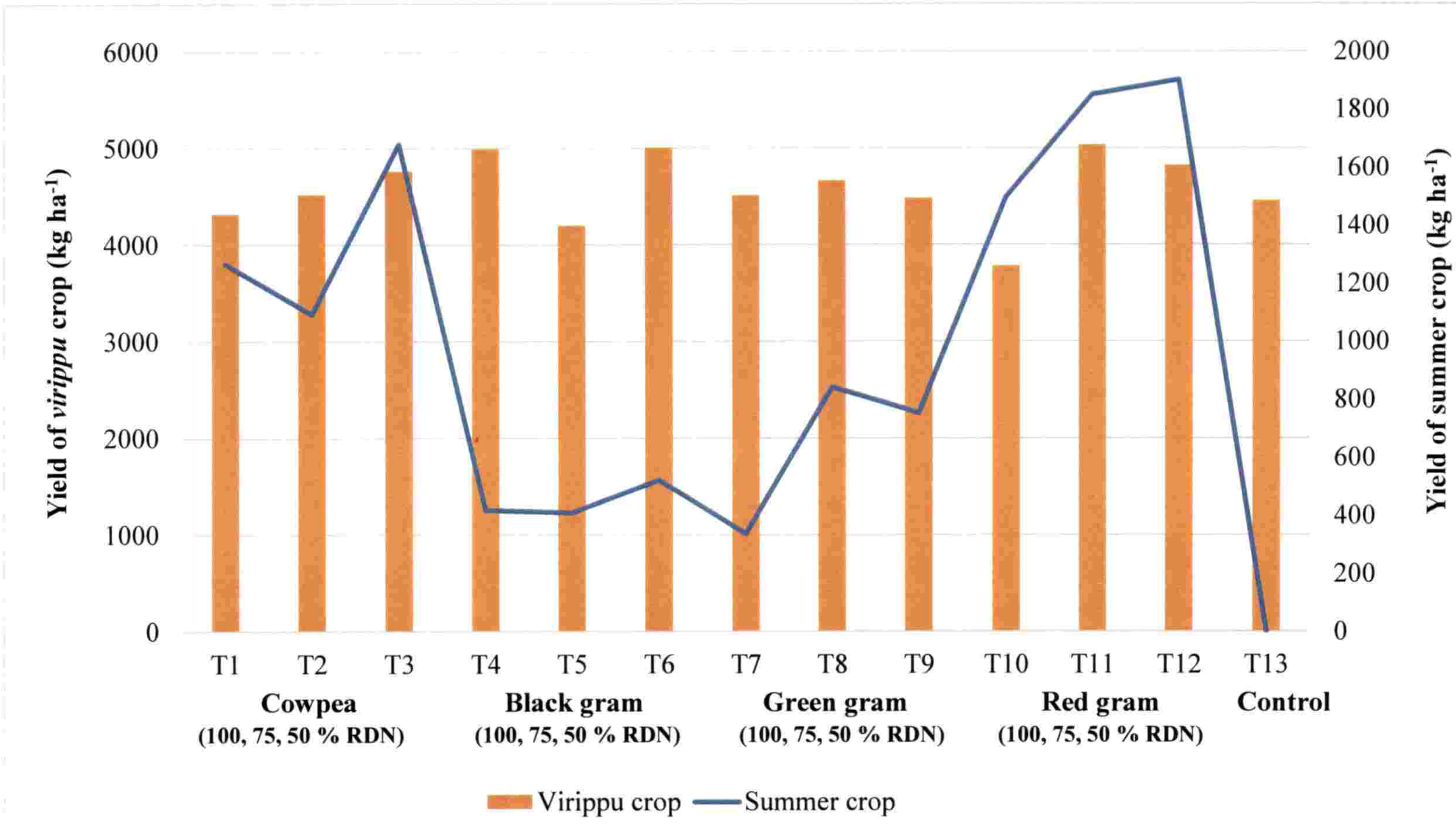

Fig. 4. Yield of crops during both seasons

It did not follow any specific trend and hence not discussed. The available N, P and K status of soil did not differ among treatments. The economic aspects were also on par.

Based on the findings that there was no noticeable difference between the growth, yield and economics of the rice crop succeeding the different pulses under varying levels of N, it can be inferred that reducing the dose of N for the pulse crop raised during summer had no detrimental effect on rice. The release /fixation of N by the pulses might have contributed in alleviating the shortage of N arising due to the reduced N dose for summer crop. However, it has not been specifically quantified in this study, which eventually throws open the scope for a detailed further investigation.

Summary

6. SUMMARY

The investigation " Productivity enhancement of rice based cropping system with pulses" was undertaken with the aim to finding a suitable pulse crop for summer fallows of double cropped lowland rice fields under varying nitrogen levels and its residual effect on the succeeding *virippu* rice crop.

The experiment was laid out in Randomised Block Design and comprised of thirteen treatments replicated thrice, distributed over summer 2017-18 and *virippu* 2018-19 seasons. The treatments were T_1 (cowpea with 100 % RDN), T_2 (cowpea with 75 % RDN), T_3 (cowpea with 50 % RDN), T_4 (black gram with 100 % RDN), T_5 (black gram with 75 % RDN), T_6 (black gram with 50 % RDN), T_7 (green gram with 100 % RDN), T_8 (green gram with 75 % RDN), T_9 (green gram with 50 % RDN), T_{10} (red gram with 100 % RDN), T_{11} (red gram with 75 % RDN), T_{12} (red gram with 50 % RDN) and T_{13} (fallow as control). The varieties of cowpea, black gram, green gram, red gram and rice used were PGCP 6, Co 6, Co 8, APK 1 and Uma respectively. The growth, physiological and yield attributes of crop were studied. The assessment of weed dynamics during summer season was done. The nutrient content in crops, weeds and soil were worked out. These data were used for working out the economics. The results of the study are summarised below.

SUMMER CROP (2017-18)

Among the summer crops raised, cowpea with 100 and 75 per cent RDN, black gram with 100 per cent RDN and green gram with 75 and 50 per cent RDN were superior in terms of plant height. The number of branches per plant were superior for cowpea (100 and 50 % RDN) and green gram (50 % RDN) . The superiority among physiological characters was seen in leaf area index by cowpea treated with 100 and 50 per cent RDN. The yield was significantly high in cowpea (with 50 % of RDN) and in green gram with 75 and 50 per cent of RDN. The highest yield was obtained in red gram with 50% of RDN.

Weed diversity was substantial during summer season. Among weeds, broad-leaved weeds dominated followed by sedge and grasses. Among grasses, *Oryza sativa* predominated, followed by *Eleusine indica.* Among sedge, the population of *Cyperus rotundus* was highest. Among broad-leaved weeds, *Boerhavia diffusa* was highest and others like *Mollugo* sp., *Euphorbia hirta, Cleome rutidospermum,* and *Oldenlandia umbellate* were absent in most of the treatments. Population of weeds from all categories were seen on par among treatments. However, black gram with 50 % of N was effective in suppressing weeds. The dry matter production of weeds was highest in fallow during summer.

The overall nutrient uptake was highest in red gram. The nutrient removal by weeds were higher for N in fallow and was on par for P and K in all treatments. The available soil nutrients showed no difference after summer crop. The gross income was significantly higher in all doses of RDN in red gram, which was on par with cowpea (50 % RDN). Net income was significantly higher in red gram (75 % RDN) among the pulse crops which was on par with cowpea (50 % RDN). The BC ratio was higher in red gram and on par on cowpea (100 and 50 % RDN) compared to other pulses crops.

VIRIPPU CROP (2018-19)

The growth attributes of rice were not significant among treatments. The yield parameters were not significant, except thousand grain weight, which was highest in plots where cowpea and green gram with 100 % of RDN were grown. The nutrient uptake was significant only for N in plots cultivated with red gram with 75 % RDN. The available soil nutrients were on par in all treatments. The economic parameters *viz.,* gross returns, net returns, B:C ratio were on par among treatments.

It was inferred from the study that the objectives of study were fulfilled. During summer, cowpea and red gram performed better among the different pulses, in terms of yield but red gram ranked first for gross income, net income and B:C ratio. There was no significant difference in yield, gross income, net income and B:C ratio of pulses under varying levels of N, thereby indicating that the lower level of N (50 % RDN) will be sufficient. Reducing the dose of N for the summer crops did not have any adverse effect on the succeeding *virippu* rice crop as evident from the almost similar yield and economics among different treatments.

Future line of work

i. To increase the production during summer season by tackling the weed competition.
ii. To explore the possibility of enhancing the system productivity by integrating short duration vegetables with red gram during summer.
iii. To study the carbon sequestration potential of system.

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Appendices

Appendix 1. Weather parameters during summer crop period (February to May 2018)

Standard Meteorological Week	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)	Rainfall (mm)
8	33.0	20.5	76.6	0
9	33.5	21.0	75.1	0
10	33.0	22.0	75.0	0
11	33.8	21.0	76.5	11.3
12	33.0	22.0	76.5	25.6
13	33.0	24.5	79.2	0
14	33.0	23.0	77.0	4.0
15	33.0	23.5	77.7	1.5
16	34.5	25.0	74.2	4.6
17	34.1	22.0	74.0	0
18	34.5	26.0	75.5	2.6
19	33.8	22.5	76.2	14.8
20	33.5	23.0	77.7	15.8

105

Appendix 2. Weather parameters during *virippu* crop period (June – October 2018)

Standard Meteorological Week	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)	Rainfall (mm)
21	33.5	21.5	79.9	87.3
22	32.2	23.0	81.8	156.9
23	31.5	23.5	91.1	450.5
24	31.5	24.0	85.2	59.3
25	30.5	22.5	92.3	198.4
26	30.5	22.5	91.2	223.3
27	31.5	22.0	86.1	153.9
28	30.8	23.5	88.9	244.7
29	30.8	23.5	90.5	339.3
30	31.5	24.5	85.5	97.9
31	31.0	23.5	86.7	152.5
32	31.5	23.0	88.5	138.0
33	29.5	23.0	90.5	280.5
34	30.0	23.0	84.9	49.3
35	30.0	23.0	87.2	98.5
36	31.0	23.0	80.9	5.2
37	31.0	22.0	79.4	0
38	31.0	23.5	77.4	4.3
39	31.8	24.0	77.2	85.0
40	32.0	23.5	82.3	52.3
41	32.0	24.5	83.9	61.7

PRODUCTIVITY ENHANCEMENT OF RICE BASED CROPPING SYSTEM WITH PULSES

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Abstract

ABSTRACT

The project "Productivity enhancement of rice based cropping system with pulses" was undertaken with the objective of assessing the suitability of different pulse crops for summer fallows of double cropped lowland rice fields under varying nitrogen levels and its residual effect on the succeeding *virippu* rice crop.

The experiment was laid out in Randomised Block Design with thirteen treatments and replicated thrice, during summer 2017-18 and *virippu* 2018-19 seasons. The treatments were T_1 (cowpea with 100 % recommended dose of nitrogen (RDN)), T_2 (cowpea with 75 % RDN), T_3 (cowpea with 50 % RDN), T_4 (black gram with 100 % RDN), T_5 (black gram with 75 % RDN), T_6 (black gram with 50 % RDN), T_7 (green gram with 100 % RDN), T_8 (green gram with 75 % RDN), T_9 (green gram with 50 % RDN), T_{10} (red gram with 100 % RDN), T_{11} (red gram with 75 % RDN), T_{12} (red gram with 50 % RDN) and T_{13} (fallow during summer). The varieties of cowpea, black gram, green gram, red gram and rice used were PGCP 6, Co 6, Co 8, APK 1 and Uma respectively. The growth parameters, yield attributes, nutrient uptake, soil available nutrient status were recorded and economics was worked out during summer and *virippu* seasons. Physiological parameters of crop, composition of weeds, absolute density of weeds and nutrient removal by weeds were assessed during summer season.

During summer, the height of cowpea (100 % RDN) and green gram (75 and 50 % RDN) was found superior. The number of branches per plant was found higher in cowpea (T_1 and T_2). Leaf area index (100 and 50 % RDN) and crop growth rate (50 % RDN) was superior in cowpea. The number of pods were significant in green gram (75 and 50 % RDN). The yield was significantly high in cowpea (50 % RDN) and it was on par in red gram.

Broad-leaved weeds dominated, followed by sedge and grasses . Among grasses, sedge and broad-leaved weeds; *Oryza sativa, Cyperus rotundus* and

Boerhavia diffusa dominated respectively. Absolute density of weeds was lesser in T_{11} and T_{12}. Black gram (50 % RDN) was effective in smothering weeds. The dry matter production of weeds was highest in fallow during summer.

The N and P uptake was on par in cowpea (100 and 50 % RDN) and green gram (75 and 50 % RDN). The K uptake was higher in cowpea (50 % RDN). The N removal by weeds was higher in fallow and that of P and K were on par in all treatments. The available soil nutrients showed no difference after summer crop. Gross income, net income, and B:C ratio were higher for red gram.

During *virippu,* growth attributes, yield, and yield parameters were on par in all treatments in rice. The thousand grain weight was highest in plots where cowpea and green gram with 100 per cent RDN were grown during summer. The N uptake of rice was significant with red gram (75 % RDN). The available soil nutrients were on par in all treatments in rice. The economic parameters *viz.,* gross returns, net returns, B:C ratio were on par among all treatments in rice.

The following conclusions, which meet the objectives, can be arrived at from the study:

- During summer, cowpea and red gram performed better among the different pulses, in terms of yield. However, regarding gross income, net income and B:C ratio, red gram ranked first.
- There was no significant difference in yield, gross income, net income and B:C ratio of pulses under varying levels of N, thereby indicating that the lower level of N (50 % RDN) will be sufficient. It is also logical to infer that the residual effect of the preceding two crops of rice contributed to reduce N dose when pulses are raised during summer in double cropped lowlands.
- Reducing the dose of N for the summer crops did not have any adverse effect on the succeeding *virippu* rice crop as evident from the on par yield and economics among different treatments.

സംക്ഷിപ്തം

സംക്ഷിപ്തം

"പയർവർഗ്ഗങ്ങൾ ഉൾപ്പെടുത്തി നെല്ലധിഷ്ഠിത വിള സമ്പ്രദായത്തിലെ ഉൽപാദനക്ഷമത മെച്ചപ്പെടുത്തൽ" എന്ന വിഷയത്തിൽ ഒരു പഠനം പടന്നക്കാടുള്ള കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. വിരിപ്പും മുണ്ടകനും നെൽകൃഷിക്ക് ശേഷമുള്ള വേനൽക്കാല ഒഴിവ് നിലത്തിലെ നിർദേശിക്കപ്പെട്ട തോതിന്റെ വ്യതസ്ത അളവുകളിൽ (100, 75, 50 ശതമാനം) പാകൃജനകം വളമായി പ്രയോഗിച്ച് കൃഷി ചെയുന്ന വിവിധ പയർ വിളകളുടെ അനുയോജ്യതയും തുടർന്നുള്ള വിരിപ്പ് നെൽകൃഷിയിൽ അതിന്റെ അവശേഷിക്കുന്ന പ്രഭാവവും വിലയിരുത്തുകയായിരുന്നു പഠനലക്ഷ്യം.

പി ജി സി പി 6 എന്ന വൻപയറിനം, സി ഒ 6 എന്ന ഉഴുന്നിനം, സി ഒ 8 എന്ന ചെറുപയറിനം, എ പി കെ 1 എന്ന തുവരപ്പയറിനം എന്നിവ വേനൽക്കാലത്ത് കൃഷി ചെയ്തു. ഉമ എന്ന നെല്ലിനം തുടർന്നുള്ള വിരിപ്പുക്കാലത്ത് കൃഷി ചെയ്തു.

വൻപയറും തുവര പയറുമാണ് വിളവ് അധികം നല്കിയത് എന്നാൽ വരുമാനത്തിന്റെ കാര്യത്തിൽ തുവര പയറായിരുന്നു ലാഭകരം. നെൽകൃഷിയിൽ ശ്രദ്ധേയമായ മാറ്റങ്ങളൊന്നും കണ്ടില്ല. പയർവർഗ്ഗങ്ങളിൽ കുറഞ്ഞ അളവിലുള്ള (50 ശതമാനം) പാകൃജനക പ്രയോഗം മതിയാകുമെന്നും അത് തുടർന്നുള്ള നെല്ലിന്റെ വിളവിനെ പ്രതികൂലമായി ബാധിക്കില്ലെന്നും പഠനത്തിൽ കണ്ടെത്തി.