INTEGRATED NUTRIENT MANAGEMENT IN UPLAND RICE-BASED INTERCROPPING SYSTEM UNDER FOOTHILL CONDITION OF NAGALAND

Thesis

submitted to

NAGALAND UNIVERSITY

in partial fulfillment of requirements for the Degree

of

Doctor of Philosophy

in

Agronomy

by

GAURI MOHAN

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Nagaland

2023

Ph.D Gauri Mohan 2023 AGR

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Affectionately Dedicated
to Baba and my loving Parents

DECLARATION

I, **Gauri Mohan**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Agronomy.

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CERTIFICATE – I

This is to certify that the thesis entitled **"Integrated Nutrient Management in Upland Rice-Based Intercropping System Under Foothilll Condition of Nagaland"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agronomy is the record of research work carried out by Ms. GAURI MOHAN Registration No. Ph.D./AGR/00207 under my personal supervision and guidance.

The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRONOMY

This is to certify that the thesis entitled **"Integrated Nutrient Management in Upland Rice-Based Intercropping System Under Foothill condition of Nagaland"** submitted by Miss Gauri Mohan Admission No. Ph-260/18 Registration No. Ph.D./AGR/00207 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agronomy has been examined by the Advisory Board and External examiner on ………………............

The performance of the student has been found **Satisfactory/Unsatisfactory.**

Member	Signature
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2. Prof. Khagen Kurmi (External examiner)	………………………….
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ACKNOWLEDGEMENTS

All praises to the Almighty God for the wisdom he bestowed upon me, the strength, peace of my mind and good health throughout my research work to complete the research successfully.

Fervently and modestly, I extol my profound sense of gratitude and heartfelt devotion to my supervisor, Dr. Tankeswar Gohain, Professor, Head, Deptt. of Agronomy, Nagaland University, SAS, Medziphema, Nagaland for his expert guidance, genuine cooperation, inspiration, painstaking help, unabiding interests, close supervision, valuable advice, untiring attention, sustained help, keen interest and concrete suggestions, right from the commencement of my research work to ship-shaping of the manuscript.

I am extremely obliged and would like to express my sincere thanks to other members of my advisory committee, Dr. A. P. Singh, Associate Professor, Deptt. of Agronomy, Dr. D. Nongmaitem, Asstt. Professor, Deptt. of Agronomy, Dr. A.K. Singh, Professor Deptt. of Agricultural Chemistry and Soil Science, Dr. Sanjoy Das, Associate Professor, Deptt. of Ag. Economics for their valuable suggestions, great help and stand by during my research work.

I am thankful to all the technical staffs, Mr. Zulutemjen Jamir, STA and all the non-teaching staffs of Department of Agronomy for their valuable help in every possible way during my Ph.D. research work. I would also like to give my sincere thanks to Dr. Damitre Lytan for rendering his heip for the statistical analysis of my research work.

Diction is not enough to express my unboundful gratitude and affection to adorable father, Suchan Mohan and mother, Mrs. Guna Mohan for bringing me up in the best of ways, for rendering me the best of education, for nurturing me in the best of ideals and for helping me to see the best of times. Their everlasting blessings, unconditional love, endless support and constant encouragement led to higher aspirations in life. There is no match to express my love to my sisters Haripriya Mohan and Jimli Borah Mohan, brother Kalyan Mohan and my dearest nieces Kosturi and Dorothy who has made my life the happiest. Finally, special acknowledgement to Nagaland University, SASRD & University Grants Commission, Ministry of Education, Government of India for providing financial assistance in the form of fellowship during the course of my study and to the Nagaland University, Library for giving me the best of the knowledge and resources for my course of study and research. These acknowledgments would not be completed without thanking my friends Sibino, Avinie, Yabi, Vero, John, Zulu who have helped me a lot in my research work. Finally, I thank one and all who helped me directly or indirectly in my research work. At last, I bow my head before God Almighty for the never-ending blessings showered on me to complete this work successfully up to my satisfaction.

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LIST OF ABBREVIATIONS

%	:	Percentage
@	:	At the rate of
°C	:	Degree Celsius
-1	:	Per
B:C	:	Benefit cost ratio
CD	:	Critical difference
cm	:	Centimetre
CR	:	Competitive ratio
CV	:	Coefficient of variance
DAS	:	Days after sowing
df	:	Degrees of freedom
et al.	:	*Et alii* (and others)
Etc	:	*Et cetera*
Fig.	:	Figure
FYM	:	Farmyard manure
g	:	Gram
ha	:	Hectare
i.e.	:	That is
K	:	Potassium
kg	:	kilogram
Kg ha^{-1}	:	Kilogram $hectare^{-1}$
LAI	:	Leaf area index

LER	:	Land equivalent ratio
m^2	:	Square meter
MA	:	Monetary advantage
Max.	:	Maximum
Min.	:	Minimum
N	:	Nitrogen
No.	:	Number
NS	:	Non-significant
OC	:	Organic carbon
P	:	Phosphorous
PER	:	Price equivalent ratio
RCC	:	Relative crowding coefficient
RDF	:	Recommended dose of fertilizer
S.Ed	:	Standard error mean
SEm±	:	Standard error of mean
t ha^{-1}	:	tonnes hectare^{-1}
viz	:	Namely

ABSTRACT

A field experiment was conducted during the *kharif* season, 2019 and 2020 in the experimental farm, Department of Agronomy, NU, SASRD, Medziphema campus to study the effect of **"Integrated nutrient management in upland rice-based intercropping system under foothill condition of Nagaland"**. The experiment was laid out in a Factorial Randomized Block Design with three replications. The treatment consisted of five cropping system *viz*., C_1: Sole rice, C_2: Sole groundnut, C_3: Sole soybean, C_4: Rice + groundnut (3:1), C_5: Rice + soybean (3:1) and three nutrient management practices *viz*., N_1: 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed, N_2: 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed, N_3: 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The result revealed that among intercropping system, rice + soybean (3:1) cropping system recorded highest plant height (cm), number of leaves $plant^{-1}$, dry matter yield (g) $plant^{-1}$, crop growth rate (g m^{-2} day^{-1}), leaf area index, number of panicles m^{-2}, weight of panicle (g), number of grains $panicle^{-1}$, filled grain %, grain yield (2.98 t ha^{-1}), straw yield (4.87 t ha^{-1}), rice equivalent yield (4.63 t ha^{-1}), land equivalent ratio (1.44), price equivalent ratio (1.40) and monetary advantage (Rs. 28536.67 ha^{-1}).

Among different nutrient management practices, application of 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly higher plant height (cm), number of leaves $plant^{-1}$, dry matter yield (g) $plant^{-1}$, leaf area index, crop growth rate (g $m^{-2}day^{-1}$), number of panicles m^{-2}, weight of panicle (g), number of grains $panicle^{-1}$, filled grain %, grain yield (3.15 t ha^{-1}), straw yield (5.16 t ha^{-1}). The soil fertility status of the post harvest soil such as available nitrogen (kg ha^{-1}), soil bacteria, fungi and actinomycetes registered maximum under rice intercropped with soybean among intercropping system. The results further revealed that application of 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded highest organic carbon, N, P, K, bacteria, fungi and actinomycetes. In terms of economics, rice + soybean (3:1) cropping system recorded highest gross return (Rs. 99382.82 ha^{-1}), net return (Rs. 68542.49 ha^{-1}), B-C ratio (2.23). Among the nutrient management practices 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded highest gross return (Rs. 90654.12 ha^{-1}) net return (Rs. 58940.12 ha^{-1}) and B-C ratio (1.87).

Key words: Rice, groundnut, soybean, intercrop, FYM, biofertilizer

CHAPTER I

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.) is the most widely cultivated cereal in the world after wheat and maize. Rice makes up around 21% of the total calories consumed and is a staple food for more than half of the world's population, including India (Anonymous, 2009; Parameswari *et al*., 2014). With the ever increasing population, world food security has become a major issue. Alarming climate change causing monsoon deficit has further aggravated water scarcity, yielding stagnant rice productivity (Choudhary *et al*., 2010). On the other side, it is reported that future rice land expansion is not sustainable due to recent urbanisation and industrial development (Mohanty *et al*., 2013).

The total amount of rice produced worldwide in 2020 was 756.7 metric tonnes, led by China and India with a combined 52% of this total (Anonymous, 2022). India is the world's second largest rice producer and consumer next to China. Rice plays a pivotal role in Indian agriculture and is the staple food more than 70% of population. It contributes 43% of total food grain production and 46% of total cereal production in India. Rice is cultivated in an area of 43.78 million hectares with an annual production of 118.4 milllion tones and productivity of about 2.7 tonnes ha^{-1} (Annual report 2020-21, Department of agriculture, cooperation and farmer's welfare). In Nagaland, rice is cultivated on 2,14,450 hectares of land with a total production of 5,35,040 t, of which upland rainfed rice occupies 91,040 hectares with a total production of 1,81,080 t (Anonymous, 2019).

There is an urgent need to design and develop innovative methods and techniques of crop production to meet the rising demand for food, feed and forage through optimal utilisation of available agricultural input resources. These resources include arable land, irrigation water, and energy. Small farmers are unable to meet their diverse household demands to maintain a reasonable lifestyle from their limited land, water and financial resources under the current system of solo cropping. Going for suitable alternative and more effective production techniques is therefore necessary. One such approach is multicropping (inter/relay cropping), which can ensure adequate resource usage to enhance production per unit area and time on a sustainable basis (Trenbath, 1986).

The practice of planting two or more crops simultaneously on a single plot of land is known as intercropping (Willey, 1979). One of the key elements affecting the relative success of the two crops grown together is the variation in the pattern and spatial extension of root growth. Component crops compete for light, water, carbon dioxide, nutrients, *etc*. in spatial patterns. According to a report, intercropping is a safer and more reliable method of agricultural production for small farms when labour is affordable and capital is scarce than solitary cropping (Guvenc and Yildirim, 1999). It has been demonstrated that the approach not only produces more crops per acre than solitary cropping, but also enhances the physical and chemical characteristics of the soil (Adelana, 2002). The fundamental goal of intercropping has been to increase the utilisation of resources including space, light and nutrients (Zhang *et al*., 2003), as well as to improve crop quality and quantity and generate more revenue from it than from solitary crops of legumes or cereals. Producing food for subsistence is significantly aided by cereal-legume intercropping in both industrialised and developing nations. Traditionally, farmers have been able to manage soil erosion, diminishing soil organic matter levels and available nitrogen (N) by using legumes in crop cultivation (Scott *et al*., 1987). Legumes fix atmospheric nitrogen, which can either be taken up by the host plant or released into the soil by the nodules and taken up by neighbouring plants. During their combined growing season, legumes can transfer fixed nitrogen to intercropped cereals and this nitrogen is a crucial resource for the cereals (Andrews, 1979). Intercropped legumes would fix nitrogen from the environment and wouldn't compete with cereal for nitrogen in the absence of nitrogen fertiliser (Adu-Gyamfi *et al.*, 2007). Compared to monoculture, a combination of nitrogen-fixing and non-fixing crops produced more (Seran and Brintha, 2009). Cereal and legume intercropping was a well-known technique for maximising the use of nitrogenous fertiliser while boosting production and profitability per unit of land and time. The ability of the component crops to use growth resources differently and utilise natural resources more effectively than when grown individually was one of the key factors contributing to intercropping's higher yield (Willey, 1979). Due to its benefits for preserving soil moisture and weed management, intercropping cereal with legume was common in rainfed areas (Dhima *et al.*, 2007).

In order to meet the rising demand for food, there is unprecedented strain on the current agriculture and natural resources due to the growing population, rising consumption and shrinking amount of accessible land and other productive units. It is very challenging to feed people in developing countries using sustainable methods, but doing so is essential for lowering poverty. Farmers have a tendency to misuse specific inputs, such as chemical agricultural inputs, to get around this problem. As a result, the soil, plants and microorganisms environmental system has already begun to deteriorate. Future food security and sustainability demands will require both significant increases in food production and sharp decreases in agriculture's environmental effect (Foley *et al.*, 2011). To meet the growing demand, global food supply must increase by 70% by 2050. (Bruinsma, 2009). It will take an increase in cereal production of 43 million metric tonnes per year on average to reach this challanging goal (FAO, 2012).

INM primarily refers to combining traditional and contemporary approaches to nutrient management into an agricultural system that is both ecologically sound and economically optimal, utilising the advantages of all available sources of organic, inorganic and biological components-substances in a wise, effective and integrated way. It optimises all facets of the nutrient cycle, including macro and micronutrient inputs and outputs, with the aim of synchronising nutrient demand by the crop and its release into the environment. INM techniques reduce losses due to leaching, runoff, volatilization, emissions, and immobilisation while maximising nutrient usage efficiency (Zhang *et al*., 2012).

Maintaining soil fertility and long-term productivity for sustainable production is made possible by integrated nutrient management, which combines several nutrient sources and management techniques (Yadav *et al*., 2016). An essential part of sustainable agricultural intensification is an integrated nutrient management system. The objective of INM is to combine the usage of all organic and inorganic plant nutrients in order to boost crop productivity effectively and sustainably without harming the soil's health (Dwivedi *et al*., 2012). INM not only lessens reliance on chemical fertilisers but also enhances the bio-physico-chemical properties of the soil such as promoting the activity and growth of mycorrhizae and other beneficial organisms, improving fertiliser use effectiveness, addressing secondary and micronutrient deficiencies and sustaining higher productivity and improved soil health (Singh, 2006).

Chemical fertilisers have originally increased crop growth and output, however the yields are not long-term sustainable. The overall condition of the soil has also gotten worse as a result of the frequent application of large amounts of chemical fertilisers, particularly nitrogen and phosphorus fertilisers. The increased use of chemical fertilisers in India is directly related to the rise in acidic areas (Subehia *et al.*, 2005). While organic manures have an advantage in delivering various macro and micronutrients that is not found in NPK fertilisers, NPK fertilisers are more successful than organic manures in the short term at giving nitrogen (N), phosphorous (P) and (K) potassium (Asiegbu and Oikeh, 1995).

Farm yard manure (FYM) significantly impacted the soil's organic matter concentration (%) when compared to applying the recommended NPK. Organic matter influences crop growth and yield either directly by supplying nutrients or indirectly by changing the physical characteristics of the soil, such as the stability of the soil aggregates, porosity and the amount of water that is available, which can enhance the root environment and promote plant growth (Mustafa *et al*., 2013).

However, it has become vital to reduce the use of chemical fertilisers by adding organic ones to the soil, particularly biofertilizers of microbial origin, in order to sustain the soil ecosystem and due to an increase in the price of chemical fertilisers. The use of biofertilizers in modern agriculture, such as consortia, Rhizobium, Azotobacter, Azospirillum, PSB and Pseudomonas, has been found to be very effective for increasing crop output and quality while also maintaining the fertility of the soil (Saikia *et al.*, 2017). PSB release specific organic acids that can solubilize P from insoluble and fixed forms to forms that are accessible to plants, unlike Azotobacter, which can convert atmospheric N_2 into plant-accessible forms of N in the soil. However, the increase in yield brought about by biofertilizer inoculation may not only be due to N_2-fixation or P-solubilization but also to a number of other factors, such as the release of growth-promoting substances, the suppression of plant pathogens and the expansion of beneficial organisms in the rhizosphere (Mathews *et al*., 2006).

Organic manures are readily available locally and, in contrast to the negative effects of chemical fertilisers, it increases the health of the soil, increasing crop output. However, due to the existence of relatively low amounts of nutrients, using organic manures alone may not be sufficient to meet the needs of plants. Therefore, in order to achieve the best yields, it is vital to employ organic manures in conjunction with inorganic fertilisers to ensure that the soil is adequately provided with all of the plant nutrients in the readily available form and to maintain good soil health (Ramalakshmi *et al*., 2013).

Keeping in view, the scope and significance of integrated nutrient management on intercropping, the experiment entitled 'Integrated nutrient management in upland rice-based intercropping system under foothill condition of Nagaland' was undertaken with the following objectives:

1) To study the comparative performance of rice-based intercropping system
2) To study the suitable integrated nutrient management practice for rice based intercropping system
3) To study the effect of integrated nutrient management and intercropping systems on soil fertility status
4) To study the economics of the treatments

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

World faces the challenge of filling food basket for ever increasing population growing beyond nine billion by 2050. It has been estimated that grain production must increase by 60 to 70 per cent to meet food requirements (Alexandratos and Bruinsma, 2012; Tilman *et al.*, 2002). At the same time, required food for the people of the world has to come with enormous environmental impacts, including soil degradation, desertification and water pollution (Gregory *et al.*, 2002). Thus, development of more sustainable practices are on top priority and one potential strategy would be intercropping. Intercropping is the cultivation of two or more crops species simultaneously in the same field for the whole or a part of their growing period (Willey, 1990). Intercropping was the practical application of basic ecological principles *viz.*, diversity, competition and facilitation for crop production (Gomez and Gomez, 1983). In recent years, intercropping has been widely used as one of the techniques for increasing crop yields in different land forms (Li *et al.*, 1999). One of the main reasons for higher yield in intercropping was that the component crops were able to use growth resources differently, so that when grown together, they complemented each other and make better overall use of growth resources than grown separately (Willey, 1979). Intercropping systems could cause more effective use of resources by providing symbiotic nitrogen from legumes, or making available inorganic phosphorus fixed in soil because of lowering of pH via nitrogen fixing legumes (Jensen, 1996; Aminifar and Ghanbari, 2014). Zhou *et al*. (2000) suggested that intercropping could enhance nitrogen utilization. Nitrogen fixation by a legume crop could be the cheapest and easiest way for supplying nitrogen to the non-legume in intercropping systems. Karlidag and Yildirim (2009) reported that legume plants might provide biologically fixed nitrogen to the non-legumes. Moreover, intercropping systems could reduce the nitrate leaching from the soil profile since intercropping systems utilized soil nutrient elements more efficiently than pure stands (Zhang and Li, 2003).

The increasing costs of fertilizers restrict the farmers to reap full benefits of modern technology. Besides, the continuous use of high analysis fertilizers in an unbalanced manner has resulted in additional problems of soil fertility. Therefore, it is necessary to maintain proper combination among natural resources and plant nutrient supply system to maintain proper growth of crop which can be achieved through integrated approach. The research reports indicate that organic resources of nutrients when supplemented with chemical fertilizers have positive influence on crop growth.

The review of literature pertaining to the present investigation on the possibility of raising a successful rice-based intercropping system through adopting integrated nutrient management practices without affecting the productivity of crop are discussed under the following sub-heads.

2.1 Rice based intercropping systems

2.1.1 Effect of rice based intercropping on growth of rice

2.1.2 Effect of rice based intercropping on yield of rice

2.1.3 Effect of rice based intercropping on nutrient uptake and use efficiency

2.1.4 Effect of rice based intercropping on biological indices

2.1.5 Effect of rice based intercropping on economics

2.2 Integrated nutrient management (INM)

2.2.1 Effect of INM on growth of rice

2.2.2 Effect of INM on yield of rice

2.2.3 Effect of INM on nutrient uptake and use efficiency in rice

2.2.4 Effect of INM on soil properties

2.2.5 Effect of INM on economics

2.1 Rice based intercropping systems

2.1.1 Effect of rice based intercropping on growth of rice

Mandal *et al*. (1999) observed that among the different inter crop plots, the highest dry matter accumulation and LAI of rice were recorded with rice + green gram intercropping system.

The types of intercrop and spatial arrangement in intercropping have important effects on of competition between component crops and their productivity (Sarkar and Pal, 2004).

Ahmad *et al*. (2007) reported that plant height of rice was affected significantly by intercropping. Monocropped rice produced significantly taller plants (146.62 cm) than the rice intercropped with forage legumes but was at par with that intercropped with maize (143.22 cm). Contrastly, significantly lower plant height of rice (131.31cm) was recorded for the crop intercropped with sesbania.

Venkatesha (2008) reported that sole cropping exhibited superior growth as it experienced no kind of suppression due to intercropping. This was evidenced by more plant height (95.70 cm), number of leaves (140.86 $plant^{-1}$), leaf area (3607.9 cm^2 $hill^{-1}$) leaf area index (4.01), leaf area duration (96.01 days), number of tillers (38.03 $plant^{-1}$), dry matter distribution (95.53 g $plant^{-1}$) and absolute growth rate (1.33 g $plant^{-1}$ day^{-1}). Alike to these, Lawrence and Gohain (2011) reported that among different ratio of rice+green gram intercropping, sole rice recorded highest plant height (140.0 cm) and number of tillers (72.7) which was at par with rice intercropped with green gram at 4:1 ratio. In the quest of searching efficient intercrops in rice ecosystem, Jadeyegowda (2015) reported that rice+bhendi intercropping system produced higher plant height (65.5 cm), number of tillers (33.5 plant^{-1}), leaf area (2660 cm^{2} plant^{-1}), leaf area index (4.03), leaf area duration (64.3 days) and dry matter accumulation (104.5 g plant^{-1}) of rice.

2.1.2 Effect of rice based intercropping on yield of rice

Roquib *et al*. (1973) from an experiment reported that the highest grain and better monetary return per unit area was obtained from the intercropping of rice and soybean.

The common upland rice intercropping patterns are 30-40% more productive than monoculture when growing conditions are favourable because of higher photosynthetic efficiency (IRRI, 1974).

Experiment conducted at CRRI, revealed that intercropping legumes (*i.e.*) greengram and groundnut with rice and finger millets increased total grain yield (Rao *et al*., 1982).

In preliminary studies on rice based intercropping system with urd, arhar and groundnut under various cropping geometry, it was observed that the combination of 4:1 followed by rice + groundnut (erect type) in 3:1 ratio yield 18.6 q ha^{-1} and 16.6 q ha^{-1}, respectively than the pure stand of rice (13.7 q ha^{-1}) on rice equivalent yield of crops (Patel *et al*., 1983).

Das (1985) reported that intercropping of rice with different legumes (mung, groundnut and red gram) increased the yield of rice by 13-50%.

Experiment conducted on intercropping of upland rice with black gram by Sengupta *et al*. (1985) achieved maximum advantage under intercropping of rice, established in paired row alternated with blackgram. Blackgram reduced the yield of rice, but owing to the contribution of grain legumes in the productivity of the intercropping system.

Ahuja and Singh (1987) from their field experiment reported that plant height of rice was not much influenced by the inclusion of legumes, however grain size, length and girth of panicle, grain weight panicle^{-1} and 1000 grain weight increased significantly in intercropped plot

Satpathy *et al*. (1987) obtained an additional paddy yield of 0.32-0.71 tones ha^{-1} in the interspaces of arhar rows.

Singh *et al*. (1987) reported that rice in regular rows (20cm apart) + broadcast of soybean was found to be the most suitable intercropping combination.

Mandal *et al*. (1989) reported that number of tillers m^{-2} was always highest in rice grown alone, but intercropping legumes increased the 1000 grain weight. In black gram sown with rice, number of seeds pods^{-1} and 1000 seed weight were higher than in pure stands.

Aggarwal *et al*. (1992) conducted a experiment on intercropping of upland rice (*Oryza sativa* L.) with short-duration grain legumes has shown promising productivity and resource use efficiency. Intercropped rice yielded 73 to 87% of sole rice and intercropped mungbeans yielded 59 to 99% of sole mungbean.

Banik and Bagchi (1994) conducted a experiment to assess the advantages or disadvantages of rice +legume intercropping system on sandy upland loamy soil in Bihar plateau, rice, soybean, blackgram, greengram and pigeonpea were sown in sole and 2:1 intercrop combination. Rice + pigeonpea was the best system, followed by rice rice+soybean with rice equivalent yield of 2.665 and 2.478 tones ha^{-1} compared with 2.254 tones ha^{-1} from rice alone.

An experiment conducted at ICAR Farm of AAU, Jorhat, to evaluate the yield and economics of intercropping green gram in direct summer rice revealed that intercropping rice and greengram (2:1) recorded the highest grain yield. The 2:2 ratio proved to be the superior to all other row ratios in respect of rice equivalent yield (20.76 q ha^{-1}) and land equivalent ratio (LER) of 1.22 (Kalita,1995)

Bijan *et al*. (1997) conducted a field trial under rainfed conditions in upland during the rainy season of 1991-92 revealed that sole crop of rice and groundnut were higher as compared with their respective intercrop yield. However, the highest intercrop yield of rice and groundnut as well as combined intercrop yield of rice + groundnut were obtained from the intercropping combination of rice cv. ‘Kalinga 3’ rice + IC6S groundnut. The highest and monetary advantages were obtained from the same system of intercropping.

Eventhough intercropped rice tend to yield less compared to sole cropped one, risk of farmers can be reduced by magnitude of yield obtained by intercrops. Supporting to this statement, Farrukh *et al*. (2000) conducted experiment to know the bio-economic efficiency of rice-based intercropping systems and the results showed that intercropping of maize, sesbania, mungbean, ricebean, cowpea and pigeonpea decreased the rice yield to the extent of 1.20, 1.11, 0.72, 0.63, 0.74 and 0.76 t ha^{-1}, respectively, compared to rice alone. However, this much reduction in rice yield was compensated by additional harvests of 41.77, 28.60, 21.40, 24.90 and 21.60 t ha^{-1} of maize, sesbania, mungbean, ricebean, cowpea and pigeonpea fodders, respectively.

Saleem *et al*. (2000) conducted a experiment on bio-economic efficiency of some rice-based intercropping systems and the results showed that intercropping of maize, sesbania, mung bean, rice bean, cowpea and pigeonpea decreased the paddy yield to the extent of 1.20, 1.11, 0.72, 0.63, 0.74 and 0.76 t ha^{-1}, respectively compared to rice alone. However, this much reduction in rice yield was compensated by additional harvests of 41.77, 28.60, 21.40, 24.90 and 21.60 t ha^{-1} of maize, sesbania, mung bean, rice bean, cowpea and pigeonpea fodders, respectively.

Intercropping being a unique property of tropical and subtropical areas is becoming popular day by day among small farmers as it offers the possibility of yield advantage relative to sole cropping through yield stability and improved yield (Nazir *et al*., 2002).

Experiment conducted at ICAR Research Complex, Kolasib, on the productivity and economics of different rice and maize based cropping system revealed that intercropping legumes with cereals was found to be highly productive and profitable inclusion of groundnut as an intercrop with rice with maize not only enhanced crop yield and highest net return but also has positive effect on soil fertility build up (Laxminarayana and Munda, 2004).

Jabbar *et al*. (2005) conducted a field experiment on the performance different upland rice-based intercropping system (Rice + forage maize, rice + sesbania, rice+ mungbean, rice +rice bean, rice + cowpea, rice+ pigeon pea and rice alone), revealed that all the intercropping system gave 16.42 to 37.67 per cent higher total rice grain yield equivalent than monocropped rice.

Similarly, Ahmad *et al.* (2007) reported that the rice yield decreased to a significant level by the forage intercrops compared to monocropped rice which varied from 10.94 to 25.87 per cent, with the maximum (25.87%) by sesbania followed by pigeon pea (16.67%) against the minimum (10.94%) by maize intercrop.

Bastia *et al*. (2008) reported from an experiment of 10 cropping system based on rice revealed that rice + groundnut + greengram resulted in maximum number of effective tillers in rice (362 m^{-2}), longest panicles (23.0 cm) and maximum number of grains per panicle (112).

Jabbar *et al.* (2010) reported that rice grain yield was decreased to a significant level by intercropping forage legume and non-legume cultures compared to monocropped rice. However, the per cent decrease in rice grain yield varied from 10.94 to 25.57 per cent with the maximum (25.57%) for rice+sesbania followed by rice+pigeonpea (16.67%) and rice+mungbean (16.42%). On the contrary, the minimum (10.94%) was recorded for rice+maize intercropping system.

Scientists tried different intercrops in the available space between rice rows for getting reasonable yield advantages. Lawrence and Gohain (2011) stated that rice intercropped with green gram at 4:1 ratio has recorded at par result for number of panicle (52.7 hill^{-1}), length of panicle (40 cm), number of grain (192.67 panicle^{-1}), grain yield (1567 kg ha^{-1}) and straw yield (1642 kg ha^{-1}) as compared to sole rice (54.3 hill^{-1}, 43 cm, 197.33, 1708 and 1858 kg ha^{-1}, number of panicle, length of panicle, number of grain, grain yield and straw yield, respectively). Later, Ogutu *et al.* (2012) reported that sole rice has performed better with production of highest number of grain (162.0 panicle^{-1}), test weight (22.16 g), grain yield (2199 kg ha^{-1}) and straw yield (8278 kg ha^{-1}) compared to rice intercropped with cowpea and common bean at different row proportion.

Rana *et al.* (2013) reported that sole rice recorded highest grain and straw yield (5.60 and 7.40 t ha^{-1}) in different rows of sesbania intercropped with rice but it was at par with intercropping sesbania in two rows interval of rice (4.90 and 6.55 t ha^{-1}). Jadav *et al.* (2014) reported that sole rice recorded higher number of panicle (145 m^{-2}) grain yield (2329 kg ha^{-1}) and straw yield (2324 kg ha^{-1}) and rice+soybean intercropping with the ratio of 3:2 has recorded at par value with sole rice. Venkatesha *et al.* (2015) reported that significantly higher grain yield was noticed in sole aerobic rice (5470 kg ha^{-1})

followed by rice + amaranthus (5085 kg ha^{-1}). Also higher yield attributing parameters like number of productive tillers (32.96 hill^{-1}), number of grains (256.77 panicle^{-1}), number of filled grains (235.93 panicle^{-1}), less number of chaffy grains (20.84 panicle^{-1}) were responsible to give significantly higher grain yield of rice.

Iwuagwu *et al*. (2019) conducted a experiment on rice intercropping consist of three treatments of rice + maize, rice + soybeans and sole rice as control were used in the experiment. The results showed that there was a significant effect of intercropping on the yield of rice. The highest yield was obtained in rice + soybean mixture. This was significantly higher than the other mixtures, followed by obtained in rice only. This was significantly the same as the least obtained in rice + maize mixture. It is therefore recommended that rice and some complementary crops such as soybean be intercropped to increase yield in order to maximize profit.

2.1.3 Effect of rice based intercropping on nutrient uptake and use efficiency

According to Vandermeer (1989), intercropping advantage depends on the net effect in the trade-off between interspecific competition and facilitation. Due to better utilization of spatial and temporal variability in intercropping system, plants can able to utilize available resources and thus nutrient uptake by the plants will be more.

Aggarwal *et al*. (1992) reported that nitrogen uptake by intercropped rice with mungbean (33.4 and 41.1 kg N ha^{-1}) approximated that of sole rice (35.4 and 38.1 kg N ha^{-1}).

Experiment conducted by various scientist on intercropping of rice with legume crops, studied effect of intercropping on soil fertility as well as on main crop nutrient uptake efficiency. Chu *et al*. (2004) reported higher soil mineral nitrogen concentration under peanut monocropping and intercropping than under the rice monocropping system. Nitrogen derived from atmosphere by peanut was 72.8, 56.5 and 35.4 per cent under monocropping and 76.1, 53.3 and 50.7 per cent under the intercropping system at nitrogen fertilizer application rates of 50, 75 and 150 kg ha^{-1}, respectively, suggesting that the transferred nitrogen from peanut in the intercropping system made a contribution to the nitrogen nutrition of rice, especially in low-nitrogen soil.

Supporting to this, Jabbar *et al*. (2010) reported the biological efficiency of intercropping in direct seeded upland rice and its effect on residual soil fertility. The intercropping systems comprised rice alone, rice+maize, rice+sesbania, rice+mungbean, rice+ricebean, rice+cowpea and rice+pigeonpea. The results also revealed that residual soil nitrogen and organic matter was improved in all the intercropping systems except rice+maize intercropping system. However, the maximum increase in soil nitrogen (7.14%) was recorded for rice+sesbania intercropping system while the residual soil phosphorus and potassium were depleted in all the intercropping systems as compared to initial soil analysis.

Many scientists studied the effect of intercropping on nutrient uptake and use efficiency. Jadeyegowda (2015) reported that among different intercrops, higher nutrient uptake of nitrogen (132 kg ha^{-1}), phosphorus (33 kg ha^{-1}) and potassium (138.2 kg ha^{-1}) in rice+bhindi intercropping systems which was statistically at par with total nutrient uptake recorded in cluster bean intercropped with rice (132 , 33.0 and 115 kg ha^{-1} NPK, respectively) compared to other intercrops. Similarly, Venkatesha *et al.* (2015) reported that higher nutrient uptake was observed in sole rice crop (170.53 kg N ha^{-1}, 55.58 kg P ha^{-1} and 128.1 kg K ha^{-1}) as compared to other intercrops but, it was at par with amaranthus intercrop with rice (98.4 kg N ha^{-1}, 31.5 kg P ha^{-1},136.5

kg K ha^{-1}). Available favourable residual nutrient status of NPK (311.1, 44.6 and 221.5 kg ha^{-1}) were recorded higher in rice+soybean as compared to sole crop of rice in the soil after harvest of the crops.

2.1.4 Effect of rice based intercropping on biological indices

Experiment conducted on intercropping of upland rice (Jha and Chandra, 1980) revealed that rice + cow pea was an excellent parallel crop as evident by evident by the highest land equivalent ratio of 1.62.

Gosh *et al*. (1986) reported that intercropping of black gram, green gram, pigeon peas and groundnut with rice increased land equivalent ratio as compared to pure rice stands.

Moinbasha and Singh (1988) reported on compatibility of upland rice with pigeon pea even when its plant population was maintained at 15 per cent of that in pure stands. The land equivalent ratio of 1.42 was also obtained from the same system.

The result of the experiment conducted indicated that intercropping upland rice with cow pea gave gross return of 4-11% with a land equivalent ratio of 1.37 (Torres *et al*., 1988).

Experiment conducted with short duration direct seeded rice cultivar as intercrop with arhar in the wet season by Singh *et al*. (1989) obtain a mean land equivalent ratio of 1.5, indicating a considerable increased in resource use efficiency.

Laskar *et al*. (2005) reported that the effect of intercropping on different biological indices of plant was studied by several scientists. Inclusion of groundnut as an intercrop with rice recorded significantly higher equivalent yield (7676 kg ha^{-1}) as compared to sole rice (1057 kg ha^{-1}). Similarly, Ahmad *et al*. (2007) reported that the highest (TRGYE) total rice grain yield equivalent (6.45 t ha^{-1}) for rice+maize followed by rice+cowpea intercropping system (5.08 t ha^{-1}) while, rest of the systems intermediated showing total rice grain yield equivalent (TRGYE) ranging between 4.45 and 4.92 t ha^{-1}compared to the minimum (4.02 t ha^{-1}) for monocropped rice. The overall increase in TRGYE of intercropping treatments over sole crop of rice varied from 16.42 to 37.67 per cent with the maximum (37.67%) in rice+maize and the minimum (16.42%) in rice+mungbean intercropping system.

Lawrence and Gohain (2011) worked out rice equivalent yield (REY) of the intercropping systems from that, it is evident that there was about 10 per cent yield advantage of growing green gram along with upland rice at 4:1 ratio (1866 kg ha^{-1}) over sole crop of rice (1708 kg ha^{-1}) and 24 per cent over sole crop of green gram (1500 kg ha^{-1}).

Ogutu *et al*. (2012) reported land equivalent ratio (LER) of 1.16 (rice+beans) and 1.84 (rice+cow pea) with an intercrop benefit of 0.16 and 0.84, respectively as compare to sole crops. Rana *et al.* 2013 reported that land equivalent ratio (LER) and total rice grain yield equivalent (TRGYE) were highest (1.59 and 6.88 ton ha^{-1}) for intercropping of sesbania in two rows interval of rice followed by intercropping sesbania in between two rows of rice (1.44 and 6.00 t ha^{-1}) and intercropping sesbania around the rice field (1.26 and 5.87 t ha^{-1}) against the minimum (1 and 5 t ha^{-1}) for sole rice, clearly indicating yield advantages of intercropping over monocropping of rice.

Supporting the above data, Jadhav *et al.* (2014) reported that rice equivalent yield of the intercropping systems was highest for rice+soybean intercropping with the ratio of 3:2 (5285 kg ha^{-1}) as compared to other combinations.

Jadeyegowda (2015) found that among different intercropping systems, rice+bhendi produced higher relative equivalent yield (8,911 kg ha^{-1}) compared to all other cropping systems. Least relative equivalent yield was obtained in rice+ragi (1,613 kg ha^{-1}) intercropping.

Venkatesha *et al*. (2015) reported that among the different intercropping systems, rice+amaranthus recorded significantly higher rice equivalent yield (18,007 kg ha^{-1}) closely followed by rice+coriander (17,926 kg ha^{-1}). Rice+amaranthus recorded more relative equivalent yield than french bean (73.81%), bhendi (19.75%), radish (42.87%), soybean (55.14%) and sole rice (69.63%).

Mugisa *et al*. (2020) conducted an experiment on suitable upland rice-based intercropping alternatives to enable upland rice farmers to benefit from intercropping. Three experiments were conducted for two consecutive seasons on rice-beans, rice-groundnuts and rice-maize intercrops. Result indicated that intercropping rice with the three crops leads to more yield benefits as observed from the land equivalent ratios obtained (average 1.5). The best intercrop with better yields and higher land equivalent ratio was intercrop three for the rice legume mixtures and rice based intercrop one for the rice maize mixture.

2.1.5 Effect of rice based intercropping on economics

Mahapatra and Satpathy (1989) reported that the mean gross nature was increased 173% in intercropped rice with pigeon pea as compared to rice in pure stand.

Mandal *et al*. (1990) conducted a field experiment on intercropping rice (*Oryza sativa* L.) and legumes. Rice was intercropped with mungbean, soybean, peanut, ricebean and blackgram on a well-drained sandy loam soil in the Gangetic Alluvial Plains (Fleuvudent). They had found rice legume intercropping resulted in greater in land equivalent ratio (LER), relative net return (RNR), monetary advantage (MA), *etc*. than monocultures.

Intercropping of rice with non-legume crops gave better results compared to pure crop. Farrukh *et al*. (2000) reported that maximum net income of Rs. 56,454.18 ha^{-1} with B:C of 3.71 was obtained from rice-maize intercropping system compared to a minimum net income of Rs. 32,519.93 ha^{-1} and B:C of 2.74 in case of rice alone.

Saleem *et al*. (2000) recorded that the maximum net income of Rs. 56,454.18 ha^{-1} with benefit cost ratio of 3.71 was obtained from rice-maize intercropping system compared to a minimum net income of Rs. 32,519.93 ha^{-1} and benefit cost ratio of 2.74 in case of rice alone.

Sarkar and Pal (2004) conducted a experiment to evaluate the production potential and economic feasibility of intercropping in rainfed direct-seeded rice with groundnut and pigeonpea under different spatial arrangements. The intercropping system of rice with either groundnut or pigeonpea was found beneficial over sole cropping of rice. Among the intercropping systems, rice with groundnut in 4:2 row proportion was most productive and remunerative, as it gave the maximum rice-equivalent yield (2,815 kg ha^{-1}), net returns (Rs. 7,720 ha^{-1}), income-equivalent ratio (1.61) and higher land-utilization efficiency (31%).

Laskar *et al.* (2005) reported that intercropping of rice+groundnut recorded significantly highest net returns (Rs. 36,227 ha^{-1}) and B:C (4.65) whereas, sole rice has recorded least net returns (Rs. 1,216 ha^{-1}) and B:C (1.22).

Annie and Rao (2006) reported that the intercropping system yielded 50 percent more than pure crop when rice was intercropped with pigeon pea, exhibiting rice equivalent of 4.39 tones ha^{-1} and net return of Rs.14130 ha^{-1} over sole rice crop.

Jabbar *et al.* (2010) reported that rice + maize and rice + cowpea gave maximum net benefits of Rs. 42,325 and Rs. 30,885 ha^{-1}, which were 37.32 and 14.03 per cent higher than sole rice (Rs. 26,526 ha^{-1}), respectively. However, the net benefits of all intercropping systems were higher than that achieved from monocropping of rice.

Rana *et al.* (2013) reported that intercropping sesbania in two rows interval of rice performed better with highest gross returns (Rs. 1,38,511 ha^{-1}), net returns (Rs. 73,531 ha^{-1}) and B:C (2.13) as compared to other treatments. Similarly, Jadav *et al*. (2014) reported that gross monitory return (Rs. 59,656 ha^{-1}) and net monitory return (Rs. 35,229 ha^{-1}) were higher with rice+soybean intercropping at the ratio of 3:2 over rest of the intercrop treatments.

Similarly, Jadeyegowda (2015) reported that rice+bhindi intercropping system recorded significantly higher gross returns (Rs. 6,89,824 ha^{-1}), net returns (Rs. 53,822 ha^{-1}) and B: C (4.6) as compared to the other intercrops. Significantly lowest gross returns (Rs. 13,107 ha^{-1}), net returns (Rs. 1,420 ha^{-1}) and B: C (1.1) was obtained in the rice+ ragi intercropping systems. Venkatesha *et al*. (2015) reported that with respect to economics, rice+amaranthus recorded significantly higher gross returns (Rs. 1,03,382 ha^{-1}), net returns (Rs. 84,107 ha^{-1}) and B:C (1:5.36) as compared to other intercrops.

By adopting intercropping, the yield reduction of main crop compared to sole crop was compensated by additional yield of intercrops. So, the B:C ratio calculated in intercropping system gave better value than sole cropping.

2.2 Integrated nutrient management (INM)

2.2.1 Effect of INM on growth of rice

Bopaiah and Abdul Khader (1989) have reported that the biofertilizer inoculation increased the plant height, weight and NPK status of the plant compared with the uninoculated control.

Sujathamma and Reddy (2004) revealed that plant height, tillers, leaf area index and dry matter production of rice were significantly higher with the application of 100% fertilizer nitrogen, which was however, comparable with 25% FYM (N)+75% fertilizer nitrogen in respect of tiller production during later stages and dry matter production during early stages.

The growth parameters increased significantly by the combined use of fertilizer nitrogen and FYM *i.e.* 75 per cent recommended dose of nitrogen through urea and 25 per cent recommended dose of nitrogen through FYM (Anny *et al*., 2005).

Gautam *et al*. (2013) while conducting an experiment on integrated nutrient management and spacing on productivity and economics of rice under system of rice intensification revealed that growth parameters of rice increased consistently and significantly with increase in FYM and fertilizer levels.

Plant height, tiller number, leaf area index, and dry matter production were all significantly higher in the chemical fertilizer and organic manure treatment (Sheikh *et al*., 2013).

Zayed *et al*. (2013) reported that application of 2/3 of the recommended dose of nitrogen with different types of organic manures, @ 7 t ha^{-1} and 5 t ha^{-1} respectively, resulting in higher leaf area index of rice under saline soil conditions.

Panwar (2014) showed that the growth parameters of rice were improved with the application of 5 tonnes FYM ha^{-1} + Azolla dual cropping + 75% of the recommended dose of NPK (80:60:40 kg ha^{-1}, RDF)

Marzia *et al*. (2016) reported that application of 75% recommended dose of inorganic fertilizers + cow dung at 5 t ha^{-1} gave the highest plant height (124.60 cm), number of total tillers $hill^{-1}$ (15.05), number of effective tillers $hill^{-1}$ (12.98), longest panicle (25.29 cm), grains $panicle^{-1}$ (155.66) and grain yield (3.89 t ha^{-1})

Apon *et al*. (2018) at Nagaland University, Medziphema and observed that maximum plant height (137 cm) and maximum tiller (160 m^{-2}) was obtained with the treatment applying 75% RDF + 5 t ha^{-1} FYM.

Significantly higher number of tillers m^{-2} was recorded with application of 75% NPK + 25% FYM which was statistically at par with 100% NPK application (Tomar *et al*., 2018).

Ram *et al*. (2020) conducted a experiment to evaluate the effect of integrated nutrient management on growth, yield, nutrient content and economics of summer rice (*Oryza sativa* L.) found that the treatments with 75% recommended dose of nitrogen along with 25% vermicompost (T_2) and 75% recommended dose of nutrients (RDN) along with 25% FYM (T_3) recorded enhanced growth, nutrient content and productivity which were at par with 100% RDN and the lowest results are found with control (no fertilizer).

Shankar *et al*. (2020) while conducting an experiment at farmer's field at Binuria village of Birbhum, West Bengal found that INM practices exerted positive and significant effect on dry matter accumulation (DMA) of summer rice. The maximum DMA and leaf area were recorded in crop receiving 75% RDN through chemical fertilizers and 25% of applied through FYM and poultry manure

2.2.2 Effect of INM on yield of rice

Study from Simanungkalit (2001) implies that application of biofertilizer and inorganic fertilizer was integrated approach in improving the growth and the production of crop.

Mondal *et al*. (2003) also observed that the number of panicle m^{-2} and number of filled grains $panicle^{-1}$ was highest (422.7 and 98.3, respectively) with 75% of the recommended dose of NPK (60 kg N+30 kg P_2O_5+30 kg K_2O) along with FYM @ 4 t ha^{-1}. The maximum rice grain yield (6 t ha^{-1}) was also recorded at 75% of the recommended dose of NPK+FYM @ 4 t ha^{-1}.

Bharambe and Tomar (2004) indicated that combined application of FYM and inorganic fertilizers was more effective as compared to inorganic fertilizers alone in building up fertility status of soil and increasing the productivity of rice.

Senapati *et al*. (2004) reported that intercropping of rice with blackgram, green manuring along with azotobacter and addition of FYM are the most suitable INM approaches for rainfed upland rice in the tribal zones.

Mishra *et al*. (2006) stated that in different sources of nitrogen *i.e.* FYM, vermicompost and poultry manure, the highest grain yield (64.3 q ha^{-1}) of aromatic rice (Pusa basmati) was obtained with incorporation of 25% nitrogen through organic source and 75% nitrogen through urea.

Experimental findings of Saha *et al*. (2007) while studying the influence of integrated nutrient management on quality of basmati rice (*Oryza sativa* L.) stated that significantly highest hulling per cent (74.8%), milling per cent (67.5%), head rice recovery per cent (53.0%) and amylose content (20.1%) in rice and grain yield of rice was recorded with treatment 75% RDF +25% N by addition of FYM whereas significantly lowest value of all these quality parameters were documented with treatment 100% RDF (80: 40:40 NPK kg ha^{-1}).

El-Ainy (2008) reported that biofertilizer application had a positive correlation with rice crop production.

Rahman *et al*. (2009) reported increased panicle length in rice with the combine use of organic and inorganic fertilizer.

Highest rice productivity (7.1 t ha^{-1}) was obtained with the application of 75 per cent nitrogen supplied through inorganic source and 25 per cent through FYM (Kharub and Chander, 2010).

Larijani and Hoseini (2012) also found that more tiller number (28%), more panicle m^{-2} (60%), number of filled grains m^{-2} (20.6%), spikelet per panicle (19.6%) and more grain yield (30.6%) with combined use of organic and chemical fertilizer compared with chemical fertilizer alone

Significant increase in grain yield of rice by 10.9, 21.8 and 28.5% with the conjunctive use of farm yard manure, vermicompost and poultry manure with NPK respectively compared to no manure treatment and NPK alone was reported by Khursheed *et al*. (2013).

Application of 1/3rd recommended dose (RD) of nitrogen through chemical fertilizer, FYM and Azolla reported higher yield components *i.e.*, number of panicles m^{-2}, number of filled grain panicle^{-1}, grain and straw yield of rice as compared to 100% recommended dose of fertilizer and control (Mohanty *et al*., 2013).

Saba *et al*. (2013) further noticed that combination of bio-fertilizer, nitrogen and phosphorous (500-120-90 kg ha^{-1}) exceeded all other treatments reported highest number of tillers m^{-2}, number of panicles m^{-2}, number of spikelets panicles^{-1}, percent normal kernels, 1000-grain weight (g) and paddy yield (t ha^{-1}).

Dissanayake *et al*. (2014) mentioned on his experiment conducted at Rajarata University of Sri Lanka that the yield attributes like panicle length, filled grains per panicle was higher in INM compared to other treatments irrespective of season and variety.

Marlina *et al*. (2014) reported that the best treatment in term of plant height at 8 weeks after planting (WAP), the maximum number of tillers, number of productive tillers, number of grains per panicle and weight of milled dry rice were obtained in combination of 75% inorganic fertilizer and 300-400 kg ha^{-1} biofertilizer.

Parihar *et al*. (2015) observed that the number of tillers m^{-1}, plant height and 1000 grain weight increased with increase graded levels of inorganic fertilizers with FYM than without FYM on similar dose.

Sohela *et al*. (2016) studied the influence of integrated use of organic and inorganic fertilizers on the growth and yield of Boro rice (*cv.* BRRI dhan 29). It was observed that cow dung, poultry manure and water hyacinth with chemical fertilizers gave better grain and straw yields than only chemical fertilizers.

Sahu *et al*. (2017) studied the effect of combined application of fertilizers, micronutrients and biofertilizers on yield in rice. Significantly higher value in grain yield, straw yield as well as biological yield was obtained with integrated application of fertilizers followed by biofertilizers inoculated treatments.

Sahu *et al*. (2018a) conducted a field experiment and results indicated that rice yield and yield contributing traits significantly increased with the use of compost, vermicompost, green manure and FYM in combination with chemical fertilizer than individual sources.

Sharada and Sujathamma (2018) on the basis of the results found that combination of organic and inorganic fertilizers not only increase qualitative parameters which resulted in higher grain and straw yield of rice cultivar.

Sravan and Singh (2019) evaluated the effect of integrated nutrient management on yield and quality of basmati rice varieties. The results indicated that application of 75% recommended dose of fertilizers with 25% recommended dose of nitrogen as farmyard manure produced higher mean values by 3.1%, 4.2% and 4.0% for hulling, milling and head recovery respectively over 100% recommended dose applied as inorganic sources.

The maximum no of panicles m^{-2} was noticed (346 m^{-2}) with the treatment having 75% RDN+25% poultry manure and also in proportion with 75% RDN+25% FYM under the experiment conducted by Shankar *et al*. (2020).

2.2.3 Effect of INM on nutrient uptake and use efficiency in rice

It has been hypothesized that legumes grown in rotation with lowland rice can intercept soil mineral nitrogen, which might, otherwise, be lost by de-nitrification on leaching after flooding the soil and this helps recycling soil nitrogen for uptake by rice (Buresh and Datta, 1991).

Application of NPK fertilizer in combination with FYM registered the higher uptake of N, P and K by both grain and straw (Natarajan *et al*., 2005).

Maximum mean nitrogen uptake (94.9 kg ha^{-1}) was recorded under combined use of farm yard manure and poultry manures. Incorporation of organic manures caused improvement in organic carbon and available nitrogen content of soil after crop harvest as compared to control (Kumar *et al*., 2006).

It is revealed from the experimental findings of Saha *et al*. (2007) that significantly highest nitrogen uptake (48.3 kg ha^{-1}) in rice grain, phosphorous uptake (16.0 kg ha^{-1}) and potassium uptake (79.3 kg ha^{-1}) in rice was recorded with treatment 75% RDF+25% N by FYM (4t ha^{-1}) where as significantly lowest NPK uptake in rice grain (42.8 kg ha^{-1}), (11.2 kg ha^{-1}) and (70.06 kg ha^{-1}) was recorded with treatment 100% RDF.

Sathish *et al*. (2011) also reported that treatments which received combination of organic and inorganic fertilizer showed higher uptake values by rice crop of all the three nutrients NPK.

Tayefe *et al.* (2011) stated that nitrogen use efficiency of all was decreased with increasing nitrogen application with inorganic fertilizers and it was increased with integration of organic manures and chemicals as the results found in an experiment conducted at Rice Research Institute, Rasht, Guilan, Iran. The agronomic nutrient use efficiency was maximum with application of integrated nutrient management. They also reported that the lower the inorganic inputs the higher the agronomic use efficiency.

Weijabhandara *et al*. (2011) reported that application of 75% RDF + biofertilizers resulted in significantly higher grain yield, uptake of N, P, K and Zn by grains and residual available N, P, Zn compared to other treatments.

Studies by Zayed *et al.* (2013) also proved that application of two-thirds of the RDN plus some organic fertilizer, either FYM or rice straw compost at a rate of 7 t ha^{-1} and 5 t ha^{-1} respectively, resulting in higher plant nitrogen and phosphorus content even under saline soil conditions of rice field.

Sahu *et al*. (2017) in their research at red and lateritic soils of West Bengal denoted that the uptake of N, P and K was more in the treatments having the combination of organic manures and fertilizers. The uptake of N and K was more in grain whereas the uptake of K was more in straw.

Kumar *et al*. (2018) reported that the incorporation of organic manures likely FYM and vermicompost along with chemical fertilizers favoured in better root growth with resulted in high uptake of N (109.21 kg ha^{-1}) P (16.41 kg ha^{-1}) and K (102.36 kg ha^{-1}) under the experiment conducted at University of Agricultural and Horticultural Sciences, Shivamogga.

Tiwari *et al.* (2020) evaluated the impact of NPK integrated with FYM under STCR approach on performance of rice and change in properties of a Vertisol. Significantly higher yields of grain (5.74 t ha^{-1}), straw (7.57 t ha^{-1}) and total N, P and K uptake by rice (114.97, 20.91 and 131.21 kg ha^{-1}) were obtained with the higher doses of NPK along with FYM as compared to control. Application of NPK integrated with FYM was significantly improved in EC, organic carbon, available N, P and K contents in post harvest surface soils over control and fertilizers alone. Soil test based integrated nutrient management maximizes dry matter accumulation, yields, NPK uptake by rice and improved soil fertility in a Vertisol.

2.2.4 Effect of INM on soil properties

In a study Pandian and Perumal (2000) have reported that the nitrogen levels and organics significantly influenced the organic carbon content. The negative balance of organic carbon is registered with the fertilizer nitrogen alone and the combination with *Azospirillum*. The conjoint application of nitrogen with the green manure and FYM resulted in build up of organic carbon content was notice (0.01 to 0.11%) with the incorporation of green manure with fertilizer nitrogen. Nearly 0.10% increase in the status was observed with 200 kg N ha^{-1} in combination with green manure + Azospirillum. The green manure contains two fractions, one of which undergoes faster decomposition and release nitrogen for the current crop, while the other mineralizes at a slower rate, enhanced level of organic carbon (Bouldin, 1987).

Continuous addition of organic matter either through green manuring or FYM is more essential to sustain soil N fertility (Ramamoorthy *et al*., 2001).

The available nitrogen was increased significantly due to combined addition of fertilizers and organics through FYM, green manure and crop residues. Continuous addition of organics through FYM, green manure and crop residues also resulted significantly higher available phosphorous and potassium (Sharma *et al*, 2001).

Sharma and Sharma (2004) recorded the increase in organic carbon and available N, P and K contents in soil due to combined application to FYM and inorganic fertilizers.

Fan *et al*. (2005) revealed that combination of organic and inorganic fertilization in rice enhanced the accumulation of soil organic carbon and maintained the highest productivity.

Farmyard manure is being used as major source of organic manure in field crops and its role in crop production cannot be overlooked. In addition to supplying all essential nutrients, it increases the activities of bacteria or microbes in soil (Sutaliya and Singh, 2005).

The increment of organic carbon, available P_2O_5 and K_2O content in soil were observed when compared with the initial values in all integrated nutrient sources except in treatment receiving only RDF (Virdia and Mehta, 2009).

Nayak *et al*. (2012) found that the application of inorganic fertilizer along with FYM significantly increased the available NPK and micronutrient content of soil, which was followed by application of inorganic fertilizer alone resulted with increase in NPK but slight decline in micronutrient contents *viz*., Zn, Fe, Cu and Mn. Thus, application of inorganic fertilizer along with FYM is an effective way of sustaining soil properties in subtropical paddy soils.

Similarly, the combined application of FYM and inorganic N and P fertilizers improved the chemical and physical properties of soil, which may lead to enhanced and sustainable production of rice (Tilahun *et al*., 2013).

Sannathimmappa *et al*. (2015) indicated that application of inorganic fertilizers along with organic sources applied to the soil, increased the status of plant available nutrients and improved the physic-chemical and biological properties of soil which directly affect soil fertility.

Hazarika *et al*. (2018) revealed that the combined application of manure and chemical fertilizer to soil increase the available N, P, K status of soil and improve the organic carbon content of soil.

Sahu *et al*. (2018b) conducted a field experiment and the results indicated that integrated application of inorganic and organic fertilizers helped in increasing the availability of nutrients and improve major physical and chemical characteristics of soil.

Gogoi *et al*. (2019) reported that available N, P and K of soil were significantly affected by integrated nutrient treatments which showed up to 65.29, 81.03 and 21.46% increase of these nutrients over RDF and control, respectively.

2.2.5 Effect of INM on economics

Acharya and Mondal (2010) from a study on rice-cabbage-greengram cropping system reported higher rice equivalent yield of 32.33 t ha^{-1} under 75% RDF + 25% N through FYM to all the crops than RDF alone which produced relative equivalent yield of 26.80 t ha^{-1}. Again the study revealed that higher net returns (Rs. 1,43, 463 ha^{-1}) and benefit: cost ratio (2.92) were obtained when crops in sequence were fertilized with 75% RDF along with 25% N through FYM than that obtained with 100% RDF (Rs.1,15,589 ha^{-1}, B:C ratio 2.46)

Gogoi *et al*. (2010) conducted a experiment on integrated nutrient management on growth, yield of crops and availability of nutrients in Inceptisol under rainfed rice (*Oryza sativa*)-niger (*Guizotia abyssinica*) sequence of Asom reported that the treatment receiving 75% N (inorganic) + 25% N (farmyard manure) + PK (inorganic and adjusted) recorded the highest benefit: cost ratio (2.21), followed by RDF (2.16).

Kumari *et al*. (2010) reported that under the experiment conducted at Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. Further, they noted that gross returns (Rs. 84167 ha^{-1}) was maximum with the application of 75% RDF along with 5t ha^{-1} FYM.

Ghosh *et al*. (2014) reported that combined application of cowdung @5 t ha^{-1} along with recommended chemical fertilizers based on IPNS was more economic compared to other treatments because maximum B:C ratio was calculated from this treatment. The overall results suggested that integrated nutrient management could be used as an alternate option of chemical fertilization to achieve maximum cost of return for rice *cv*. NERICA 10 cultivation.

Imade *et al*. (2017) reported that B:C ratio (1.39) was highest with the application of 75% recommended dose of nitrogen (RDN) through chemical fertilizer + 25% recommended dose of nitrogen (RDN) through biocompost because of lower cost of cultivation.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment titled **"Integrated nutrient management in upland rice-based intercropping system under foothill condition of Nagaland"** was conducted during *kharif* season, 2019 and 2020 at the Experimental Research Farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus. The details of experimental materials used and the research methodology adopted during the course of experimentation has been discussed in this chapter.

3.1 General Information

3.1.1 Geographical location of the experimental site

The location of the experimental site was situated at $25^{0}45^{/}43^{//}$N latitude and $95^{0}53^{/}04^{//}$E longitude at an elevation of 310 m above mean sea level.

3.1.2 Weather and Climatic condition:

The climate of the experimental farm represents sub-humid tropical climate zone with high relative humidity, moderate temperature with medium to high rainfall. The mean temperature ranges from 21^{0}C to 32^{0}C during summer and rarely goes below 8^{0}C in winter due to high atmospheric humidity. The average annual rainfall varies between 2000-2500 mm starting from April and ends with the month of September while the period from October to March remains complete dry.

The meteorological data recorded during the period of experimentation from the time of field preparation till the final harvest of the crop for two successive years have been presented in Table 3.1(a) and 3.1 (b) and graphically sown in Fig 3.1 (a) and 3.1 (b)

Table 3.1 (a):Meteorological data during the period of investigation June-December, 2019

Standard week no.	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days	Sunshine (hours)
	Max	Min	Max	Min			
22	33.3	21.4	92	62	111.3	5	5.6
23	32.5	23.5	91	70	15.9	4	4.5
24	33.2	24.4	91	67	41.0	2	4.8
25	34.5	24.9	91	73	66.0	4	5.1
26	34.4	24.6	91	68	21.0	3	3.8
27	32.5	25.2	94	78	63.7	5	2.6
28	30.8	24.9	94	78	34.1	2	0.2
29	35.0	24.7	92	61	57.4	1	7.1
30	33.5	24.5	93	70	111.5	5	3.1
31	33.1	24.8	95	72	29.1	4	3.7
32	35.1	25.3	92	68	42.5	3	5.8
33	33.8	24.5	92	74	121.6	4	3.9
34	34.0	25.1	91	72	24.5	3	5.0
35	33.8	24.7	93	75	64.6	4	5.1
36	34.0	25.1	94	72	21.2	2	5.2
37	33.1	24.7	94	73	16.3	2	3.1
38	33.9	23.3	92	66	37.3	3	5.2
39	29.6	22.5	95	79	94.6	3	2.2
40	31.0	22.6	95	77	22.1	2	5.9
41	31.2	23.2	95	69	50.8	4	6.4
42	32.5	21.6	94	65	19.0	2	7.6
43	26.5	20.1	96	81	152.9	3	2.9
44	30.7	19.2	97	69	0.0	0	8.3
45	28.7	19.6	97	76	34.9	3	4.2
46	29.0	16.2	97	59	18.0	1	8.0
47	27.8	13.3	98	58	0.0	0	7.6
48	27.9	13.5	98	63	0.0	0	7.0

Source: ICAR, Nagaland Center, Jharnapani

Table 3.1 (b): Meteorological data during the period of investigation June-December, 2020

Standard week no.	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days	Sunshine (hours)
	Max	Min	Max	Min			
22	30.1	21.2	92	63	74.0	4	5.7
23	31.9	22.7	94	68	16.5	2	4.1
24	33.2	24.7	92	80	67.1	4	4.0
25	33.1	24.3	92	71	111.9	6	4.9
26	31.8	23.9	92	73	53.6	3	2.3
27	32.9	24.6	94	78	79.5	5	3.7
28	32.9	24.8	93	71	29.7	3	1.9
29	32.3	24.6	93	72	18.5	3	2.8
30	32.0	23.9	93	76	71.4	6	2.2
31	33.6	25.3	94	70	3.5	0	4.8
32	34.7	25.3	92	71	10.8	3	4.5
33	33.6	25.2	92	67	31.4	2	3.0
34	32.4	24.4	96	74	32.3	3	4.0
35	33.1	24.7	93	71	42.9	2	4.8
36	33.8	24.3	94	64	10.7	1	7.3
37	33.3	24.3	95	72	58.5	1	4.5
38	33.2	24.5	96	76	17.3	2	3.6
39	31.3	24.1	95	80	31.3	4	3.4
40	32.5	23.5	95	80	103.9	4	4.6
41	32.2	23.4	95	71	2.5	0	7.0
42	32.4	23.6	94	64	1.1	0	6.2
43	28.6	22.0	97	80	68.2	4	3.6
44	30.1	22.5	96	74	34.8	2	4.1
45	29.3	17.7	97	61	0.4	0	7.4
46	29.0	15.2	98	60	0.0	0	8.1
47	26.2	14.0	97	56	0.0	0	5.7
48	26.3	12.1	97	55	0.0	0	7.2

Source: ICAR, Nagaland Center, Jharnapani

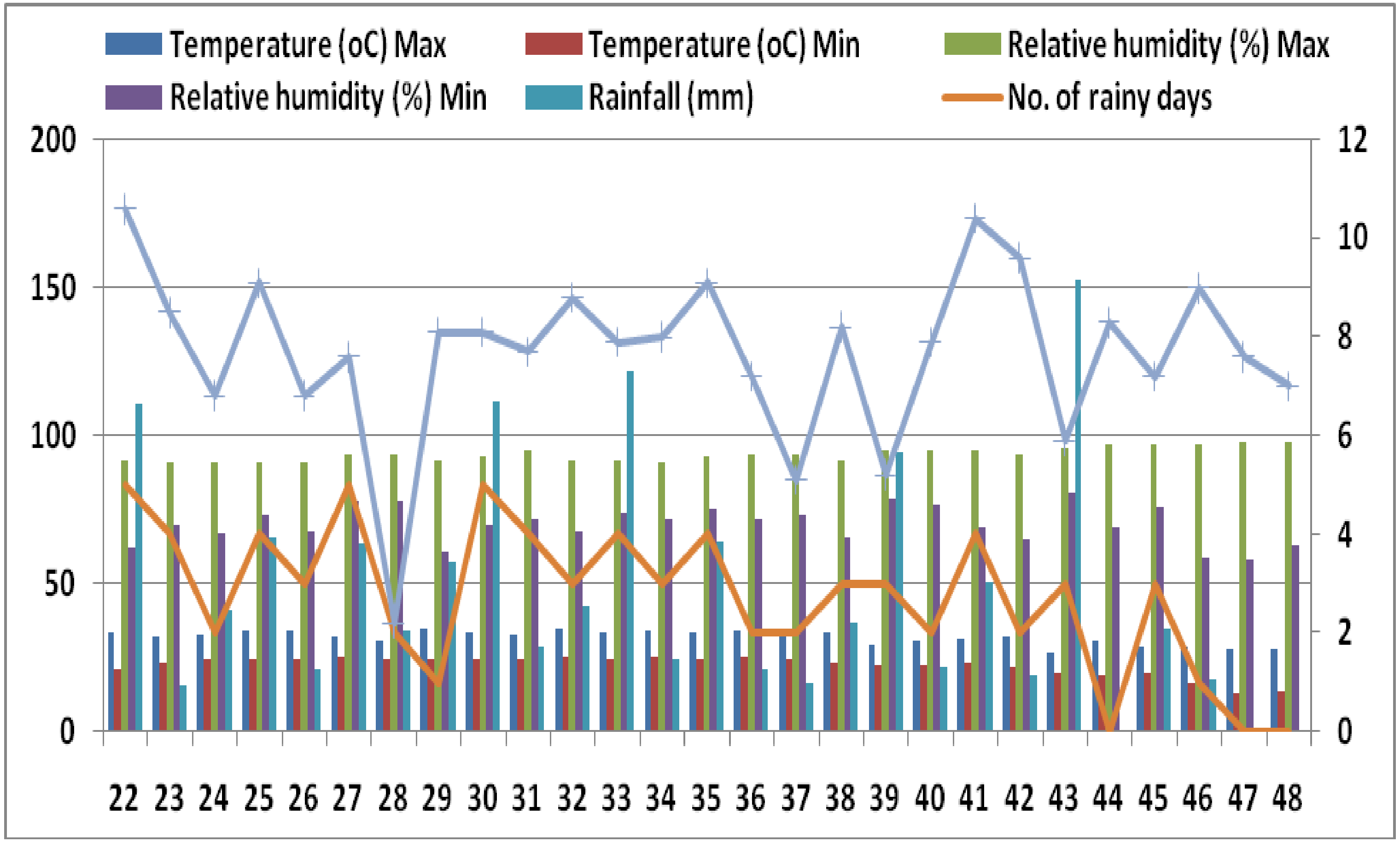


Fig 3.1 (a): Meteorological data during the period of investigation June- December, 2019

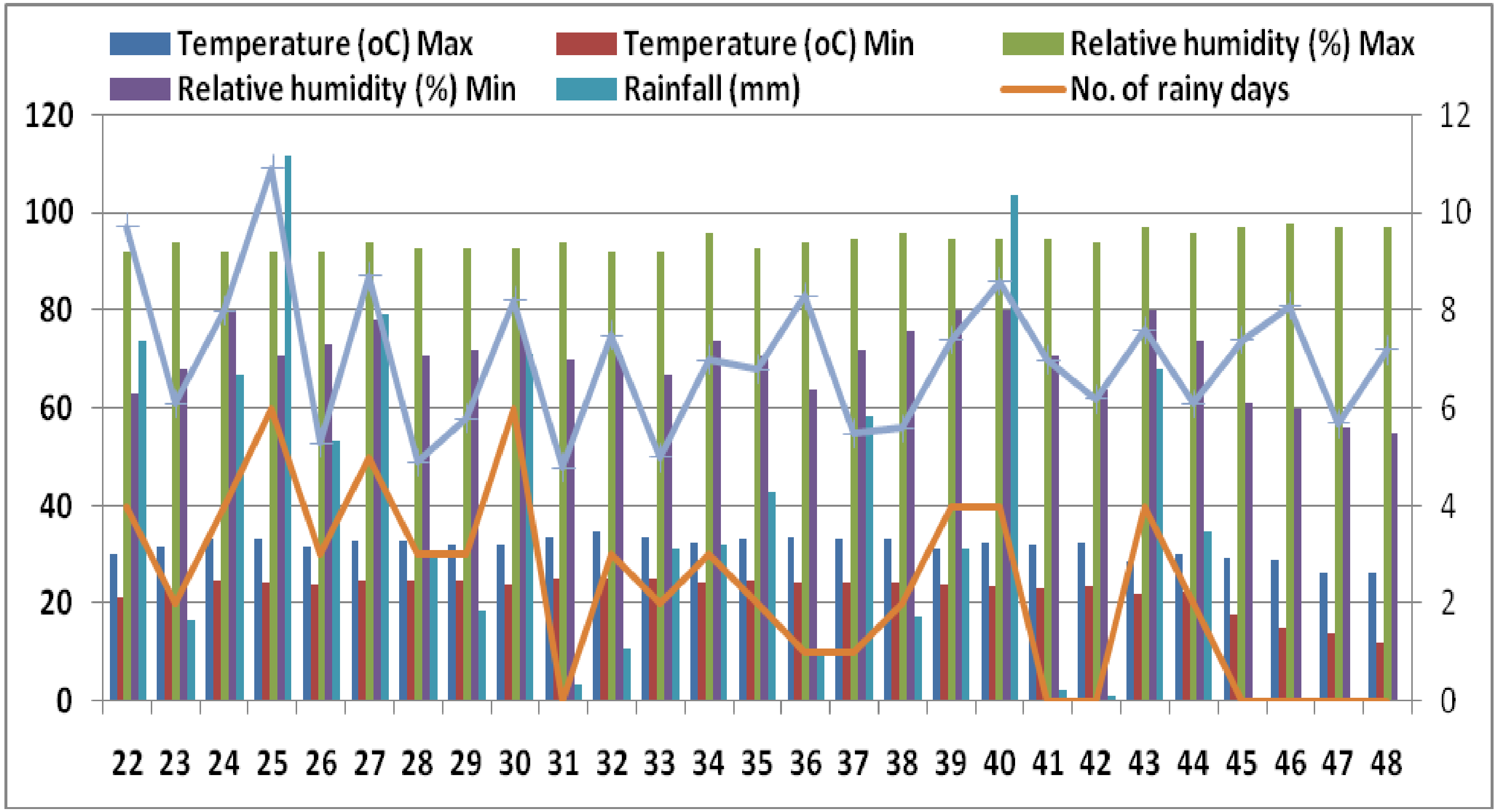


Fig 3.1 (b): Meteorological data during the period of investigation June- December, 2020

3.1.3 Soil condition

The surface soils up to 0-15cm depth were collected from different points selected at random to determine the physical, chemical and biological properties of the experimental area. The collected composite bulk soil samples were air dried and ground with a wooden roller and finally passed through 0.2 mm sieve. After through mixing, the soil samples were analyzed for both physical, chemical and biological properties of the soil. The initial status of the soil has been presented in Table 3.2 (a) and 3.2 (b).

3.2 Experimental details

3.2.1 Experimental design

The experiment was laid in Randomized Block Design (RBD) with three replications and it has factorial concept. The whole experimental field was divided into three equal blocks, with each block subdivided into fifteen equal plots. The different treatments were randomly allocated within the plots of each block. The layout of the experiment is given in Fig. 3.2.

3.2.2 Details of the experimental techniques

Design of the experiment	: Randomized Block Design (RBD)
Number of replications	: 3
Number of treatment	: 15
Total number of plots	: 45
Plot size	: 4 m × 3 m
Net area	: 540 m^2
Gross area	: 728 m^2
Varieties	: Rice – Sahbhagi Dhan Groundnut - ICGS 76 Soybean- JS 9752

Table 3.2: Initial soil status of the experimental field

Characteristics	Method followed	2019	2020	Inference
		Content	Content	
Soil texture	International pipette method (Piper,1966)	Sand: 52.40% Silt: 27% Clay: 20.60%	Sand:53.70% Silt: 27.2% Clay: 19.10%	Sandy loam
Soil pH	Digital pH meter (Jackson, 1973)	4.92	4.95	Acidic
Organic carbon (%)	Titrimetric determination (Walkley and Black method, 1934)	1.35	1.37	High
Available N (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	267.52	278.78	Low/Medium
Available P (kg ha^{-1})	Bray's I method (Bray and Kurtz, 1945)	20.65	21.48	Low
Available K (kg ha^{-1})	Neutral normal ammonium acetate method (Jackson, 1973)	144.12	147.34	Medium
Bacteria (No. x 10^6cfu g^{-1} soil)	Serial dilution agar-plating method	29.45	32.68	-
Fungi (No. x 10^3cfu g^{-1} soil)		28.72	33.23	-
Actinomycetes (No. x 10^5cfu g^{-1} soil)		1.62	1.65	-

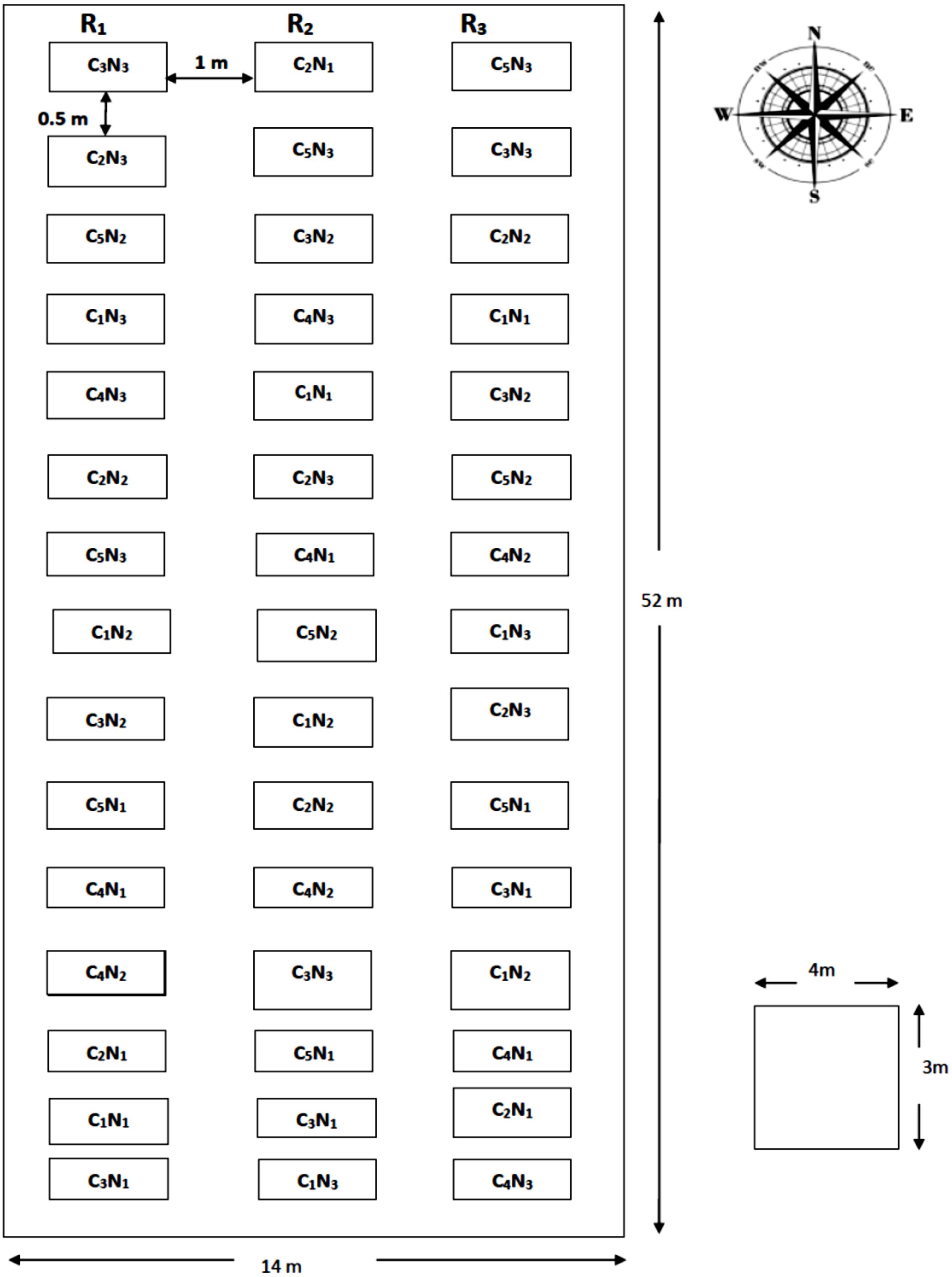


Fig 3.2: Layout of the experimental field in Randomized Block Design

3.2.3Treatments details

The present experiment entitled is “Integrated nutrient management in upland rice-based intercropping system under foothill condition of Nagaland” designed with five cropping systems and three nutrient management practices which are described below.

A) Cropping system (C)

C_1- Sole rice

C_2- Sole groundnut

C_3- Sole soybean

C_4- Rice + groundnut (3:1)

C_5- Rice + soybean (3:1)

B) Nutrient management (N)

N_1-100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed

N_2- 75% RDF + FYM @ 5 t ha^{-1}+ biofertilizer consortium @ 20 g kg^{-1} seed

N_3-50% RDF + FYM @ 7.5 t ha^{-1}+ biofertilizer consortium @ 20 g kg^{-1} seed

3.2.3 Varietal description

a) Rice

Variety: Sahbhagi Dhan

Sahbhagi Dhan is a dwarf, drought tolerant variety. This variety possess long-bold grain, highly resistant to leaf blast, moderately resistant to brown spot, sheath blight, stem borer and leaf folder. Adapted to both rainfed upland and lowland with duration of 105-110 days in plain areas and 110-115 days in upland. This allows farmers to plant the next crop earlier, which in turn gives them enough time to plant three crops in a year.

b) Groundnut

Variety: ICGS 76

ICGS 76 is a high yielding variety. Matures in 120 days in the rainy season. It has a ability of good recovery from mid- season drought. It has a oil content of 43% and good oil quality (oleic/linoleic acid ratio of 1.69).

C) Soybean

Variety: JS 9752

JS 9752 is a wide adaptable, high yielding and multiple resistant variety. It possesses excellent germinability, field emergence and longevity during storage. It is a medium duration variety and recommended for Central and North East zone

3.3 Cultivation details

The agronomic practices carried out during the course of experimentation are detailed hereunder. The calendar of agronomic management practices performed during the investigation period are presented in Appendix-A.

3.3.1 Preparation of the field

In order to facilitate sowing, the experimental field was thoroughly ploughed with a tractor drawn disc plough in the month of May during both the years. Final ploughing and breaking of clods were done with the help of a rotovator. All the stubbles, debris and undecomposed plant materials were removed before layout.

3.3.2 Application of Farm yard manure (FYM)

The amount of FYM was calculated for each plot separately and applied three weeks before sowing of rice, groundnut and soybean as per treatment as mentioned earlier.

3.3.3 Application of fertilizers

Fertilizer requirement of the crops were met through Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O).

a) Rice intercrop and sole crop of rice

Intercrop and sole crop of rice received different levels of fertilizer i.e. for 100% NPK-60 kg ha^{-1} N + 30 kg ha^{-1} P_2O_5 + 20 kg ha^{-1} K_2O, for 75% NPK-45 kg ha^{-1} N + 22.5 kg ha^{-1} P_2O_5 + 15 kg ha^{-1} K_2O and for 50% NPK- 30 kg ha^{-1} N + 15 kg ha^{-1} P_2O_5 + 10 kg ha^{-1} K_2O. The total quantity of P and K and one-third (⅓) of nitrogen was applied at the time of sowing and remaining two-third (⅔) of N was applied in two equal doses at tillering and panicle initiation stage as per treatment as mentioned earlier.

b) Groundnut and Soybean as intercrop

No additional dose of fertilizer was given to groundnut and soybean in intercropping with rice.

c) Groundnut and soybean as sole crop

Sole crop of groundnut received different levels of fertilizer i.e. for 100% NPK-20 kg ha^{-1} N + 40 kg ha^{-1} P_2O_5 + 30 kg ha^{-1} K_2O, for 75% NPK- 15 kg ha^{-1} N + 30 kg ha^{-1} P_2O_5 + 22.5 kg ha^{-1} K_2O and for 50% NPK- 10 kg ha^{-1} N + 20 kg ha^{-1} P_2O_5 + 15 kg ha^{-1} K_2O.

Sole crop of soybean received different levels of fertilizer i.e. for 100% NPK-20 kg ha^{-1} N + 60 kg ha^{-1} P_2O_5 + 40 kg ha^{-1} K_2O, for 75% NPK- 15 kg ha^{-1} N + 45 kg ha^{-1} P_2O_5 + 30 kg ha^{-1} K_2O and for 50% NPK- 10 kg ha^{-1} N + 30 kg ha^{-1} P_2O_5 + 20 kg ha^{-1} K_2O.

In case of sole groundnut and soybean full dose of nitrogen, phosphorous and potassium were applied as basal dose at the time of sowing.

3.3.4 Application of biofertilizer

Seeds were treated with biofertilizer consortium before sowing @ 20 g kg^{-1} seed. First of all about ½ kg gur was mixed in 2 litres water and boiled. After cooling it, biofertilizer consortium was mixed in the solution and stirred well for proper mixing. The seeds were spread on a jute mat and sprinkled with culture solution for proper coating. The seeds were used for sowing after drying in shade.

3.3.5 Seed rate

Healthy seeds were selected and sown as per their recommended seed rate i.e. 80 kg ha^{-1} for sole rice and 60 kg ha^{-1} for rice intercrop with groundnut and soybean, while seed rate of groundnut as sole crops and intercrops were 70 kg ha^{-1} and 35 kg ha^{-1}, respectively. Similarly, the seed rate of soybean as sole crop and intercrops were 60 kg ha^{-1} and 30 kg ha^{-1}, respectively.

3.3.6 Planting geometry

a) Sole crops

Sowing of rice was done in rice rows at a spacing of 20 cm row to row and 10 cm plant to plant. In case of groundnut and soybean, planting was done by dibbling in furrows at the spacing of 40 cm row to row and 15 cm plant to plant for groundnut crop and 10 cm plant to plant for soybean crop.

b) 3: 1 method of intercrop planting

Rice sowing as main crop was done by line sowing at the spacing of 20 cm row to row and 10 cm plant to plant. The groundnut and soybean as intercrop, were sown at row to row spacing of 20 cm for both the crops and plant to plant spacing of 15 cm for groundnut 10 cm for soybean intercrops in 3:1 method of planting. Upland rice with intercropping crop geometry was represented in Fig. 3.3.

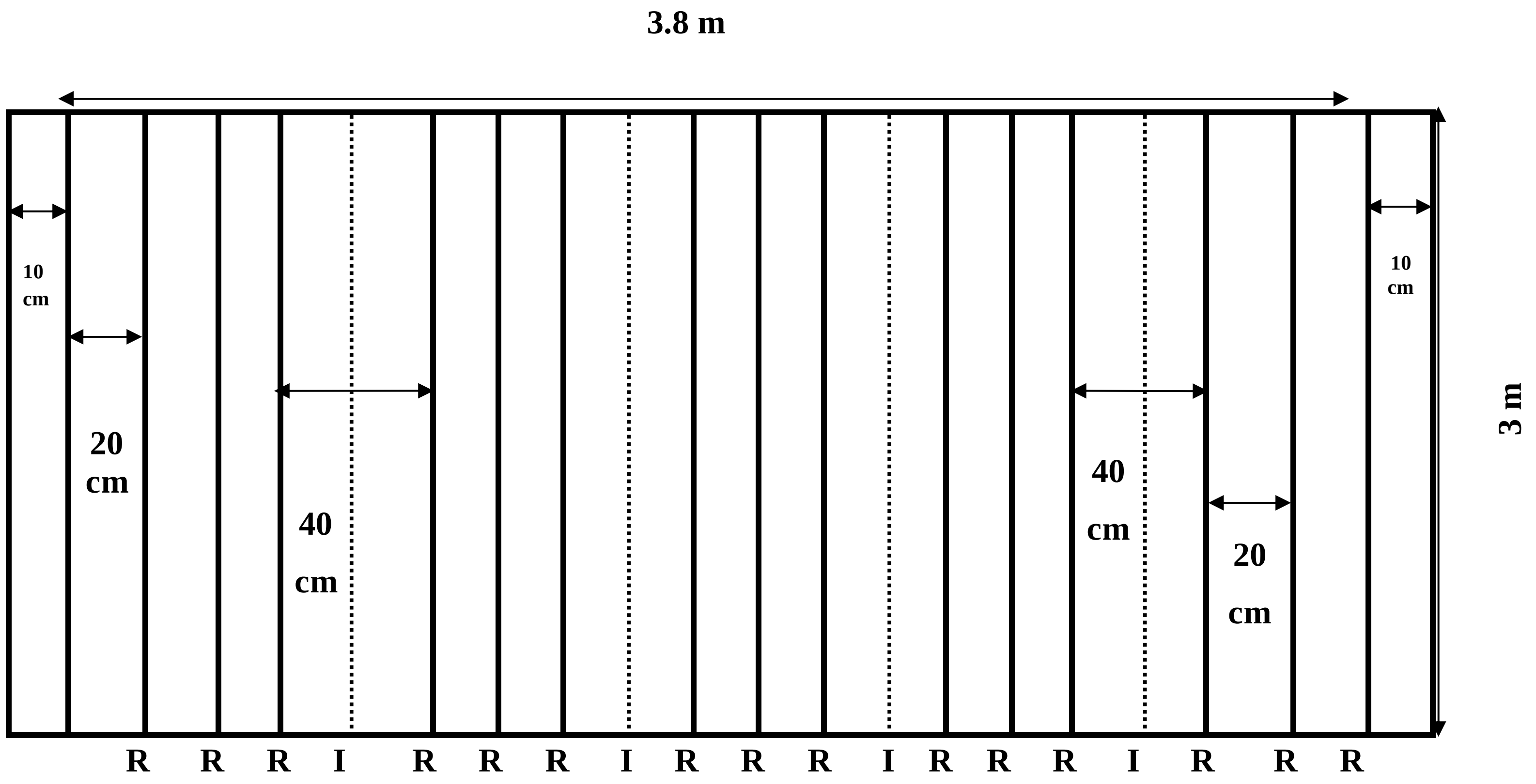


Fig 3.3: planting geometry layout

3.3.7 Sowing of seeds

Both the base crop and components crops were sown on 3rd week of June during 2019 and 4th week of June during 2020. Seeds of rice were sown in open furrows and covered it with soil. While that of groundnut and soybean were dibbled in their respective lines as per the row proportions of the treatment.

3.3.8 Intercultural operation

The thinning operation was carried out with an objective to remove excess plants after germination from the crop field and ensure optimum plant population so as to avoid intra crop competition. The gap filling was carried out at the same time. Two hand weeding were performed at vegetative and reproductive (pegging) stage of crops.

3.3.9 Harvesting

a) Rice

The crop was harvested manually with the help of a sickle and bunded separately for each plot. The harvested crop was sun dried, threshed and winnowed manually. The grains were packed separately for each plot and marked according to the plot number.

b) Groundnut

The crop was harvested and then tied in bundles, tagged and sun dried. Thereafter, threshing was done by beating the plants and picking the pods. The pods and stover were separated by manual winnowing and their yield was recorded.

c) Soybean

The crop was harvested, bundled and tagged separately. These bundles were brought to threshing floor and left for sun drying. The dried bundles were weighed for biological yield. After threshing and winnowing seeds were weighed separately to record seed yield per plot. A composite seed and stover sample was collected from each plot for laboratory studies.

3.4 Experimental observations

I) Crop observation

A) Rice

1 Growth attributes

Five plants were selected randomly in each plot and tagged as plant 1, 2, 3, 4 and 5. The readings were recorded at 30, 60 and 90 days after sowing.

1.1 Plant height (cm)

The tagged plants in every plot were measured from ground level to the tip of the longest leaf and recorded at 30, 60 and 90 DAS (Same as groundnut and soybean).

1.2 Number of leaves plant^{-1}

The numbers of leaves of the five tagged plant leaves per plant were counted and mean value was calculated at different stages as mentioned above.

1.3 Plant dry weight (g m^{-2})

The plant samples were uprooted in five different spot in each plot leaving the plants near the border. The samples collected were sun dried, cleaned and oven dried at 75^{0}C for 48 hours. When the samples attained a desired weight, the dry weight was recorded in g m^{-2} by using electronic weighing balance. The reading was recorded at 30, 60 and 90 DAS (Same as groundnut and soybean).

1.4 Leaf Area Index (LAI)

Leaf area index at 30, 60 and 90 DAS was calculated using the formula given by Watson, 1952 (Same as groundnut and soybean).

$$\text{Leaf area index} = \frac{\text{Leaf area (cm}^2)}{\text{Land area (cm}^2)}$$

1.5 Crop growth rate (CGR)

Crop growth rate is defined as rate of dry matter production per unit ground area per unit time (Watson, 1952). It is expressed in g m^{-2} day^{-1} and calculated by the formula (Same as groundnut and soybean).

$$\text{Crop growth rate} = \frac{W_2 - W_1}{(t_2 - t_1)s}$$

Where,

W_1 and W_2 are dry matter production $plant^{-1}$ in g at time t_1 and t_2, respectively.

S is the land area over which dry matter was recorded

1.6 Relative growth rate (g g^{-1} day^{-1})

It is the rate of increase in dry weight per unit dry weight already present and is expressed in g g^{-1} day^{-1}. Relative growth rate was calculated as suggested by Radford, 1967 (Same as groundnut and soybean).

$$\text{Relative growth rate (RGR)} = \frac{\text{In}W_2 - \text{In}W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry weight of plant at time t_1 and t_2, respectively.

1.7 Net assimilation rate (NAR)

It is the rate of increase in dry weight per unit leaf area per unit time. The net assimilation rate was estimated by using formula given by Gregory (1926) and expressed as g m^{-2} day^{-1} (Same as groundnut and soybean).

$$\text{Net assimilation rate (NAR)} = \frac{(W_2 - W_1) \times (\text{In}W_2 - \text{In}W_1)}{(t_2 - t_1) \times (L_2 - L_1)}$$

Where

W_1 and W_2 are plant dry weight at time t_1 and t_2 respectively

L_1 and L_2 are leaf area at time t_1 and t_2 respectively

2 Phenological parameters

2.1 Days to 50% flowering

The days taken by the crops for 50% flowering were observed and recorded (Same as groundnut and soybean).

2.2 Days to 50% maturity

Days to 50% maturity were observed when 50% leaves were drying /senescencing (Same as groundnut and soybean).

2.3 Days to harvesting

The days taken by the crops *i.e.* from sowing to harvesting were recorded (Same as groundnut and soybean).

3 Yield attributes

Primary panicles were selected from the sampled plants for the determination of number of panicles m^{-2}, panicle length (cm), weight of panicle (g), number of grains panicle^{-1}, filled grain % and test weight (g).

3.1 Number of panicles m^{-2}

Total number of panicles was recorded from a quadrate of $1m^2$ fixed randomly from each plot at harvest.

3.2 Panicle length (cm)

Five random panicles were selected in each plot and the length of each panicle was measured from the base to the tip of the panicle and average length was recorded.

3.3 Weight of panicle (g)

Five panicles were selected randomly from each plot and their weight was measured by using electronic weighing balance and average was recorded.

3.4 Number of grains panicle^{-1}

The number of grains per panicle from five panicles was counted and average was recorded.

3.5 Filled grains %

Number of filled grains and unfilled grains were counted separately from the total grains panicle^{-1}. The average for 5 panicles were worked out per plot, thereafter, the filled grain percentage was calculated and recorded using the formula.

$$\text{Filled grain \%} = \frac{\text{Number of filled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.6 Test weight (g)

For the individual plots, 1000 dried filled grains were counted at a random to obtain the test weight of grain for each treatment

4 Yield

4.1 Grain (t ha^{-1})

The harvested crop was sun dried, threshed and winnowed properly. The grains were packed separately for each plot and marked. The weight of the grains was taken, recorded and converted to t ha^{-1} (Same as groundnut and soybean).

4.2 Straw yield (t ha^{-1})

The straw was sun dried properly for few days to reduce the moisture and weight was taken separately for each plot, recorded and converted to t ha^{-1} (Same as groundnut and soybean).

4.3 Rice equivalent yield (t ha^{-1})

Crop equivalent yield in general refers to the yields of different intercrops/crops were converted into equivalent yield of any one crop based on cost of the produce. Efforts have also been made to convert the yields of different crops into equivalent yield of main crop.

The rice equivalent yield of intercropping system was calculated by the following formula.

$$\text{REY (t ha}^{-1}\text{)} = \text{Yield of rice in Intercropping system (t ha}^{-1}\text{)} + \text{Yield of intercrop (t ha}^{-1}\text{)} \times \frac{\text{Market price of intercrop (Rs. t}^{-1}\text{)}}{\text{Market price of rice (Rs. t}^{-1}\text{)}}$$

4.4 Harvest index (%)

Harvest Index was calculated by the formula (Same as groundnut and soybean)

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

5 Quality Parameters

5.1 Protein content (%)

The percent protein content in grain was calculated by multiplying the percentage of nitrogen content with the conversion factor 6.25 (Same as groundnut and soybean).

5.2 Protein yield (kg ha^{-1})

The protein yield was calculated by taking the product of per cent protein content and corresponding grain yield (kg ha^{-1}) (Same as groundnut and soybean).

6 Nutrient study

6.1 N, P and K content in grain and straw and nutrient uptake

Randomly selected plant samples were collected treatment wise for chemical analysis. Straw and grains were separated, air-dried and finally oven dried at a temperature of 65°C and grounded in grinding machine to pass through a 30 mesh sieve. Grain and straw samples were analyzed for nitrogen by modified Kjeldahl's method (Jackson, 1973), phosphorus by di-acid digestion and yellow colour development method (Jackson, 1973) and potassium by flame photometric method (Jackson, 1973). The uptake was further calculated by using the formula Nutrient uptake (kg ha^{-1}) (Same as groundnut and soybean).

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Per cent nutrient content in grain or staw} \times \text{grain or straw yield (kg ha}^{-1}\text{)}}{100}$$

B) Groundnut/ Soybean

1 Growth attributes

Five plants were selected randomly in each plot and tagged as plant 1, 2, 3, 4 and 5. The readings were recorded at 30, 60 and 90 days after sowing.

1.1 Number of branches plant^{-1}

The number of branches from each five tagged plants was counted and the average value was recorded for each plot separately.

1.2 Number of root nodules plant^{-1}

The number of nodules were counted from randomly selected five plants and their average was calculated as the number of nodules plant $^{-1}$ at 30, 60 and 90 DAS.

1.3 Fresh weight of nodules plant^{-1} (g)

Fresh weight of nodule was taken by uprooting the five randomly selected plants from each treatment leaving the border rows. The nodule were detached from each plant and their total fresh weight was determine in g plant^{-1}. The average value was recorded.

1.4 Dry weight of nodules plant^{-1} (g)

Dry weight of nodule was taken by uprooting the five randomly selected plants from each treatment plot leaving the border rows. The nodules were detached from each plant and dry the nodules to constant weight at 75^{0}C for 2 days. When nodule samples attained constant weight the nodule dry weight was recorded in g plant^{-1}. The average value was recorded.

2 Yield attributes

2.1 Number of pods plant^{-1}

Five plants were selected randomly from every plot and the total number of pods were counted and thereafter average number of pods per plant was calculated.

2.2 Number of seeds pod^{-1}

At random five pods from the total pods of sample plants were taken and their seeds were counted and divided by five to obtain the average number of seeds pod^{-1}.

2.3 Pod weight (g) plant^{-1}

Five plants were selected randomly from every plot and the total pods of plants weighed and thereafter average pod weight (g) plant^{-1} was calculated.

2.4 1000 seed weight (g)

Thousand seeds from the representative sample of each plot were counted and weighed after properly sun dried.

3 Quality Parameters

3.1 Oil content (%)

The oil content in the seed was determined by Soxhlet's apparatus using petroleum ether (60-80^{0}C) as an extractant.

3.2 Oil yield (kg ha^{-1})

The oil yield (kg ha^{-1}) was calculated by multiplying per cent oil content with respective seed yield (kg ha^{-1}).

II) Competition studies

1 Land equivalent ratio (LER)

Land equivalent ratio is defined as the relative land area under sole crop that is required to produce the yields in intercropping. The LER was worked out by using the following formula given by Willey (1979).

$$\text{LER} = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where,

Y_{ab} and Y_{ba} are the yield of a and b in intercrop

Y_{aa} and Y_{bb} are the yield of a and b in sole crop

2 Price equivalent ratio

Price equivalent ratio (PER) is the ratio of price obtained under intercropping system as compared to the price that coluld have been obtained under sole cropping. The PER can be mathematically represented as follows

$$\text{PER} = \frac{(Y_{ab} \times Y_{ap}) + (Y_{ba} \times Y_{bp})}{\frac{1}{2}(Y_{aa} \times Y_{ap} + Y_{bb} \times Y_{bp})}$$

Where,

Y_{aa}= yield of component crop 'a' as sole crop

Y_{bb}= yield of component crop 'b' as sole crop

Y_{ab}= yield of component crop 'a' as intercrop in combination with 'b'

Y_{ba}= yield of component crop 'b' as intercrop in combination with 'a'

Y_{ap}= market price of produce of component crop 'a'

Y_{bp}= market price of produce of component crop 'b'

3 Relative crowding co-efficient (RCC)

RCC was calculated following the formulas as given by De Wit, (1960).

$$K = (K_{cereal} \text{ x } K_{legume})$$

Where,

K = RCC of the intercropping system

K_{cereal} = RCC of intercropped cereal

K_{legume} = RCC of intercropped legume

$$K_{cereal} = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab}) \times Z_{ba}}$$

$$K_{legume} = \frac{Y_{ba} \times Z_{ab}}{(Y_{bb} - Y_{ba}) \times Z_{ba}}$$

Where,

Y_{ab} = yield of cereal 'a' in intercropping

Z_{ba} = sown proportion of legume 'b' in intercropping

Y_{aa} = yield of cereal 'a' in sole cropping

Z_{ab}= sown proportion of cereal 'a' in intercropping

Y_{ba} = yield of legume 'b' in intercropping

Y_{bb} = yield of legume 'b' in sole cropping

When the value of the product of two coefficients ($K_{cereal} \times K_{legume}$) is higher than one (>1), there is a yield advantage in the intercropping. However, if the value of K is one (1), there is no yield advantage/disadvantage in the system. If the value of K is less than one (<1), there is competition between intercrops and associated crops with disadvantage in intercropping.

4 Competition ratio

Competitive ratio (CR) was calculated by the following formula as given by Willey and Rao (1980).

$$CR_a = \frac{\text{LER a}}{\text{LER b}} \times \frac{\text{Zba}}{\text{Zab}}$$

$$CR_a = \frac{\text{LER b}}{\text{LER a}} \times \frac{\text{Zba}}{\text{Zab}}$$

Where,

CR = Competition Ratio of ‘a’ in the mixture over ‘b’

LER_a = LER of component ‘a’

LER_b = LER of component ‘b’

Z_{ba} = sown proportion of component ‘b’ in combination with ‘a’

Z_{ab} = sown proportion of component ‘a’ in combination with ‘b’

If the values of CR<1, there is a positive benefit. It means there is limited competition between component crops and they can be grown as intercrops (Ghosh, 2004). However, if the value is higher than one (CR>1), there is a negative impact. In this condition, the competition between intercrops in the association is too high, and they are not recommended to grow as intercrops. The competition ratio (CR) of legume and intercrop cereal has an inverse relationship.

5 Monetary advantage ($Rs.ha^{-1}$)

$$\text{Monetary advantage} = \frac{\text{LER -1}}{\text{LER}}(\text{value of combimed intercrop yield in Rs.})$$

Where,

LER is Land Equivalent Ratio

III Soil analysis

To determine the nutrient status of the soil, after harvest of the crop soil samples were collected from each plot separately with the same sampling procedure that was adopted for initial sampling before the investigation. The processed soil was analyzed for pH, organic carbon, available nitrogen, available phosphorous and available potassium at harvest.

1 Soil pH

Soil pH was determined in soil:water (1:2) ratio by Digital pH meter (Jackson,1973).

2 Organic carbon (%)

Titrimetric determination method by Walkley and Black (1934) determined the soil organic carbon and was expressed in terms of percentage.

3 Available nitrogen (kg ha^{-1})

The alkaline potassium permanganate method by Subbiah and Asija (1956) was used to determine the available nitrogen. The results were expressed in kg ha^{-1}.

4 Available phosphorous (kg ha^{-1})

Bray's No. 1 method was adopted and phosphorous was estimated colorimetrically. This method is suitable for moderate to strongly acidic soil with pH around 5.5 or less (Bray and Kurtz, 1945).

5 Available potassium (kg ha^{-1})

Available K content of the soil sample was extracted with neutral normal ammonium acetate as outlined by Jackson (1973). The potassium content was determined with the help of Flame Photometer and expressed as available K_2O (kg ha^{-1}).

6 Microbial population

6.1 Soil sample collection and sample preparation for microbial analysis

Soil sample for microbial analysis was collected from each plot and taken to the soil laboratory and kept air dry. Further soil samples were prepared for microbial analysis through serial dilution method as follows: Four test tube containing 9 ml of sterile distilled water were taken. One test tube containing 10 ml of sterile distillled water was taken and added 1g of soil to the test tube. Thereafter, the soil was mixed thoroughly with the sterile distilled water. Then, 1ml of microbial suspension was added to another test tube containing 9 ml of sterile distilled water. The same step was repeated serially for the other test tubes. In this way the microbial suspension was diluted 10 fold. Finally 100 µl of diluted suspension was poured into surface of nutrient agar plate and spread by "L" shaped spreader. The bacteria can thus be isolated and counted by C.F.U *i.e.* Colony forming unit. The same procedure was carried out in actinomycetes and fungi.

Bacteria (No. x 10^{6}cfu g^{-1} soil)

Nutrient agar medium was used for the enumeration of bacteria.

Fungi (No. x 10^{3}cfu g^{-1} soil)

Potato dextrose agar medium was used for the enumeration of fungi.

Actinomycetes (No. x 10^{5}cfu g^{-1} soil)

Nutrient agar medium was used for the enumeration of actinomycetes.

IV Economics

The economics was calculated for different treatments adopted in the field as per the current market prices.

1 Cost of cultivation (Rs. ha^{-1})

Cost of cultivation was calculated on the basis of existing local charges for different inputs used in the experimental plot.

2 Gross return (Rs. ha^{-1})

Economic yield was converted into gross return for the treatments on the basis of existing local market prices.

3 Net returns (Rs. ha^{-1})

The net return was calculated by subtracting the total cost of cultivation from the gross return.

Net return = Gross return – Cost of cultivation

4 Benefit cost ratio (BCR)

Benefit cost ratio was calculated by using the formula:

$$\text{Benefit cost ratio} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

V Statistical analysis

The experimental data recorded during the course of investigation from each parameter were analyzed statistically by applying the techniques of Factorial RBD as described by Gomez and Gomez (1984). 'F' test was used to determine the significant difference between two means and critical difference (CD) was calculated for comparison in those cases where 'F' was significant at 5% level of significance. The treatment means were compared among themselves by calculating critical difference (CD) as follows:

$$CD_{0.05} = \sqrt{2} \text{ x SEm} \times t_{0.05} \text{ for error degrees of freedom}$$

Where,

SEm ±= Standard error mean

$t_{0.05}$= Table value of students obtained at 5 % probability test

The standard error mean (SEm) was calculated by using the formula:

$$SEm\pm = \sqrt{\frac{\text{Error mean square}}{\text{Replication}}}$$

The ANOVA are annexed under the appendices.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results obtained during the course of present investigation on "**Integrated nutrient management in upland rice-based intercropping system under foothill condition of Nagaland**" was conducted in the Experimental Research Farm of School of Agricultural Sciences (SAS), Medziphema campus, Nagaland University during two consecutive *kharif* season of 2019 and 2020. The data related to the effect of different treatments on main crop and intercrops as well as their pooled data were statistically analyzed and presented in this chapter with the help of appropriate tables and illustrations and are discussed with available literature and evidences wherever necessary under the following heads:

4.1. Rice

4.1.1 Growth parameters

4.1.1.1 Plant height (cm)

The data on plant height of rice was recorded at 30 days interval till up to 90 days in both the years during the *kharif* of 2019 and 2020. The data on plant height and interaction effect of plant height due to cropping system and nutrient management and pooled data for both the years are presented in Table 4.1 (a) and 4.1 (b), respectively.

Effect of cropping system

Between cropping systems, plant height was influenced significantly at all stages of observations during both the years of experiment. It was indicated from the data that during 2019, maximum plant height (54.33, 91.59 and 110.27 cm at 30, 60 and 90 DAS, respectively) of rice was recorded from sole rice, which was at par with rice intercropped with soybean (50.76, 86.91 and 107.73 at 30, 60 and 90 DAS, respectively). Rice intercropped with groundnut recorded the minimum plant height (47.40, 80.40 and 98.22 cm at 30, 60 and 90 DAS, respectively). Similarly, during 2020 the maximum plant height (55.64, 93.69 and 112.03 cm at 30, 60 and 90 DAS, respectively) was recorded from sole rice, which was at par with rice intercropped with soybean (53.15, 88.76 and 108.75 cm at 30, 60 and 90 DAS, respectively). Rice intercropped with groundnut recorded the minimum plant height (48.90, 82.70 and 99.77 cm at 30, 60 and 90 DAS, respectively). From the pooled data of 2019 and 2020 on plant height revealed that the highest plant height of 54.99, 92.64 and 111.15cm at 30, 60 and 90 DAS respectively was recorded in sole rice which was at par with rice + soybean intercropping system (51.96, 87.84 and 108.24 cm at 30, 60 and 90 DAS, respectively), while the minimum plant height of rice was recorded from rice + groundnut (48.15, 81.55 and 99 cm at 30, 60 and 90 DAS, respectively). This may be attributed to the presence of more available nutrients for individual crop without any competition. For intercropping system, the wastage of nutrients can be avoided, thus maximum utilization of resources is possible with a complementary relationship and also, maximum absorption of light is possible which leads to production of more photosynthetic area and finally leads to more number of tillers and leaves

Effect of nutrient management

The effect of different nutrient management practices on plant height was found to be significant at all the growth stages. During 2019, significantly the highest plant height of 56.58, 94.04 and 113.33 cm at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 75% RDF FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest plant height of 45.53, 79.16 and 97.92 cm at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. Similarly during 2020, plant height showed significant variation among the various treatments with the highest observed in

Table 4.1 (a): Effect of cropping systems and nutrient management practices on plant height (cm) at different growth stages of rice

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	54.33	55.64	54.99	91.59	93.69	92.64	110.27	112.03	111.15
C_4 - Rice + groundnut (3:1)	47.40	48.90	48.15	80.40	82.70	81.55	98.22	99.77	99.00
C_5 - Rice + soybean (3:1)	50.76	53.15	51.96	86.91	88.76	87.84	107.73	108.75	108.24
SEm±	1.58	1.40	1.06	2.35	2.37	1.67	1.84	2.44	1.53
CD (P=0.05)	4.73	4.20	3.04	7.03	7.10	4.80	5.50	7.30	4.39
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	50.38	51.66	51.02	85.70	87.98	86.84	104.97	106.71	105.84
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	56.58	58.57	57.58	94.04	96.18	95.11	113.33	114.26	113.80
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	45.53	47.48	46.50	79.16	81.00	80.08	97.92	99.58	98.75
SEm±	1.58	1.40	1.06	2.35	2.37	1.67	1.84	2.44	1.53
CD (P=0.05)	4.73	4.20	3.04	7.03	7.10	4.80	5.50	7.30	4.39
Interaction (C X N)	NS	NS	NS	NS	NS	NS	S	NS	S

Table 4.1 (b): Interaction effect of cropping systems and nutrient management practices on plant height (cm) at 90 DAS of rice

Treatments	90 DAS	
	2019	**Pooled**
$C_1 N_1$	105.30	106.90
$C_4 N_1$	103.82	104.30
$C_5 N_1$	105.77	106.32
$C_1 N_2$	124.35	124.75
$C_4 N_2$	102.82	103.29
$C_5 N_2$	112.81	113.35
$C_1 N_3$	101.14	101.81
$C_4 N_3$	88.01	89.41
$C_5 N_3$	104.60	105.03
SEm±	3.18	2.64
CD (P=0.05)	9.53	7.61

sole rice with 58.57, 96.18 and 114.26 cm at 30, 60 and 90 DAS respectively. While 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the lowest data on plant height at almost all the growth stages. The pooled data of both the years also revealed a significant difference with the highest plant height of 57.58, 95.11 and 113.8 cm at 30, 60 and 90 DAS, respectively when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest plant height was recorded of 46.50, 80.08 and 98.75 cm at 30, 60 and 90 DAS, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The increase in plant height in response to application of organic and chemical fertilizers was probably due to enhanced availability of nutrients. Singh *et al*. (2012) reported a significant increase in plant height of rice due to the integrated application of biofertilizers and organic manure in combination with chemical fertilizer. Singh *et al*. (2013) also reported that INM results in higher plant height having longer leaves than chemical fertilizers alone attributing to enhance seed quality parameters *viz*. germination rate and vigor index.

Interaction effect

The interaction effect between cropping system and nutrient management at 30 and 60 DAS during both the years failed to show any significant variation on plant height. During 2019, significantly highest plant height (124.35 cm) was recorded in C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination. Lowest plant height (88.01cm) was recorded in C_4N_3 (Rice + groundnut (3:1) along with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination at 90 DAS. During 2020 there was no interaction effect between cropping system and nutrient management at 90 DAS. Pooled data of 2019 and 2020 did not show any significant variation in plant height at 30 and 60 DAS, while the highest plant height (124.75 cm) was recorded in C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination and lowest plant height (89.41cm) was recorded in C_4N_3 (Rice + groundnut at 3:1 row ratio + 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination at 90 DAS.

4.1.1.2 Number of leaves plant^{-1}

The results recorded on the effect of cropping system and nutrient management on the number of leaves $plant^{-1}$ recorded at 30, 60 and 90 DAS are presented in Table 4.2.

Effect of cropping system

The effect of cropping system on number of leaves $plant^{-1}$ of rice was found to be significant under different treatments. A close scrutiny of the data during 2019 recorded, highest number leaves $plant^{-1}$ of 15.00, 28.22 and 33.04 at 30 DAS, 60 DAS and 90 DAS, respectively were recorded in sole rice (C_1), which remained at par with rice intercropped with soybean (14.20, 26.76 and 31.09 at 30, 60 and 90, DAS respectively). Significantly the lowest number leaves $plant^{-1}$ was recorded in rice intercropped with groundnut (13.31, 22.56 and 26.16 at 30, 60 and 90 DAS, respectively). Similarly during 2020, the highest number of leaves of 15.64, 29.07 and 33.71 at 30, 60 and 90 DAS respectively were recorded in sole rice, which was statistically at par with rice intercropped with soybean (15.14, 27.61 and 31.79 at 30, 60 and 90 DAS, respectively). While rice intercropped with groundnut recorded lowest number of leaves $plant^{-1}$ of 13.80, 23.35 and 26.67 at 30, 60 and 90 DAS, respectively. The pooled data of both the years revealed that sole rice reported maximum number of leaves $plant^{-1}$ (15.32, 28.65 and 33.38 at 30, 60 and 90 DAS, respectively), which was statistically at par with rice intercropped with soybean (14.67, 27.18 and 31.44 at 30, 60 and 90 DAS, respectively). While the lowest was recorded in rice intercropped with groundnut with 13.55, 22.95 and 26.41 at 30, 60 and 90 DAS, respectively. The result was supported by the findings of

Table 4.2: Effect of cropping systems and nutrient management practices on number of leaves plant^{-1} at different growth stages of rice

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	15.00	15.64	15.32	28.22	29.07	28.65	33.04	33.71	33.38
C_4 - Rice + groundnut (3:1)	13.31	13.80	13.55	22.56	23.35	22.95	26.16	26.67	26.41
C_5 - Rice + soybean (3:1)	14.20	15.14	14.67	26.76	27.61	27.18	31.09	31.79	31.44
SEm±	0.36	0.34	0.25	0.83	0.93	0.62	1.39	1.06	0.87
CD (P=0.05)	1.08	1.01	0.71	2.49	2.79	1.80	4.17	3.16	2.52
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	13.98	14.64	14.31	25.38	25.97	25.68	31.29	31.54	31.42
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	15.64	16.20	15.92	30.25	31.13	30.69	36.04	36.96	36.50
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	12.89	13.73	13.31	21.91	22.93	22.42	22.96	23.67	23.32
SEm±	0.36	0.34	0.25	0.83	0.93	0.62	1.39	1.06	0.87
CD (P=0.05)	1.08	1.01	0.71	2.49	2.79	1.80	4.17	3.16	2.52
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Wangiyana *et al*. (2018) who also reported that the presence of soybean plants growing together with those rice plants resulted in higher tiller number, leaf number and filled panicle number, and greener leaves, indicating better nitrogen nutrition of the rice plants growing together with soybean plants, compared with the rice plants in monocrop.

Effect of nutrient management

Statistically, it was found that application of different nutrient management practices had a significant effect on number of leaves plant^{-1} during both the years of experiment. During both the years, result revealed that 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed alone recorded the significantly highest number of leaves plant^{-1} of 15.64, 30.25 and 36.04 at 30, 60 and 90 DAS, respectively during 2019 and 16.20, 31.13 and 36.96 at 30, 60 and 90 DAS, respectively during 2020. Application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the minimum number of leaves plant^{-1} 12.89, 21.91 and 22.96 at 30, 60 and 90 DAS, respectively during 2019 and 13.73, 22.93 and 23.67 at 30, 60 and 90 DAS, respectively during 2020. Similar effect was also reflected in pooled data. Anny *et al*. (2005) also reported that the growth parameters increased significantly by the combined use of fertilizer nitrogen and FYM *i.e*. 75 per cent recommended dose of nitrogen through urea and 25 per cent recommended dose of nitrogen through FYM.

Interaction effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.1.1.3 Dry matter (g) plant^{-1}

Data pertaining to dry matter (g) plant^{-1} due to cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.3.

Table 4.3: Effect of cropping systems and nutrient management practices on dry matter (g) plant^{-1} at different growth stages of rice

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	1.73	1.85	1.79	18.66	19.72	19.19	35.43	36.45	35.94
C_4 - Rice + groundnut (3:1)	1.56	1.68	1.62	16.63	17.65	17.14	30.02	30.86	30.44
C_5 - Rice + soybean (3:1)	1.65	1.75	1.70	17.95	19.08	18.52	33.77	34.61	34.19
SEm±	0.04	0.04	0.03	0.34	0.37	0.25	0.83	0.95	0.63
CD (P=0.05)	0.12	0.13	0.09	1.02	1.10	0.72	2.48	2.85	1.82
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.51	1.69	1.60	16.86	17.99	17.43	31.69	32.81	32.25
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.03	2.09	2.06	21.49	22.56	22.02	38.82	39.59	39.21
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.40	1.50	1.45	14.90	15.90	15.40	28.70	29.52	29.11
SEm±	0.04	0.04	0.03	0.34	0.37	0.25	0.83	0.95	0.63
CD (P=0.05)	0.12	0.13	0.09	1.02	1.10	0.72	2.48	2.85	1.82
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect of cropping system

An inquisition of the data on dry matter (g) plant^{-1} revealed that there was significant variation among the different treatments in both the years. During 2019, it was evident from the data that the maximum dry matter (g) plant^{-1} (1.73, 18.66 and 35.43 g at 30, 60 and 90 DAS, respectively) was obtained in sole rice and it was at par with C_5 (Rice+ Soybean at 3:1 row ratios) with 1.65, 17.95 and 33.77 g at 30, 60 and 90 DAS, respectively). Significantly lowest was recorded in rice intercropped with groundnut (1.56, 16.63 and 30.02 g at 30, 60 and 90 DAS, respectively). In 2020, the highest dry matter (g) plant^{-1} obtained in sole rice (1.85, 19.72 and 36.45 g at 30, 60 and 90 DAS, respectively) which was statistically remained at par with rice intercropped with soybean with values of 1.75, 19.08 and 34.61 g at 30 60 and 90 DAS, respectively. The significantly lowest dry matter (g) plant^{-1} was recorded at C_4 (Rice + groundnut with 3:1 ratio) with values of 1.68, 17.65 and 30.86 g at 30, 60 and 90 DAS, respectively. Pooled data from both the years it was evident that highest dry matter (g) plant^{-1} was recorded in sole rice (1.79, 19.19 and 35.94 g at 30, 60 and 90 DAS, respectively), which was at par with C_5 (Rice+ soybean at 3:1 ratio) with a value of 1.70, 18.52 and 34.19 g at 30, 60 and 90 DAS, respectively. The significantly lowest values were recorded in rice intercropped with groundnut (1.62, 17.14 and 30.44 at 30, 60 and 90 DAS, respectively). This was due to better photosynthetic activity due to higher light penetration, root development which in turn resulted in better dry matter production and distribution in plant parts and finally reflected in producing better yield and yield components. These results are in conformity with the findings of Kavil *et al*. (2003); Singh and Thenua (2014). However, the reduced dry matter accumulation in intercropping accumulation was due to the partial competition exerted by the component crops for the growth resources during various stages of crop growth. These results are

are in line with the findings of Singh *et al*. (2008b).

Effect of nutrient management

The effect of different treatments on dry matter (g) plant^{-1} was significant. In 2019, the significantly highest dry matter (g) plant^{-1} (2.03, 21.49, 38.82 g at 30, 60 and 90 DAS, respectively) was registered at 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed and significantly lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 1.40, 14.90 and 28.70g at 30, 60 and 90 DAS, respectively. During the second year also recorded similar result with the maximum dry matter (g) plant^{-1} of 2.09, 22.56, 39.59 g at 30, 60 and 90 DAS, respectively under treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and the significantly lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 1.50, 15.90, 29.52 g at 30, 60 and 90 DAS, respectively. Pooled data of both the years followed the similar findings with the significantly highest dry matter (g) plant^{-1} observed with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (2.06, 22.02 and 39.21 g at 30, 60 and 90 DAS, respectively), while the significantly lowest dry matter (g) plant^{-1} was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with 1.45, 15.40 and 29.11 g at 30, 60 and 90 DAS, respectively. This could be due to the increase in organic carbon content in treatments with combination of both organic and inorganic sources may be attributed to higher biomass addition to soil through crop residues. Sharma and Sharma (2002) also reported similar results. Few studies have shown that, organic manures with associate adequate quantity of chemical N fertilizers may manufacture higher dry matter yield than those of conventional inorganic N fertilizers treatments (Singh *et al*., 1994 and Chung *et al*., 2000). Biswanath *et al*. (2019) also noted different proportion of organic manures and chemical fertilizers influenced on plant height and dry matter accumulation of the rice.

Interaction effect

During both the years of study, cropping system and nutrient management interaction effects were found to be non-significant.

4.1.1.4 Leaf area index

The data on leaf area index of rice due to different cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.4.

Effect of cropping system

From the perusal of the result, it was evident that the leaf area index was found significant among different treatments during both the years. In 2019, the highest leaf area index was recorded at sole rice (1.08, 2.60 and 2.86 at 30, 60 and 90 DAS, respectively), which was remained statistically at par with C_5 (Rice intercropped with soybean at 3:1 row ratio) with the values of 1.04, 2.47 and 2.69 at 30, 60 and 90 DAS, respectively. Similarly during 2020, maximum leaf area index 1.09, 2.67 and 2.88 at 30, 60 and 90 DAS respectively were recorded at sole rice, which was at par with rice intercropped with soybean with the values of 1.05, 2.50 and 2.74 at 30, 60 and 90 DAS, respectively. From the pooled data of 2019 and 2020 on leaf are index revealed that the highest leaf area index (1.09, 2.63 and 2.87 at 30, 60 and 90 DAS, respectively) was recorded in sole rice, which was at par with rice + soybean (3:1) intercropping system (1.05, 2.49 and 2.72 at 30, 60 and 90 DAS respectively) while the minimum LAI of rice was recorded from rice + groundnut (0.95, 2.24 and 2.47 at 30, 60 and 90 DAS, respectively) intercropping system. Leaf area index is an important factor determining the dry matter production of a crop and subsequently the yield. The reason being leaf area index is depends on number of leaves and leaf area of a plant which was recorded maximum in the treatment which directly reflected on the leaf area index. Putra *et al*. (2017) also reported that among intercropping system rice + soybean gives highest leaf area.

Effect of nutrient management

The effect of different nutrient management practices on leaf area index was found to be significant at all the growth stages. During 2019, significantly the highest leaf area index of 1.18, 2.95 and 3.04 at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest leaf area index of 0.87, 1.98 and 2.29 at 30, 60 and 90 DAS respectively were recorded 2.96, 3.07 at 30, 60 and 90 DAS, respectively. While 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the lowest data on leaf area index at almost all the growth stages. The pooled data of both the years also revealed a significant difference with the highest leaf area index of 1.18, 2.95 and 3.05 at 30, 60 and 90 DAS, respectively when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest leaf area index was recorded of 0.88, 1.98 and 2.32 at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. LAI is one of the important growth indicators which have been used as a phosynthetic system measurement. It is related to biologic and economic yields and increase in LAI causes higher yield (Singh *et al*., 2009). The higher LAI may be attributable to an increase in tiller production or leaves on each tiller and in size of the successive leaves. Increasing LAI resulted in higher dry matter production, but net canopy photosynthesis cannot increase indefinitely because of increased mutual shading of leaves (Fageria, 2007). Cumulative effect of organic sources combined with inorganic and biofertilizer proved much instrumental in effective photosynthesis. These results are in close conformity with the findings of Jat *et al*. (2016) and Yadav and Meena (2014).

Table 4.4: Effect of cropping systems and nutrient management practices on leaf area index at different growth stages of rice

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	1.08	1.09	1.09	2.60	2.67	2.63	2.86	2.88	2.87
C_4 - Rice + groundnut (3:1)	0.94	0.96	0.95	2.24	2.25	2.24	2.46	2.49	2.47
C_5 - Rice + soybean (3:1)	1.04	1.05	1.05	2.47	2.50	2.49	2.69	2.74	2.72
SEm±	0.02	0.02	0.01	0.08	0.07	0.05	0.09	0.07	0.06
CD (P=0.05)	0.07	0.05	0.04	0.23	0.20	0.14	0.28	0.20	0.17
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.01	1.03	1.02	2.38	2.46	2.42	2.69	2.69	2.69
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.18	1.19	1.18	2.95	2.96	2.95	3.04	3.07	3.05
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.87	0.88	0.88	1.98	1.99	1.98	2.29	2.36	2.32
SEm±	0.02	0.02	0.01	0.08	0.07	0.05	0.09	0.07	0.06
CD (P=0.05)	0.07	0.05	0.04	0.23	0.20	0.14	0.28	0.20	0.17
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Interaction effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.1.1.5 Crop growth rate (g m^{-2} day^{-1})

The effects of cropping system and nutrient management on crop growth rate (g m^{-2} day^{-1}) of rice recorded at 30- 60 and 60-90 DAS are presented in Table 4.5.

Effect of cropping system

An inquisition of the data on crop growth rate revealed that there was significant variation among the different treatments in both the years. It was evident from the data that the maximum crop growth rate of 28.23 and 29.78 g m^{-2} day^{-1} at 30-60 DAS was recorded during both the years were obtained in sole rice and which was found to be at par with C_5 (Rice+ soybean at 3:1 row ratio) with the values being 27.17 and 28.89 g m^{-2} day^{-1} at 30-60 DAS during both the years, respectively. Significantly lowest was recorded in rice intercropped with groundnut (25.11 and 26.61 g m^{-2} day^{-1} at 30-60 DAS during 2019 and 2020, respectively). Pooled data of both the years revealed that highest (29.00 g m^{-2} day^{-1}) was recorded in C_1 (Sole rice), which was at par with rice intercropped with soybean (28.03 g m^{-2} day^{-1}). The lowest (25.86 g m^{-2} day^{-1}) was recorded in C_4 (Rice + groundnut with the ratio 3:1).

At 60-90 DAS, the highest crop growth rate was recorded in sole rice (27.94 g m^{-2} day^{-1}) during 2019, which was followed by rice intercropped with soybean with value 26.36 g m^{-2} day^{-1}. The lowest (22.31g m^{-2} day^{-1}) was recorded in rice intercropped with groundnut. There is no significant difference in crop growth rate during 2020. Pooled data of both the years registered that crop growth rate was recorded highest (27.91 g m^{-2} day^{-1}) in sole rice, which was remained at par with rice intercropped with soybean (26.12 g m^{-2} day^{-1}), while the lowest (22.17 g m^{-2} day^{-1}) was recorded in C_4 (Rice + groundnut with 3:1

ratio). The crop growth rate showed similar tendency to that of dry matter accumulation. The production of dry matter was limited due to the low light received by upland rice due to the shade of soybean and groundnut leaf. It is resulting in lower carbohydrate supply and the proportion of the distribution of dry matter throughout the crop growth rate (CGR). These results are in consonance with results of Adeniyan *et al*. (2014). Among intercropping rice + soybean (3:1) treatment resulted highest crop growth rate. Ghosh *et al*. (2006) explained that high crop growth rate gave a high yield. The crop growth rate was influenced by an adequate supply of nitrogen. Nitrogen was used by crops for metabolic processes in crop cell division and enlargement. The increased of crop growth rate and yield per clump were influenced by the increased soybean proportion. The increasing of soybean proportion was able to provide nitrogen supply from N_2 fixation to be utilized by upland rice. Through this explanation, it could be assumed that the presence of soybean in upland rice crops has a positive effect on nitrogen supply.

Effect of nutrient management

Statistically, it was found that application of different nutrient management practices had a significant effect on crop growth rate during both the years of experiment. During 2019 and 2020 result revealed that 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed alone recorded the significantly highest crop growth rate of 32.42 and 34.10 g m^{-2} day^{-1} at 30-60 DAS during 2019 and 2020, respectively. Application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the minimum crop growth rate of 22.49 and 24.01 g m^{-2} day^{-1} at 30-60 DAS during 2019 and 2020, respectively. Pooled data of both the years also showed the significant difference with the maximum in treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and minimum was at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). There is no significant difference in crop growth rate during 2020. Pooled data

Table 4.5: Effect of cropping systems and nutrient management practices on crop growth rate (g m^{-2} day^{-1}) at different growth stages of rice

Treatments	30-60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	28.23	29.78	29.00	27.94	27.88	27.91
C_4 - Rice + groundnut (3:1)	25.11	26.61	25.86	22.31	22.02	22.17
C_5 - Rice + soybean (3:1)	27.17	28.89	28.03	26.36	25.87	26.12
SEm±	0.56	0.60	0.41	1.50	1.62	1.10
CD (P=0.05)	1.67	1.81	1.18	4.48	NS	3.18
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	25.60	27.17	26.39	24.71	24.69	24.70
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	32.42	34.10	33.26	28.90	28.40	28.65
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	22.49	24.01	23.25	23.01	22.69	22.85
SEm±	0.56	0.60	0.41	1.50	1.62	1.10
CD (P=0.05)	1.67	1.81	1.18	4.48	NS	3.18
Interaction (C X N)	NS	NS	NS	NS	NS	NS

of both the years also showed the significant difference with the maximum in treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and minimum was at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). CGR depends on the amount of radiation intercepted by the crop and on the efficiency of conversion of intercepted radiation into dry matter (Sinclair and Horie, 1989). Therefore, higher CGR indicate high dry matter accumulation with increase in leaf area (Azarpour *et al.*, 2014; Nwokwu *et al.*, 2015)

Interaction effect

During both the years of study, cropping system and nutrient management interaction effects were found to be non-significant.

4.1.1.6 Relative growth rate (g g^{-1} day^{-1})

The result presented in Table 4.6 showed the effects of cropping system and nutrient management practices on relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS and 60-90 DAS.

Effect of cropping system

There was no significant difference on relative growth rate due to cropping systems at various growth stages during both the years of experiment.

Effect of nutrient management

The effects of nutrient management on relative growth rate were found to be non-significant during both the years of experiment at all stages of observation.

Table 4.6: Effect of cropping systems and nutrient management practices on relative growth rate (g g^{-1} day^{-1}) at different growth stages of rice

Treatments	30-60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	0.079	0.079	0.079	0.021	0.020	0.021
C_4 - Rice + groundnut (3:1)	0.078	0.078	0.078	0.019	0.018	0.019
C_5 - Rice + soybean (3:1)	0.156	0.080	0.118	0.021	0.020	0.020
SEm±	0.044	0.001	0.022	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.080	0.079	0.079	0.021	0.020	0.020
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.079	0.079	0.079	0.020	0.019	0.019
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.155	0.079	0.117	0.022	0.020	0.021
SEm±	0.044	0.001	0.022	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Interaction effect

The interaction effects between cropping system and nutrient management on relative growth rate failed to show any significant variation during both the years at all stages of observation.

4.1.1.7 Net assimilation rate (g m^{-2} day^{-1})

The data pertaining to net assimilation rate (g m^{-2} day^{-1}) of rice as influenced by cropping system and nutrient management at 30-60 DAS and 60-90 DAS are presented in Table 4.7.

Effect of cropping system

Upland rice based intercropping systems found non-significant for net assimilation rate at 30-60 DAS and 60-90 DAS during both the years of experiment.

Effect of nutrient management

Nutrient management practices did not differ significantly with respect to net assimilation rate at 30-60 DAS and 60-90 DAS during both the years of study.

Interaction effect

Interaction effect between cropping systems and various nutrient management practices found to be non-significant during both the years of experimentation

4.1.2 Phenological parameters

4.1.2.1 Days to 50% flowering, 50% maturity and days to harvesting

The data on days to 50% flowering, 50% maturity and days to harvesting were recorded in both the cropping period of the years and which are presented in Table 4.8

Table 4.7: Effect of cropping systems and nutrient management practices on net assimilation rate (g m^{-2} day^{-1}) at different growth stages of rice

Treatments	30-60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	16.33	16.92	16.62	10.07	9.82	9.94
C_4 - Rice + groundnut (3:1)	16.80	17.64	17.22	9.01	9.21	9.11
C_5 - Rice + soybean (3:1)	16.45	17.28	16.87	9.52	10.09	9.81
SEm±	0.48	0.48	0.34	0.64	0.63	0.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	16.08	16.54	16.31	9.67	9.48	9.58
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	16.84	17.63	17.24	8.43	9.23	8.83
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	16.67	17.66	17.17	10.50	10.40	10.45
SEm±	0.48	0.48	0.34	0.64	0.63	0.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Table 4.8: Effect of cropping systems and nutrient management practices on phenological parameters of rice

Treatments	Days to 50% flowering			Days to 50% maturity			Days to harvesting		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	84.11	83.84	83.98	105.76	105.67	105.71	121.56	121.33	121.44
C_4 - Rice + groundnut (3:1)	84.29	84.02	84.16	105.93	105.82	105.88	121.44	121.13	121.29
C_5 - Rice + soybean (3:1)	84.27	84.11	84.19	105.58	105.42	105.50	121.78	121.58	121.68
SEm±	0.37	0.38	0.27	0.31	0.30	0.21	0.22	0.23	0.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	84.16	84.11	84.13	105.89	105.78	105.83	121.56	121.24	121.40
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	84.38	84.16	84.27	106.13	106.04	106.09	121.56	121.36	121.46
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	84.13	83.71	83.92	105.24	105.09	105.17	121.67	121.44	121.56
SEm±	0.37	0.38	0.27	0.31	0.30	0.21	0.22	0.23	0.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect of cropping system

The critical analysis of the data clearly revealed that there was no significant variation in the different cropping systems on 50% flowering, 50% maturity and days to harvesting.

Effect of nutrient management

There was no significant difference on 50% flowering, 50% maturity and days to harvesting due to various nutrient management practices during both the years of experiment.

Interaction effect

Interaction effect of cropping system and nutrient management did not show any significant difference in both the years.

4.1.3 Yield attributes

4.1.3.1 Number of panicles m^{-2}

Data on number of panicles m^{-2} as influenced by cropping system and nutrient management practices are presented in Table 4.9.

Effect of cropping system

The variation on number of panicles m^{-2} due to cropping system was found to be significant during both years of experiment. During 2019 and 2020, the highest number of panicles m^{-2} 101.93 and 103.58 was recorded with the treatment sole rice which was statically at par with rice + soybean (3:1) intercropping system with the values of 92.20 and 98.88. The lowest number of panicles m^{-2} was recorded in C_4 (Rice + groundnut at 3:1 ratio). Pooled result thus obtained compiled with the findings of both the years. The highest number of panicles m^{-2} (102.75) was recorded in C_1 (Sole rice) which was statically at par with rice along with soybean intercropping system (95.54). The lowest (80.12) was recorded in rice intercropped with groundnut. The higher values with respect to yield attributing parameters are attributed to lack of inter space competition under sole cropping that could otherwise happen in intercropping system. Above results are in conformity with the findings of Shri *et al*. (2014).

Effect of nutrient management

The variation on number of panicles m^{-2} due to different nutrient management practices found to be significant during both the years of experiment. During 2019 and 2020, the highest number of panicles m^{-2} (109.10) and (116.53) was recorded with the treatment N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed), while the lowest (75.56) and (77.18) was recorded in (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Pooled result thus obtained recorded the highest number of panicles m^{-2} (112.82) with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. The lowest (76.37) was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Increase in panicles m^{-2} through FYM was supported by Mirza *et al*. (2005), Barik *et al*. (2006) and Revathi *et al*. (2014). Larijani and Hoseini (2012) also found that more tiller number, more panicle m^{-2}, number of filled grains m^{-2} and more grain yield with combined use of organic and chemical fertilizer compared with chemical fertilizer alone.

Interaction effect

The interaction effects between cropping system and nutrient management practices on number of panicles m^{-2} recorded non-significant during both the years of experimentation.

4.1.3.2 Panicle length (cm)

The effects of cropping system and nutrient management practices on panicle length (cm) are presented in Table 4.9.

Effect of cropping system

The result revealed that different cropping system had non-significant effect on panicle length during both the years of experiment.

Effect of nutrient management

Length of panicle (cm) due to nutrient management practices was found to be significant during both the years of experiment. During both the years longest panicle was recorded in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (24.93 and 25.35 cm in 2019 and 2020, respectively). The shortest panicle of 21.02 cm and 21.95 cm were recorded with the treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Pooled result thus obtained also recorded the longest panicle length (25.14 cm) with N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and the shorted (21.49 cm) recorded with N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). It may be due to the fact that balanced supply of nutrients enhanced panicle length which might be due to more availability of macro as well as micronutrients. Similar result was reported by Arif *et al*. (2014). Choudhary *et al*. (2007) also reported that application of FYM at 5 t ha^{-1} resulted in greater panicle length in rice compared to each counterpart treatment having the same NPK levels. Rahman *et al*. (2009) reported that increased panicle length in rice with the combine use of organic and inorganic fertilizer.

Interaction effect

Interaction between cropping system and nutrient management practices did not show any differences on panicle length during both the experimental year.

4.1.3.3 Weight of panicle (g)

Data pertaining to variation in weight of panicle (g) and interaction effect of weight of panicle (g) due to different cropping system and nutrient management practices are presented in Table 4.9 (a) and 4.9(b), respectively.

Effect of cropping system

Data revealed that cropping system exerted significant influence on weight of panicle (g). The highest panicle weight of 3.86 and 3.95 g were recorded at C_1 (sole rice) during both the years respectively, which was at par with rice intercropped with soybean (3.68 and 3.76 g during 2019 and 2020, respectively). The lowest panicle weight 3.01 and 3.07g were recorded at rice along with groundnut intercropping system during both the years of experiment. Pooled data also followed the similar trend of findings with the highest panicle weight (3.91 g) was recorded in sole rice which was at par with rice intercropped with soybean (3.72 g), while the lowest was recorded in rice intercropped with groundnut (3.04 g).

Effect of nutrient management

The variations on panicle weight due to nutrient management practices were found to be significant during both the years of experiment. Significantly superior panicle weight was recorded in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed with the values of 3.98 and 4.09 g during both the years of experiment respectively, while the lowest was recorded in N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment with the values of 3.08 and 3.14 g during 2019 and 2020, respectively. On the further scanning of pooled data of both the years revealed that the highest (4.03 g) panicle weight recorded in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and the significantly lowest (3.11g) was recorded in N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). The findings of the present

Table 4.9 (a): Effect of cropping systems and nutrient management practices on yield attributes of rice

Treatments	Number of panicles m^{-2}			Panicle length (cm)			Weight of panicle (g)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	101.93	103.58	102.75	23.22	23.90	23.56	3.86	3.95	3.91
C_4 - Rice + groundnut (3:1)	79.49	80.76	80.12	22.43	23.20	22.82	3.01	3.07	3.04
C_5 - Rice + soybean (3:1)	92.20	98.88	95.54	23.04	23.42	23.23	3.68	3.76	3.72
SEm±	3.98	4.23	2.90	0.52	0.66	0.42	0.08	0.10	0.07
CD (P=0.05)	11.94	12.68	8.37	NS	NS	NS	0.25	0.30	0.19
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	88.95	89.51	89.23	22.75	23.21	22.98	3.48	3.55	3.52
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	109.10	116.53	112.82	24.93	25.35	25.14	3.98	4.09	4.03
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	75.56	77.18	76.37	21.02	21.95	21.49	3.08	3.14	3.11
SEm±	3.98	4.23	2.90	0.52	0.66	0.42	0.08	0.10	0.07
CD (P=0.05)	11.94	12.68	8.37	1.55	1.97	1.20	0.25	0.30	0.19
Interaction (C X N)	NS	NS	NS	NS	NS	NS	S	S	S

Table 4.9 (b): Interaction effect of cropping systems and nutrient management practices on weight of panicle (g) of rice

Treatments	Weight of panicle (g)		
	2019	2020	Pooled
$C_1 N_1$	3.68	3.82	3.75
$C_4 N_1$	3.11	3.18	3.15
$C_5 N_1$	3.64	3.66	3.65
$C_1 N_2$	4.55	4.67	4.61
$C_4 N_2$	3.08	3.15	3.12
$C_5 N_2$	4.29	4.45	4.37
$C_1 N_3$	3.33	3.36	3.35
$C_4 N_3$	2.82	2.87	2.85
$C_5 N_3$	3.10	3.17	3.13
SEm±	0.15	0.17	0.11
CD (P=0.05)	0.44	0.51	0.33

investigation was in close proximity with Singh *et al*. (2018), who reported that the substitution of FYM in combination with 50-75% RDF releases nutrients slowly throughout the growth period in adequate quantities and enabled the rice plants to assimilate sufficient photosynthetic products and thus, resulted in superior grain yield attributing characters.

Interaction effect

The interaction effects between cropping system and nutrient management practices on panicle weight was significantly affected in both the years of experiment. The highest panicle weight of 4.55 and 4.67 g were registered at C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination which was statistically at par with C_5N_2 (Rice + soybean at 3:1 row ratio along with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values being 4.29 and 4.45 g during both the years of experiment respectively. The lowest was recorded in C_4N_3 (Rice + groundnut at 3:1 row ratio along with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values being 2.82 and 2.87 g during 2019 and 2020 respectively. Pooled data obtained also revealed similar findings with the highest panicle weight (4.61g) recorded for treatment C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed), which was at par with C_5N_2 (4.37 g) treatment combination, while the lowest (2.85g) was recorded in C_4N_3 (Rice + groundnut at 3:1 row ratio + 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

4.1.3.4 Number of grains panicle^{-1}

The data obtained on number of grains panicle^{-1} of rice as influenced by cropping system and nutrient management are presented in Table 4.10.

Effect of cropping system

Sole crop of rice recorded higher number of grains panicle^{-1} (101.93 and 103.58 panicle^{-1} in 2019 and 2020, respectively) and it was found to be at par with rice intercropped with soybean (92.20 and 98.88 panicle^{-1} in 2019 and 2020, respectively). Significantly lower number of grains panicle^{-1} (79.49 and 80.76 panicle^{-1} in 2019 and 2020, respectively) registered in rice+ groundnut (3:1) intercropping system during both the years. Further analysis of the pooled data revealed that highest number of grains panicle^{-1} was recorded in sole rice with the value of 102.75 panicle^{-1}, which was statistically remained at par with C_5 (Rice + soybean at 3:1 row ratio) with a value of 95.54 panicle^{-1}. The minimum was recorded from rice intercropped with groundnut (80.12 panicle^{-1}). Probably, reduction in grains per panicle of intercropped rice may be due to cessation of grain development at early stage as a result of overshading of the rice by groundnut and soybean plant. Saleem *et al*. (2000) also reported similar findings.

Effect of nutrient management

The data indicated that the effect of different treatments on number of grains panicle^{-1} was found to be significant. Application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed resulted in significantly highest number of grains panicle^{-1} (109.10 and 116.53 panicle^{-1} 2019 and 2020, respectively). The lowest number of grains panicle^{-1} was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 75.56 and 77.18 panicle^{-1} in 2019 and 2020, respectively. On further scanning of the pooled data revealed that the highest number of grains panicle^{-1} (112.82 panicle^{-1}) recorded in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. The significantly lowest (76.37 panicle^{-1}) was recorded in application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The findings of the present investigation was in close proximity with Singh *et al*.

(2018), who reported that all the yield attributes were higher with the substitution of FYM / green manure or wheat straw in combination with 50-75% RDF due slow release and continuous supply of nutrients in balance quantity throughout the various growth stages and enables the rice plants to assimilate sufficient photosynthetic products and thus, resulted in superior grain yield attributing characters which in turn increases the number of filled grains panicle^{-1}. Naing *et al*. (2010) also reported that combination of FYM along with inorganic fertilizers increases panicle number hill^{-1}, grain number panicle^{-1}.

Interaction effect

During both the years of study, interaction between cropping system and nutrient management practices was found non-significant.

4.1.3.5 Filled grain %

Filled grain % of rice differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.10.

Effect of cropping system

During both the year 2019 and 2020, sole crop of rice recorded higher number of filled grain % of 82.36 and 82.73% respectively and it was remained at par with intercropping of rice with soybean (80.41 and 80.80% during 2019 and 2020, respectively). Rice + groundnut at 3:1 row ratio recorded significantly lower number of filled grains % (75.86 and 76.20 % in 2019 and 2020, respectively). Pooled data of both the years revealed highest filled grain % in sole rice (82.54%) which was statistically at par with rice intercropped with soybean at 3:1 row ratio (80.61%), while the lowest was recorded in C_4 (Rice+ groundnut with 3: 1 row ratio) with a value of 76.03%. A higher filled grains % recorded may be due to a better environment for plant growth, higher plant dry matter production and higher photosynthates available for grain filling. All these characters positively correlated to grain filling. These results are in conformity with the finding of Maharajan *et al*. (2020). Similarly, this finding may be attributed due to the reason that maximum filled grain percentage corresponds to the weight of panicles and number of grain panicle^{-1}.

Effect of nutrient management

During both the year, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly higher number of filled grain of 83.80 and 84.19 % in 2019 and 2020, respectively, while the lowest (75.68 and 76.05 % in 2019 and 2020 respectively) was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Pooled data of both the years revealed that highest filled grain 84% recorded in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed, while the lowest (75.86%) was recorded in N_3 treatement (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). These results indicate that proper partitioning might have occurred from source to sink and as a result the filled grain % has improved. This finding is in corroboration with the finding of Ramesh *et al*. (2005). Another reason formaximum number of filled grain % may be due to application of FYM and inorganic fertilizers which provide K in adequate amounts. K increases the number of filled grain panicle^{-1}. Similar result was reported by Dobermann and Fairhurst (2000); Bahmaniar *et al*., 2007.

Interaction effect

Interactive effects were non-significant during both the years of experimentation.

4.1.3.6 Test weight (g)

Data on test weight (g) as influenced by cropping system and nutrient management practices are presented in Table 4.10.

Table 4.10: Effect of cropping systems and nutrient management practices on yield attributes of rice

Treatments	Number of grains panicle^{-1}			Filled grain (%)			Test weight (g)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	101.93	103.58	102.75	82.36	82.73	82.54	25.62	25.81	25.71
C_4 - Rice + groundnut (3:1)	79.49	80.76	80.12	75.86	76.20	76.03	25.35	25.51	25.43
C_5 - Rice + soybean (3:1)	92.20	98.88	95.54	80.41	80.80	80.61	25.46	25.64	25.55
SEm±	3.98	4.23	2.90	1.36	1.36	0.96	0.45	0.46	0.32
CD (P=0.05)	11.94	12.68	8.37	4.08	4.07	2.77	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	88.95	89.51	89.23	79.15	79.49	79.32	25.47	25.65	25.56
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	109.10	116.53	112.82	83.80	84.19	84.00	25.60	25.78	25.69
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	75.56	77.18	76.37	75.68	76.05	75.86	25.36	25.53	25.44
SEm±	3.98	4.23	2.90	1.36	1.36	0.96	0.45	0.46	0.32
CD (P=0.05)	11.94	12.68	8.37	4.08	4.07	2.77	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect of cropping system

There was no significant difference on test weight due to cropping system at various growth stages during both the years of experiment.

Effect of nutrient management

There was no significant difference on test weight of rice due to nutrient management at various growth stages during both the years of experiment.

Interaction effect

The interaction effects between cropping system and nutrient management practices on test weight (g) recorded non-significant variation during both the years of experimentation.

4.1.4 Yield

4.1.4.1 Grain yield (t ha^{-1})

Data pertaining to grain yield and interaction effect on grain yield due to cropping system and nutrient management are presented in Table 4.11 (a) and 4.11 (b) respectively and Fig 4.1 (a) and 4.1 (b), respectively.

Effect of cropping system

Adaption of different cropping system practices markedly influenced the grain yield of rice in both the years. Among the cropping system sole rice produced highest yield (3.07 and 3.08 t ha^{-1} in 2019 and 2020 respectively), which was at par with rice intercropped with soybean (2.97 and 2.99 t ha^{-1} in 2019 and 2020, respectively). The lowest grain yield was observed from C_4 (Rice + groundnut at 3:1 row ratio) with the values being 2.63 and 2.64 t ha^{-1} in 2019 and 2020, respectively. Maximum value (3.08 t ha^{-1}) of pooled was in N_1 (Sole rice) treatment which was at par with rice intercropped with soybean (2.98 t ha^{-1}). The lowest value was recorded in rice intercropped with groundnut (2.64 t ha^{-1}). The highest grain yield of rice was obtained in sole cropping of rice in all the intercropping system. This results confirm the findings Mandal *et al*. (1997)

who obtained more yield of rice in sole cropping than inclusion of intercrop. Among intercropping system highest grain yield was registerd in rice + soybean (3:1) intercropping system. It might be due to soybean, being a leguminous crop, it restores the fertility of the soil by fixing large amount of atmospheric nitrogen *i.e*. 125-150 kg N ha^{-1} through nodules (Chandel *et al*., 1989) and by leaves about 30-40 kg N ha^{-1} for succeeding crops (Saxena and Chandel,1992). Dulur *et al*. (2016) also reported that higher yield of rice plants was also obtained from rice plants grown in intercropping with soybean than in conventional system.

Effect of nutrient management

The effect of nutrient management on grain yield showed significant increase in yield. It was observed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly increased the yield during both the years as well as pooled data with the value of 3.14 t ha^{-1} during the first year, 3.16 t ha^{-1} during the second year and 3.15 t ha^{-1} in pooled data. The minimum value was registered at application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed during both the years and as well as in pooled data with the value being 2.60 t ha^{-1} during first year, 2.61 t ha^{-1} during second year and 2.60 t ha^{-1} in pooled data. The highest grain yield in FYM and fertilizer treatment plot might be due to its profuse tillering, maximum dry matter accumulation and higher value of yield attributing characters *viz* number of panicles m^{-2} and number of filled grains $panicles^{-1}$. Improved yields were due to instantaneous and rapid supply of nutrients through chemical fertilizers and steady supply through mineralization of FYM for prolonged period. Similar results on rice yields were reported due to integrated application of chemical fertilizer and organic manures (Sharma *et al.*, 2016; Tang *et al.*, 2018). Sravan and Singh (2019) also got similar result that application of recommended nutrients in integrated approach (75% RDF + 25% FYM) enhanced rice grain yield. Singh *et al.* (2001) reported that higher yield in the NPK+FYM treatment was due to the prolonged availability of plant nutrients. The perusal of data by Saha *et al*. (2007) stated that significantly highest grain yield of rice was recorded with treatment 75 % RDF+25 % N by addition of FYM when compared with RDF and other treatments under study. The upsurge in grain yield of rice was might be due to increase in soil fertility due to addition of FYM and timely release of nutrients during the crop growing period.

Interaction effect

Grain yield was significantly affected by the combine practice of cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the grain yield was highest in C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (3.24 t ha^{-1}), 2020 (3.25 t ha^{-1}) and pooled (3.25 t ha^{-1}), which was found to be comparable with plot assigned to C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 3.15, 3.17 and 3.16 t ha^{-1} during first, second and as well as in pooled data, respectively, (C_1N_1) sole rice along with 100% RDF + FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (3.06, 3.07 and 3.07 t ha^{-1} during first, second and as well as in pooled data, respectively), C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values being 3.04 and 3.05 t ha^{-1} during 2019 and 2020, respectively, C_5N_1 (Rice intercropped with soybean and application of 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 2.97 and 2.99 t ha^{-1} in 2019 and 2020, respectively. The lowest was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during both the years.

4.1.4.2 Straw yield (t ha^{-1})

Data related to straw yield due to cropping system and nutrient management are presented in Table 4.11 and Fig 4.2.

Effect of cropping system

The perusal of data indicated that straw yield was significantly influenced by different cropping system. Treatment N_1 (sole rice) recorded highest value over rest of the treatments during both the years and even in pooled data (5.03, 5.08 and 5.05 t ha^{-1} in 2019, 2020 and in pooled, respectively), which was statistically at par with treatment C_5 (Rice + soybean at 3:1 row ratio). The value recorded during 2019 was 4.84 t ha^{-1}, 4.90 t ha^{-1} was in 2020 and pooled data recorded 4.87 t ha^{-1}. The lowest straw yield was recorded rice intercropped with groundnut intercropping system in both the years and similar trend was followed in pooled. These results are in accordance with Ogutu *et al*. (2012) who found that sole rice has performed better with production of higher grain yield (2199 kg ha^{-1}) and straw yield (8278 kg ha^{-1}) compared to rice intercropped with cowpea and common bean at different row proportion.

Effect of nutrient management

It was apparent from the data presented in table that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly enhanced straw yield during both the years and similarly in pooled with the values being 5.13 t ha^{-1} in 2019, 5.19 t ha^{-1} in 2020 and 5.16 t ha^{-1} in pooled data. Significantly minimum straw yield was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years (4.45 and 4.49 t ha^{-1} in 2019 and 2020, respectively) and in pooled (4.47 t ha^{-1}). This may be due to the fact that integrated use of organic manures and chemical fertilizers had beneficial effect on yield contributing characters of different crops as supported by the results of several workers (Gupta *et al*., 2006 and Mehdi *et al*., 2011). Balasubramanian and Wahab (2012) also observed that straw yield was favorably influenced by combined application of inorganic fertilizers and organic manures.

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant on straw yield of rice.

4.1.4.3 Rice equivalent yield (t ha^{-1})

Data on rice equivalent yield (t ha^{-1}) and interaction effect on rice equivalent yield (t ha^{-1}) due to cropping system and nutrient management are presented in Table 4.11 (a) and 4.11 (b), respectively and Fig 4.3 (a) and 4.3 (b), respectively.

Effect of cropping system

There was marked influence of different crop management practices on rice equivalent yield. The significantly highest values of 4.59, 4.68 and 4.63 t ha^{-1} were reflected in C_5 treatment (Rice + soybean at 3:1 row ratio) during 2019, 2020 and in pooled data, respectively, which was followed by rice intercropped with groundnut (4.22, 4.27 and 4.25 t ha^{-1} in 2019, 2020 and in pooled data, respectively). Significantly lowest was achieved in sole rice with values of 3.07 t ha^{-1} in 2019, 3.08 t ha^{-1} in 2020 and 3.08 t ha^{-1} in pooled data. All the intercropping systems gave higher rice equivalent yield than sole rice crop. Rice + soybean and rice + groundnut intercropping systems are the biologically efficient as well as cash ensuring and profitable crop sequence and fetched more return per unit. Similar finding was reported by Virdia and Mehta (2010) and Laskar *et al*. (2005).

Effect of nutrient management

The data indicated that the effect of different nutrient management on rice equivalent yield was found to be significant. Significantly highest rice equivalent was observed in N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer

Table 4.11 (a): Effect of cropping systems and nutrient management practices on yield of rice

Treatments	Grain yield ($t\ ha^{-1}$)			Straw yield ($t\ ha^{-1}$)			Harvest index (%)			Rice equivalent yield ($t\ ha^{-1}$)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	3.07	3.08	3.08	5.03	5.08	5.05	37.98	37.76	37.87	3.07	3.08	3.08
C_4 - Rice + groundnut (3:1)	2.63	2.64	2.64	4.50	4.55	4.52	36.74	36.63	36.68	4.22	4.27	4.25
C_5 - Rice + soybean (3:1)	2.97	2.99	2.98	4.84	4.90	4.87	38.04	37.88	37.96	4.59	4.68	4.63
SEm±	0.05	0.06	0.04	0.13	0.10	0.08	0.73	0.72	0.51	0.06	0.06	0.05
CD (P=0.05)	0.15	0.17	0.11	0.40	0.30	0.24	NS	NS	NS	0.19	0.19	0.13
Nutrient management (N)												
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.93	2.94	2.94	4.79	4.85	4.82	38.00	37.80	37.90	3.94	4.03	3.99
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.14	3.16	3.15	5.13	5.19	5.16	38.05	37.85	37.95	4.42	4.44	4.43
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.60	2.61	2.60	4.45	4.49	4.47	36.71	36.62	36.66	3.52	3.56	3.54
SEm±	0.05	0.06	0.04	0.13	0.10	0.08	0.73	0.72	0.51	0.06	0.06	0.05
CD (P=0.05)	0.15	0.17	0.11	0.40	0.30	0.24	NS	NS	NS	0.19	0.19	0.13
Interaction (C X N)	S	S	S	NS	NS	NS	NS	NS	NS	S	S	S

Table 4.11 (b): Interaction effect of cropping systems and nutrient management practices on yield of rice

Treatments	Grain yield ($t\ ha^{-1}$)			Rice equivalent yield ($t\ ha^{-1}$)		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 N_1	3.06	3.07	3.07	3.06	3.07	3.07
C_4 N_1	2.76	2.77	2.76	4.27	4.38	4.32
C_5 N_1	2.97	2.99	2.98	4.49	4.64	4.57
C_1 N_2	3.24	3.25	3.25	3.24	3.25	3.25
C_4 N_2	3.04	3.05	3.05	4.89	4.89	4.89
C_5 N_2	3.15	3.17	3.16	5.12	5.17	5.15
C_1 N_3	2.91	2.93	2.92	2.91	2.93	2.92
C_4 N_3	2.10	2.11	2.10	3.51	3.55	3.53
C_5 N_3	2.78	2.80	2.79	4.15	4.22	4.18
SEm±	0.09	0.10	0.07	0.11	0.11	0.08
CD (P=0.05)	0.27	0.30	0.19	0.34	0.33	0.23

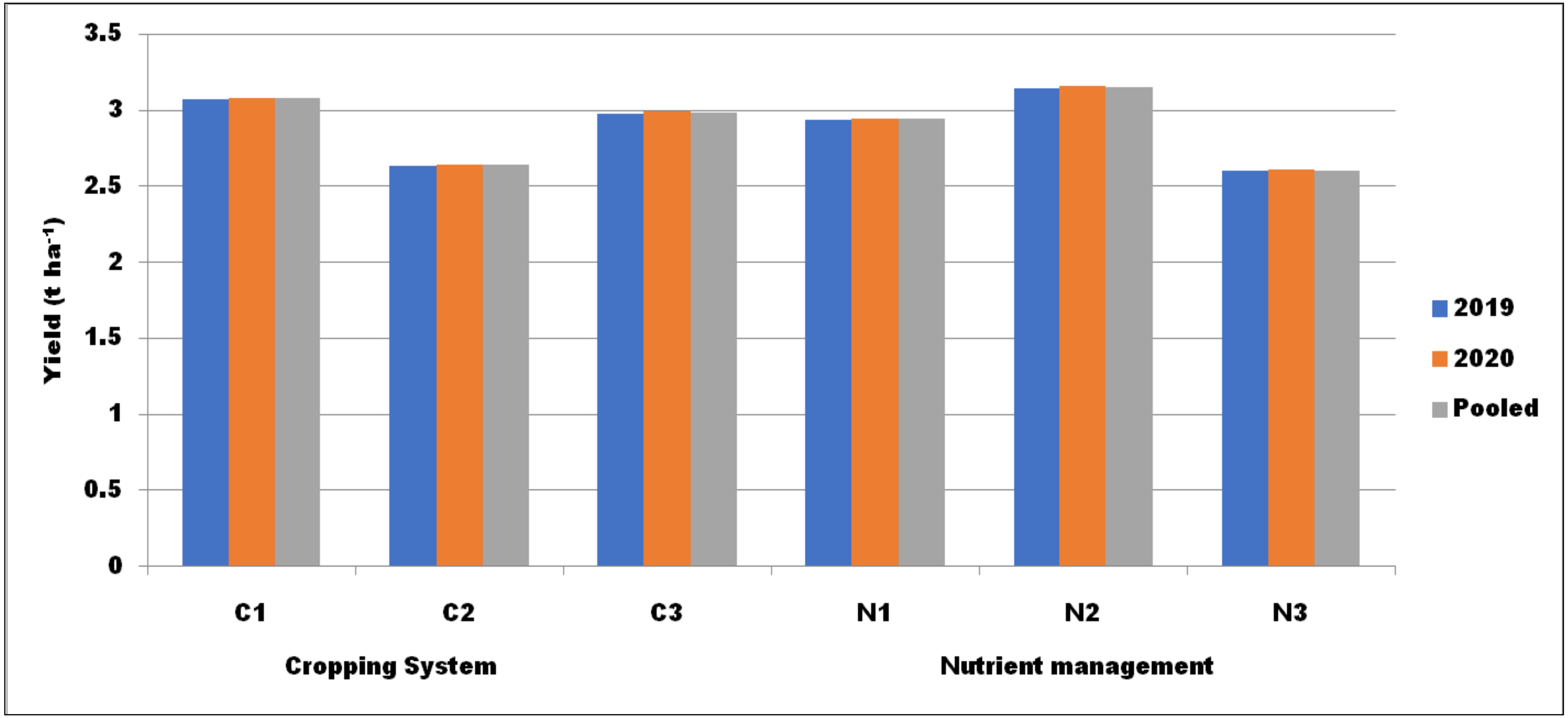


Fig 4.1 (a): Effect of cropping system and nutrient management on grain yield of rice

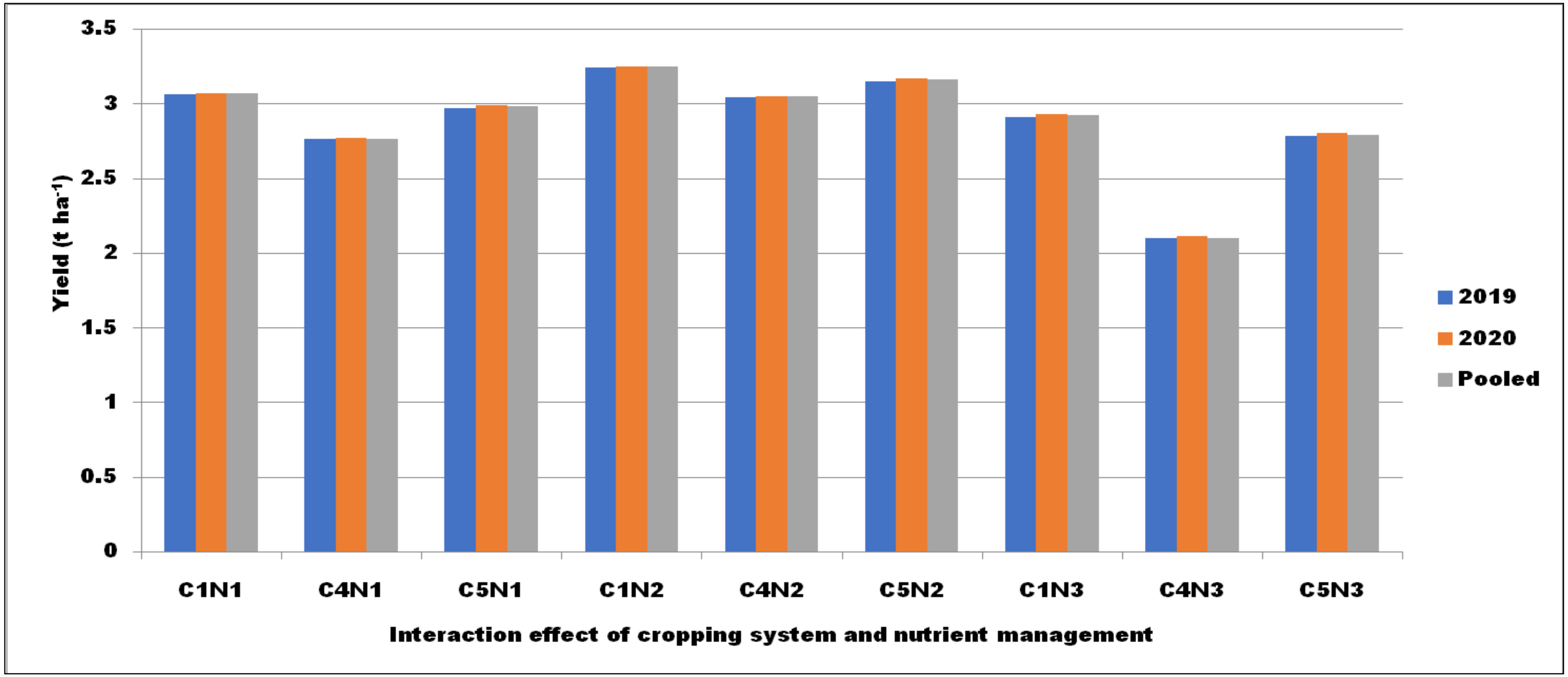


Fig 4.1 (b): Interaction effect of cropping system and nutrient management on grain yield of rice (t ha^{-1})

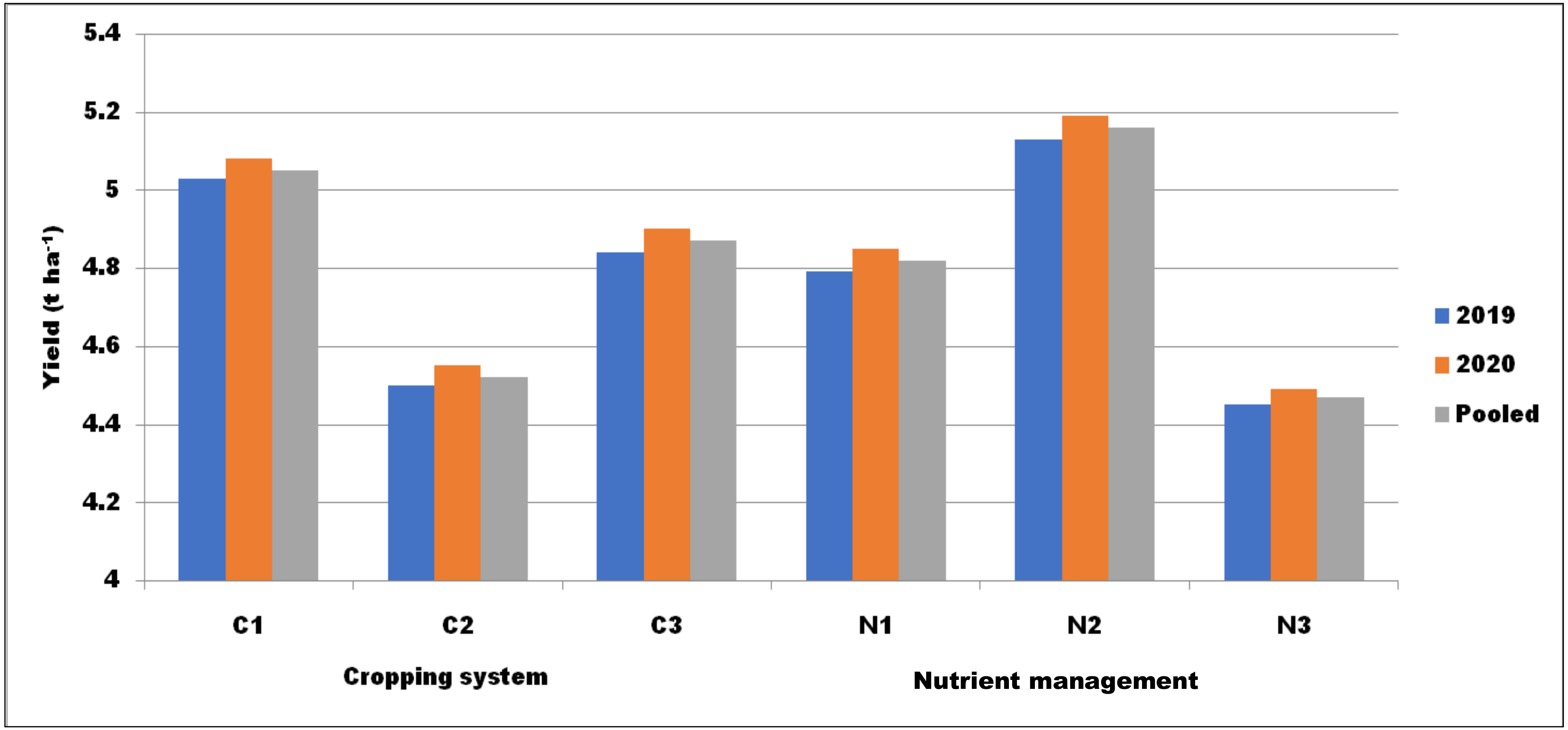


Fig 4.2: Effect of cropping system and nutrient management on straw yield of rice (t ha^{-1})

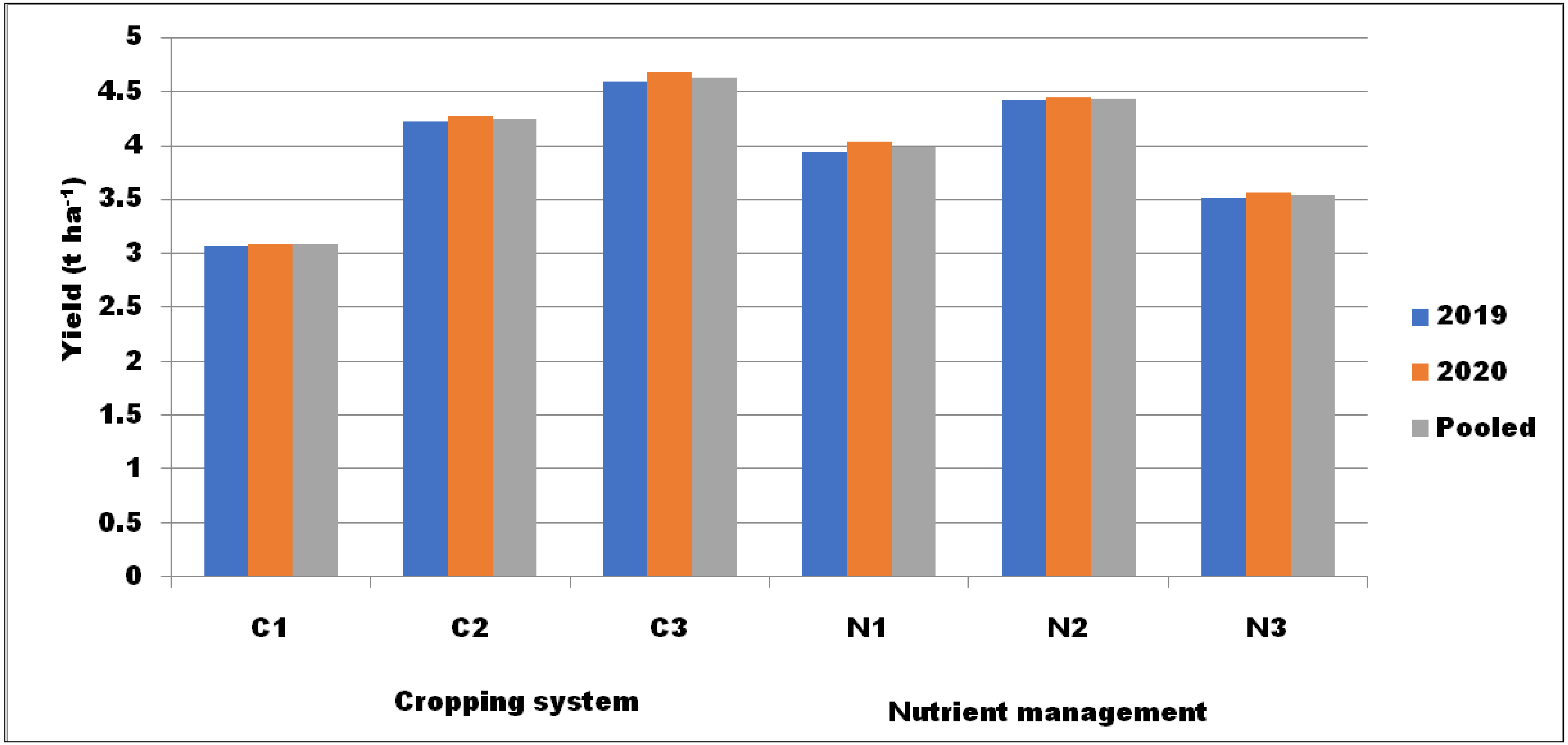


Fig 4.3 (a): Effect of cropping system and nutrient management on rice equivalent yield (t ha^{-1})

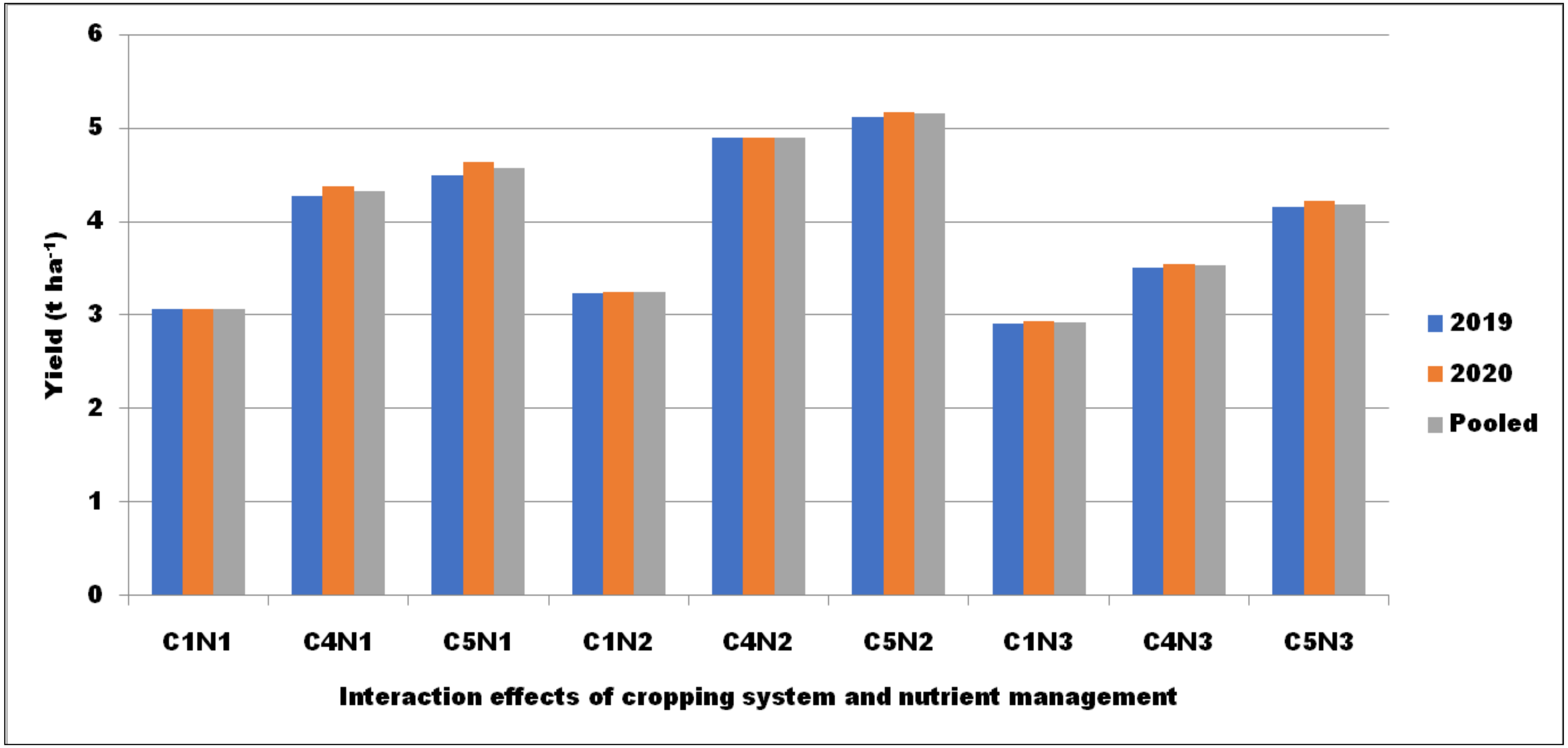


Fig 4.3 (b): Interaction effect of cropping system and nutrient management on rice equivalent yield (t ha^{-1})

consortium @ 20 g kg^{-1} seed) treatment with the value 4.42, 4.44 and 4.43 t ha^{1} during 2019, 2020 and in pooled data, respectively. The lowest (3.52, 3.56 and 3.54 t ha^{-1} during 2019, 2020 and pooled data, respectively) was registered in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the experimentation. It may be attributed to various yield attributes of component crops. It may be ascribed to assimilation and translocation of more pohotosynthates towards sink at integrated use of organic manures and chemical fertilizers application. Bhowmick *et al*. (2011) found that higher yields under combined use of RDF and FYM could be attributed to well decomposition of FYM, which favoured better nutrient availability coupled with higher assimilation of nutrients. High rice equivalent yield due to inclusion of pulses such as pea and lentil after ice has been also reported by Das *et al.* (2014).

Interaction effect

Rice equivalent yield was significantly affected by the combine practice cropping system and nutrient management during both the year and in pooled data. The data revealed that the yield was highest in C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (5.12 t ha^{-1}), 2020 (5.17 t ha^{-1}) and pooled (5.15 t ha^{-1}), which was followed by C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (4.89 t ha^{-1} during first, second and as well as in pooled data) and significantly minimum was observed in C_1N_3 (Sole rice + 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 2.91 t ha^{-1} in 2019, 2.93 t ha^{-1} in 2020 and 2.92 t ha^{-1} in pooled data.

4.1.4.4 Harvest index (%)

The data pertaining to harvest index due to cropping system and nutrient management practices are presented in Table 4.11

Effect of cropping system

Application of different cropping system did not show any significant effect on harvest index.

Effect of nutrient management

The effect of different nutrient management practices did not bring significant impact on the harvest index of rice.

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on harvest index.

4.1.5 Nutrient study

4.1.5.1 Nitrogen content in grain (%)

Data on nitrogen content in grain (%) as influenced by cropping system and nutrient management practices are presented in Table 4.12.

Effect of cropping system

Effect of cropping system could not show significant response on per cent nitrogen content in grain.

Effect of nutrient management

Different nutrient management showed significant differences in respect of nitrogen content in grain. The maximum nitrogen content in grain recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during both the years and similar trend followed in pooled with the values being 1.268, 1.274 and 1.271 %, respectively. The lowest value

Table 4.12: Effect of cropping systems and nutrient management practices on nitrogen content (%) in rice

Treatments	Nitrogen content (%)					
	Grain			Straw		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	1.234	1.239	1.236	0.306	0.311	0.308
C_4 - Rice + groundnut (3:1)	1.220	1.225	1.222	0.293	0.298	0.296
C_5 - Rice + soybean (3:1)	1.226	1.231	1.228	0.301	0.304	0.303
SEm±	0.015	0.016	0.011	0.005	0.005	0.003
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.221	1.225	1.223	0.298	0.302	0.300
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.268	1.274	1.271	0.362	0.367	0.365
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.191	1.195	1.193	0.240	0.244	0.242
SEm±	0.015	0.016	0.011	0.005	0.005	0.003
CD (P=0.05)	0.044	0.047	0.031	0.014	0.014	0.010
Interaction (C X N)	NS	NS	NS	NS	NS	NS

was recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (1.191, 1.195 and 1.193% during 2019, 2020 and in pooled data, respectively). The results are in conformity with the works of Sai Ram *et al*. (2020).

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on nitrogen content in grain.

4.1.5.2 Nitrogen content in straw (%)

The data pertaining to nitrogen content in straw (%) due to cropping system and nutrient management practices are presented in Table 4.12.

Effect of cropping system

Effect of cropping system could not show significant response on per cent nitrogen content in straw.

Effect of nutrient management

Close examination of the data revealed that in both the years as well as pooled data, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed resulted in significantly highest nitrogen content in straw with the values of 0.362, 0.367 and 0.365 % respectively. However application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed registered significantly lowest data with the values being 0.240 % in 2019, 0.244% in 2020 and 0.242% in pooled data. Similar finding was also reported by Garai *et al*. (2014).

Interaction effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.1.5.3 Phosphorous content in grain (%)

Data related to phosphorous content in grain (%) due to cropping system and nutrient management are presented in Table 4.13.

Effect of cropping system

No significant changes in grain phosphorous content was observed during both the years of experimentation.

Effect of nutrient management

An inference of the data presented in table revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly increased the percent phosphorous content in grain. Similar trend of effect was observed in both the year as well as pooled data with the value of 0.237, 0.242 and 0.240 %, respectively. The lowest percent phosphorous content was recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values being 0.217, 0.222 and 0.220 during 2019, 2020 and in pooled data, respectively. This might be due to the combined effect of organic and inorganic fertilizers that significantly influenced the concentration of P content in grain (%) during both the years.

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.1.5.4 Phosphorous content in straw (%)

The effects of cropping system and nutrient management practices on phosphorous content in straw (%) are presented in Table 4.13.

Table 4.13: Effect of cropping systems and nutrient management practices on phosphorous content (%) in rice

Treatments	Phosphorous content (%)					
	Grain			Straw		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	0.229	0.234	0.232	0.144	0.149	0.147
C_4 - Rice + groundnut (3:1)	0.221	0.224	0.223	0.142	0.148	0.145
C_5 - Rice + soybean (3:1)	0.224	0.228	0.226	0.143	0.150	0.147
SEm±	0.005	0.005	0.004	0.004	0.004	0.003
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.219	0.223	0.221	0.140	0.147	0.143
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.237	0.242	0.240	0.155	0.160	0.157
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.217	0.222	0.220	0.136	0.141	0.138
SEm±	0.005	0.005	0.004	0.004	0.004	0.003
CD (P=0.05)	0.015	0.015	0.010	0.011	0.012	0.008
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Effect of cropping system

No significant differences in phosphorous content in straw was observed in all the treatments.

Effect of nutrient management

Nutrient management practices significantly influenced the per cent phosphorous content of straw the highest being 0.155% in 2019, 0.160% in 2020 and 0.157% in pooled were recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). The significantly lowest value of 0.136% in 2019, 0.141% in 2020 and 0.138% in pooled data was recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). The results are in conformity with the works of Samaint (2015).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management on phosphorous content in straw during both the years of experimentation.

4.1.5.5 Potassium content in grain (%)

Potassium content in grain (%) of rice differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.14.

Effect of cropping system

The data revealed that there was no significant effect of the treatments on percent potassium content in grain during both the years.

Effect of nutrient management

An examination of the data in both the years as well as pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded highest potassium concentration in grain with the values of 0.314% in 2019, 0.317% in 2020 and a pooled value of 0.316%, while the treatments recorded lowest value (0.283%,0.287% and 0.285% during 2019, 2020 and in pooled data respectively) at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). It might be due to combined use of organic and inorganic fertilizers significantly influenced the concentration of K in grain (%) during both the years. The results are in conformity with the works of Mondal *et al*. (2015).

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.1.5.6 Potassium content in straw (%)

The result presented in Table 4.14 showed the effects of cropping system and nutrient management practices on potassium content in straw (%)

Effect of cropping system

Effect of cropping system could not show significant response on potassium content in straw.

Effect of nutrient management

It was noted that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed obtained statistically superior values of 1.210, 1.212 and 1.211% during both the years and in pooled data respectively. While the lowest was recorded in N_3 treatment (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values recorded 1.103, 1.106 and 1.104% in 2019, 2020 and in pooled data, respectively.

Table 4.14: Effect of cropping systems and nutrient management practices on potassium content (%) in rice

Treatments	Potassium content (%)					
	Grain			Straw		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	0.298	0.303	0.301	1.159	1.161	1.160
C_4 - Rice + groundnut (3:1)	0.293	0.296	0.295	1.148	1.152	1.150
C_5 - Rice + soybean (3:1)	0.295	0.299	0.297	1.153	1.156	1.155
SEm±	0.007	0.007	0.005	0.014	0.011	0.009
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.290	0.294	0.292	1.148	1.151	1.150
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.314	0.317	0.316	1.210	1.212	1.211
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.283	0.287	0.285	1.103	1.106	1.104
SEm±	0.007	0.007	0.005	0.014	0.011	0.009
CD (P=0.05)	0.020	0.021	0.014	0.041	0.032	0.025
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.1.5.7 Nitrogen uptake by grain (kg ha^{-1})

Data related to nitrogen uptake by grain (kg ha^{-1}) and interaction of nitrogen uptake by grain (kg ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.15 (a) and 4.15 (b), respectively.

Effect of cropping system

The variations on nitrogen uptake due to cropping system were found to be significant during both the years of experiment. The highest nitrogen uptake 37.93, 38.24 and 38.09 kg ha^{-1} were recorded in treatment sole rice during 2019, 2020 and in pooled data, respectively, which was found statistically at par with rice intercropped with soybean with the values of 36.42, 36.82 and 36.62 kg ha^{-1} in 2019, 2020 and in pooled data, respectively. The lowest was recorded in rice intercropped with groundnut. This could be mainly due to significant higher uptake of nutrient by grains and straw because of their higher grain and straw yield as a consequence of increased total dry matter in rice. Uptake of any nutrient by crop is directly proportional to dry matter production, grain and straw yield, the increased grain and straw yield have led to higher uptake of these nutrients under sole crop of rice.

Effect of nutrient management

The analysis of variance study of the data indicated towards a significant difference among the responses of the various nutrient management practices. Significantly highest value was recorded in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment during both the years (39.86, 40.20 and 40.03 in 2019, 2020 and in pooled data, respectively), while the lowest was recorded in 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed treatment (30.93, 31.20 and 31.07 in 2019, 2020 and in pooled data, respectively). Banik and Sharma (2008) reported that nutrient uptake in rice under the integrated nutrient management system was greater due to greater biomass production and greater nutrient mineralization from organic sources. Increase in fertilizer levels significantly increased the N uptake in rice (Choudhary and Suri, 2009). Similar finding was also reported by Sujathamma and Reddy (2004).

Interaction Effect

The interaction effects between cropping system and nutrient management practice was found to be significant in 2019. But it showed non-significant effect during 2020. The highest nitrogen uptake in 2019 was associated with the interaction C_1N_2 (Sole rice + 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the value of 41.31 kg ha^{-1}, which was followed by C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the value of 39.89 kg ha^{-1} and C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with a value of 38.39 kg ha^{-1}, while the lowest was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with value of 24.85 kg ha^{-1}. The pooled data thus obtained compiled with the findings of both the years of experiment with interaction C_1N_2 giving the highest value (41.46 kg ha^{-1}) which was at par with C_5N_2 (40.10 kg ha^{-1}) treatment combination, while the lowest was obtained in C_4N_3 with a value of 24.91 kg ha^{-1}.

Table 4.15 (a): Effect of cropping systems and nutrient management practices on nitrogen uptake (kg ha^{-1}) in rice

Treatments	**Nitrogen uptake (kg ha^{-1})**					
	Grain			**Straw**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	37.93	38.24	38.09	15.48	15.87	15.68
C_4 - Rice + groundnut (3:1)	32.24	32.42	32.33	13.40	13.85	13.62
C_5 - Rice + soybean (3:1)	36.42	36.82	36.62	14.64	14.94	14.79
SEm±	0.64	0.75	0.49	0.36	0.25	0.22
CD (P=0.05)	1.92	2.25	1.42	1.08	0.76	0.64
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	35.80	36.07	35.94	14.28	14.65	14.47
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	39.86	40.20	40.03	18.53	19.03	18.78
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	30.93	31.20	31.07	10.70	10.98	10.84
SEm±	0.64	0.75	0.49	0.36	0.25	0.22
CD (P=0.05)	1.92	2.25	1.42	1.08	0.76	0.64
Interaction (C X N)	S	NS	S	NS	S	NS

Table 4.15 (b): Interaction effect of cropping systems and nutrient management practices on nitrogen uptake (kg ha^{-1}) in rice

Treatments	Nitrogen uptake (kg ha^{-1})		
	Grain		Straw
	2019	Pooled	2020
C_1 N_1	37.64	37.76	15.96
C_4 N_1	33.47	33.55	13.57
C_5 N_1	36.29	36.50	14.42
C_1 N_2	41.31	41.46	19.50
C_4 N_2	38.39	38.53	18.97
C_5 N_2	39.89	40.10	18.62
C_1 N_3	34.85	35.04	12.16
C_4 N_3	24.85	24.91	9.01
C_5 N_3	33.09	33.26	11.77
SEm±	1.11	0.85	0.44
CD (P=0.05)	3.32	2.46	1.32

4.1.5.8 Nitrogen uptake by straw (kg ha^{-1})

The data pertaining to nitrogen uptake by straw (kg ha^{-1}) and interaction of nitrogen uptake by straw (kg ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.15 (a) and 4.15 (b), respectively.

Effect of cropping system

The variations on nitrogen uptake by straw due to cropping system were found to be significant during both the years of experiment. The highest nitrogen uptake of 15.48, 15.87 and 15.68 kg ha^{-1} were recorded in treatment sole rice during 2019, 2020 and in pooled data, respectively, which was found statistically at par with rice intercropped with soybean with the values of 14.64, 14.94 and 14.79 kg ha^{-1} in 2019, 2020 and in pooled data, respectively. The lowest was recorded in rice intercropped with groundnut (13.40, 13.85 and 13.62 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). Similar result was also reported by Sharma *et al*. (1998).

Effect of nutrient management

Significant differences in nitrogen uptake by the crop were noticed among all the treatments, the maximum being 18.53, 19.03, and 18.78 kg ha^{-1} during 2019, 2020 and pooled data, respectively were recorded at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment. The uptake value was recorded low at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during both the years. The higher uptake of nutrient might be due to better vegetative growth and higher straw yield. Ranjitha and Reddy (2013) also observed similar result.

Interaction Effect

The interaction effects of different treatments were found to be non significant during 2019. During 2020, significant variation was observed with the highest value of 19.50 kg ha^{-1} associated with the interaction of C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) which was statistically at par with C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with a value of 18.97 kg ha^{-1} and C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed with value being 18.62 kg ha^{-1}).

4.1.5.9 Phosphorous uptake by grain (kg ha^{-1})

Phosphorous uptake by grain (kg ha^{-1}) of rice differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.16.

Effect of cropping system

Data on phosphorous uptake presented in table revealed that cropping system exerted significant influence on phosphorous uptake by grain. Highest phosphorous uptake in grain was recorded in sole rice (7.06, 7.24 and 7.15 kg ha^{-1} in 2019, 2020 and in pooled data, respectively), which was statistically at par with rice intercropped with soybean with the values of 6.67, 6.84 and 6.75 kg ha^{-1} during 2019, 2020 and in pooled data, respectively. The significantly lowest phosphorous uptake was recorded in rice intercropped with groundnut (5.83, 5.95 and 5.89 kg ha^{-1} in 2019, 2020 and in pooled, respectively). The higher removal of P by sole rice as compared to intercropping treatments probably happened due to vigorous growth and better root system under optimum spacing which had helped in adequate supply of these nutrients resulting in higher biological yield coupled with their effective transfer to the ultimate sink *i.e*. the grains thus leading to numerically higher rice grain nutrient contents of N, P and K. Similar result was reported by Kour *et al.* (2013).

Effect of nutrient management

Significant variation in respect to phosphorous uptake in grain was observed during both the years of investigation. Values of 7.48, 7.66 and 7.57

kg ha^{-1} in 2019, 2020 and in pooled data, respectively were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and were statistically superior to rest of the treatments. The lowest was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation (5.65, 5.79 and 5.72 kg ha^{-1} during 2019, 2020 and in pooled data, respectively). Various integrated nutrient management affected significantly nutrient uptake by rice. Talathi *et al.* (2009) reported that the maximum NPK uptake was recorded by the application of 75% NPK + 25% FYM through inorganic and organic fertilizer. Availability of nutrients might be sufficient and it led to higher nutrient uptake. Virdia and Mehta (2009) studied that the pooled result of nutrient uptake and they found that the application of organic fertilizer along with recommended dose of fertilizer (RDF) gave numerically higher uptake value of N, P and K than only RDF treatment in grain, straw and total uptake.

Interaction Effect

During both the years of study, cropping system and nutrient management interaction effects were found to be non-significant.

4.1.5.10 Phosphorous uptake by straw (kg ha^{-1})

Data related to phosphorous uptake by straw (kg ha^{-1}) due to cropping system and nutrient management are presented in Table 4.16.

Effect of cropping system

Adaption of different crop management practices did not show any significant variation in phosphorous uptake by straw in both the years.

Effect of nutrient management

Data tabulated in table indicated that nutrient management practices showed significant influence during both the years of study. The highest phosphorous uptake values of 7.93, 8.30 and 8.11 kg ha^{-1} were obtained in N_2

Table 4.16: Effect of cropping systems and nutrient management practices on phosphorous uptake (kg ha^{-1}) in rice

Treatments	Phosphorous uptake (kg ha^{-1})					
	Grain			Straw		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	7.06	7.24	7.15	7.28	7.58	7.43
C_4 - Rice + groundnut (3:1)	5.83	5.95	5.89	6.44	6.77	6.60
C_5 - Rice + soybean (3:1)	6.67	6.84	6.75	6.97	7.37	7.17
SEm±	0.20	0.23	0.15	0.31	0.26	0.20
CD (P=0.05)	0.61	0.69	0.44	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.42	6.57	6.50	6.73	7.10	6.92
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	7.48	7.66	7.57	7.93	8.30	8.11
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	5.65	5.79	5.72	6.03	6.32	6.18
SEm±	0.20	0.23	0.15	0.31	0.26	0.20
CD (P=0.05)	0.61	0.69	0.44	0.92	0.77	0.58
Interaction (C X N)	NS	NS	NS	NS	NS	NS

(75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during 2019, 2020 and in pooled respectively. The lowest was recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed during both the years of investigations. Sathish *et al*. (2011) also reported that treatments which received combination of organic and inorganic fertilizer showed higher uptake values by rice crop of all the three nutrients N, P and K.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.1.5.11 Potassium uptake by grain (kg ha^{-1})

The result presented in Table 4.17 (a) and 4.17 (b) showed the effects of cropping system and nutrient management practices on potassium uptake by grain (kg ha^{-1}) and interaction effect of potassium uptake by grain (kg ha^{-1}), respectively.

Effect of cropping system

Significant differences in potassium uptake by the crop were noticed among all the treatments, the maximum being 9.17, 9.34 and 9.26 kg ha^{-1} during 2019, 2020 and in pooled data, respectively were observed in sole rice which was statistically at par with rice intercropped with soybean (8.78 kg ha^{-1} in 2019, 8.96 kg ha^{-1} in 2020 and 8.87 kg ha^{-1} in pooled data). The lowest values of 7.75, 7.85 and 7.80 kg ha^{-1} during 2019, 2020 and in pooled data, respectively were recorded in rice intercropped with groundnut. These results are in accordance with Venkatesha (2008) who found that higher nutrient uptake was observed in sole rice crop (170.53 kg N ha^{-1}, 55.58 kg P ha^{-1} and 128.1 kg K ha^{-1}) as compared to other intercrops.

Effect of nutrient management

Potassium uptake was also influenced by different nutrient management practices. Significant differences in potassium uptake by the crop were noticed among all the treatments, the maximum being 9.86, 10 and 9.93 kg ha^{-1} with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed during 2019, 2020 and in pooled data respectively. The minimum being recorded in adaptation of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (7.35, 7.49 and 7.42 kg ha^{-1} during 2019, 2020 and in pooled data, respectively). Weijabhandara *et al*. (2011) reported that application of 75% RDF + biofertilizers resulted in significantly higher grain yield, uptake of N, P, K and Zn by grains and residual available N, P, Zn compared to other treatments. Rani and Sukumari (2013) also observed that higher total N, P, K, Fe, Mn and Zn uptake by medicinal rice (Njavara) was recorded under integrated nutrient source than the individual organic and inorganic sources.

Interaction Effect

The interaction effects between cropping system and nutrient management practice were found to be significant in 2019. The highest potassium uptake (10.26 kg ha^{-1}) in 2019 was associated with the interaction of C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) which was statistically at par with C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the value of 9.85 kg ha^{-1} and C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the value of 9.47 kg ha^{-1}, while the lowest was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the value being 5.87 kg ha^{-1}. The

Table 4.17 (a): Effect of cropping systems and nutrient management practices on potassium uptake (kg ha^{-1}) in rice

Treatments	Potassium uptake (kg ha^{-1})					
	Grain			Straw		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	9.17	9.34	9.26	58.33	59.11	58.72
C_4 - Rice + groundnut (3:1)	7.75	7.85	7.80	51.78	52.60	52.19
C_5 - Rice + soybean (3:1)	8.78	8.96	8.87	55.89	56.79	56.34
SEm±	0.16	0.21	0.13	1.38	1.48	1.01
CD (P=0.05)	0.48	0.63	0.38	4.13	4.45	2.92
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	8.49	8.66	8.57	54.93	55.84	55.39
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	9.86	10.00	9.93	61.97	62.95	62.46
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	7.35	7.49	7.42	49.10	49.70	49.40
SEm±	0.16	0.21	0.13	1.38	1.48	1.01
CD (P=0.05)	0.48	0.63	0.38	4.13	4.45	2.92
Interaction (C X N)	S	NS	S	NS	NS	NS

Table 4.17 (b): Interaction effect of cropping systems and nutrient management practices on potassium uptake (kg ha^{-1}) in rice

Treatments	Potassium uptake (kg ha^{-1})	
	Grain	
	2019	Pooled
C_1 N_1	8.91	9.01
C_4 N_1	7.93	7.96
C_5 N_1	8.63	8.75
C_1 N_2	10.26	10.34
C_4 N_2	9.47	9.52
C_5 N_2	9.85	9.93
C_1 N_3	8.34	8.42
C_4 N_3	5.87	5.93
C_5 N_3	7.85	7.92
SEm±	0.28	0.23
CD (P=0.05)	0.83	0.66

pooled data thus obtained compiled with the findings of both the years of experiment with interaction C_1N_2 giving the highest value (10.34 kg ha^{-1}) which was at par with C_5N_2 (9.93 kg ha^{-1}) treatment combination, while the lowest was obtained in C_4N_3 with a value of 5.93 kg ha^{-1}.

4.1.5.12 Potassium uptake by straw (kg ha^{-1})

Data on potassium uptake by straw (kg ha^{-1}) as influenced by cropping system and nutrient management practices are presented in Table 4.17.

Effect of cropping system

The data on potassium uptake by straw revealed significant variation due to different cropping system during both the years of experiment. During 2019 and 2020, highest potassium uptake was recorded from sole rice with the values of 58.33 and 59.11 kg ha^{-1}, respectively, which was at par with rice intercropped with soybean (55.89 and 56.79 kg ha^{-1} during 2019 and 2020, respectively). The statistically lowest was recorded in rice intercropped with groundnut treatment with the values 51.78 in 2019 and 52.60 in 2020. The similar trend was followed in pooled data of two years. The results are in close proximity of Kour *et al.* (2014) in winter maize and potato intercropping system, who reported that sole winter maize recorded highest uptake of K.

Effect of nutrient management

Among the nutrient management, potassium uptake showed significant variation during both the years of experiment. It is indicated from the data that highest value was noticed in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment with the values 61.97 kg ha^{-1} in 2019, 62.95 kg ha^{-1} in 2020 and 62.46 kg ha^{-1} in pooled data. The statistically minimum was observed in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed treatment (49.10, 49.70 and 49.40 in 2019, 2020 and in pooled data, respectively). Natarajan *et al*. (2005) registered that application of NPK fertilizer in combination with FYM registered the higher uptake of N, P and K by both grain and straw. Moreover, Kumar *et al*. (2014) proved that application of organic and inorganic sources of nutrient in combination remarkably increased N uptake in grain (36.81%) and straw (42.81%), P uptake in grain (32.62%) and straw (31.56%) and K uptake in grain (35.46%) and straw (25.39%) over control.

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.1.6 Quality parameters

4.1.6.1 Protein content (%)

The effect of cropping system and nutrient management practices on protein content (%) are presented in Table 4.18.

Effect of cropping system

No significant differences in per cent protein content of rice was observed among the treatments during both the years.

Effect of nutrient management

The highest protein content was recorded at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 7.93, 7.96 and 7.94 % during 2019, 2020 and in pooled data, respectively. The lowest value of 7.44, 7.47 and 7.46 % were observed at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during 2019 and 2020 and pooled, respectively. Dixit and Gupta (2000) reported that quality parameters like hulling percentage, milling percentage, protein and amylase content increased due to use of FYM and NPK fertilizers.

Table 4.18 (a): Effect of cropping systems and nutrient management practices on protein content (%) and protein yield (kg ha^{-1}) in rice

Treatments	Protein content (%)			Protein yield (kg ha^{-1})		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	7.71	7.74	7.73	237.09	238.99	238.04
C_4 - Rice + groundnut (3:1)	7.63	7.65	7.64	201.48	202.62	202.05
C_5 - Rice + soybean (3:1)	7.66	7.69	7.68	227.65	230.11	228.88
SEm±	0.09	0.10	0.07	4.00	4.69	3.08
CD (P=0.05)	NS	NS	NS	11.99	14.07	8.88
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	7.63	7.66	7.64	223.76	225.44	224.60
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	7.93	7.96	7.94	249.14	251.27	250.21
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	7.44	7.47	7.46	193.32	195.02	194.17
SEm±	0.09	0.10	0.07	4.00	4.69	3.08
CD (P=0.05)	0.27	0.29	0.19	11.99	14.07	8.88
Interaction (C X N)	NS	NS	NS	S	NS	S

Table 4.18 (b): Interaction effect of cropping systems and nutrient management practices on protein yield (kg ha^{-1}) in rice

Treatments	Protein yield (kg ha^{-1})	
	2019	**Pooled**
$C_1 N_1$	235.24	235.99
$C_4 N_1$	209.20	209.66
$C_5 N_1$	226.84	228.15
$C_1 N_2$	258.19	259.15
$C_4 N_2$	239.96	240.83
$C_5 N_2$	249.28	250.63
$C_1 N_3$	217.84	218.98
$C_4 N_3$	155.30	155.66
$C_5 N_3$	206.84	207.87
SEm±	6.93	5.34
CD (P=0.05)	20.76	15.38

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.1.6.2 Protein yield (kg ha^{-1})

The results recorded on the effect of cropping system and nutrient management on the protein yield (kg ha^{-1}) and interaction effect of protein yield (kg ha^{-1}) are presented in table 4.18 (a) and 4.18 (b), respectively.

Effect of cropping system

The various crop management practices brought significant results on the protein yield of rice grain. Highest protein yield was recorded in sole rice (237.09, 238.99 and 238.04 kg ha^{-1} in 2019, 2020 and in pooled data, respectively), which was statistically at par with rice intercropped with soybean with the values of 227.65, 230.11 and 228.88 kg ha^{-1} during 2019, 2020 and in pooled data, respectively. The significantly lowest protein yield was recorded in C_4 treatment (201.48, 202.62 and 202.05 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The protein yield of intercrop rice was reduced probably due to intercrop competition.

Effect of nutrient management

Significant variations in respect protein yield were observed during both the years of investigation. Values of 249.14, 251.27 and 250.21 kg ha^{-1} during 2019, 2020 and in pooled data, respectively were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and were statistically superior to rest of the treatments. The lowest was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation with the values of 193.32 kg ha^{-1} during 2019, 195.02 kg ha^{-1} during 2020 and 194.17 kg ha^{-1} in pooled data.

Highest protein yield (7.72 q ha^{-1}) of the rice-rice system was obtained when 50% N was substituted through FYM (Raju and Reddy, 2000).

Interaction Effect

The interaction effects between cropping system and nutrient management practices on protein yield was significantly affected only in the year 2019. Data shows that highest protein yield of 258.19 kg ha^{-1} was recorded in C_1N_2 (Sole rice + 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination, which was statistically at par with (C_5N_2) rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed with value of 249.28 kg ha^{-1} and (C_4N_2) rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed with value of 239.96 kg ha^{-1}. Pooled data revealed that significantly highest protein yield was observed in C_1N_2 (259.15 kg ha^{-1}), which was at par with C_5N_2 (250.63 kg ha^{-1}) treatment combination.

4.2 Groundnut

4.2.1 Growth parameters

4.2.1.1 Plant height (cm)

The data on plant height of groundnut was recorded at 30 days interval till up to 90 days in both the years during the *kharif* of 2019 and 2020. The mean data and pooled for both the years are presented in Table 4.19.

Effect of cropping system

There was statistical difference between plant height values of two different cropping systems during both the years of experimentation. During 2019, sole groundnut (C_2) registered significantly higher plant height values of 13.10, 21.62 and 31.15 cm at 30, 60 and 90 DAS, respectively. The corresponding values under rice intercropped with groundnut (C_4) were 10.91, 19.76 and 27.82 cm at 30, 60 and 90 DAS, respectively. During 2020, similar trend followed significantly highest plant height recorded in sole groundnut (14.25, 22.40 and 32.04 cm at 30, 60 and 90 DAS, respectively) and the lowest (11.48, 20.05 and 29.19 cm at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with groundnut. Pooled data also revealed that there was a significant effect on plant height due to cropping systems. Significantly highest plant height (13.68, 22.01 and 31.59 cm at 30, 60 and 90 DAS, respectively) was recorded in sole groundnut and the lowest (11.20, 19.90 and 28.51 cm at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with groundnut. There was significant variation in plant height among the treatments in all the successive growth stages. Sole groundnut recorded the tallest plant height in all the growth stages as compared to rice intercropped with groundnut. This might be due to the reason of absence of intercrop competition in sole groundnut.

Effect of nutrient management

The effect of different nutrient management practices on plant height was found to be significant at all the growth stages. During 2019, significantly the highest plant height of 15.07, 24.23 and 32.87 cm at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest plant height of 9.67, 17.89 and 26.32 cm at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. Similarly during 2020, plant height showed significant variation among the various treatments with the highest observed in sole groundnut with 16.28, 25.24 and 34.64 cm at 30, 60 and 90 DAS, respectively, while 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the lowest data on plant height at almost all the growth stages. The pooled data of both the years also revealed a significant difference with the highest plant height of 15.67, 24.74 and 33.76 cm at 30, 60 and 90 DAS, respectively, when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} +

Table 4.19: Effect of cropping systems and nutrient management practices on plant height (cm) at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	13.10	14.25	13.68	21.62	22.40	22.01	31.15	32.04	31.59
C_4 - Rice + groundnut (3:1)	10.91	11.48	11.20	19.76	20.05	19.90	27.82	29.19	28.51
SEm±	0.54	0.36	0.33	0.53	0.62	0.41	0.76	0.84	0.57
CD (P=0.05)	1.71	1.13	0.96	1.67	1.97	1.21	2.39	2.66	1.67
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	11.29	12.18	11.73	19.94	20.26	20.10	29.27	30.17	29.72
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	15.07	16.28	15.67	24.23	25.24	24.74	32.87	34.64	33.76
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	9.67	10.15	9.91	17.89	18.18	18.03	26.32	27.03	26.67
SEm±	0.66	0.44	0.40	0.65	0.76	0.50	0.93	1.03	0.69
CD (P=0.05)	2.09	1.39	1.17	2.04	2.41	1.48	2.93	3.25	2.05
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

biofertilizer consortium @ 20 g kg^{-1} seed. The lowest plant height were recorded of 9.91, 18.03 and 26.67 cm at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. This might be due to the fact that beneficial effect of FYM in conjunction with recommended dose of fertilizers and biofertilizers may be due to the effect of organic matter in improving physical, chemical and biological environment of soil conductive to better plant growth. Vala *et al*. (2017) reported that application of 75% RDF + 25% N through FYM + Biofertilizer recorded significantly taller plants at harvest, higher plant spread, higher number of root nodules per plant.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.2.1.2 Number of branches plant^{-1}

The results recorded on the effect of cropping system and nutrient management on the number of branches plant^{-1} recorded at 30, 60 and 90 DAS are presented in Table 4.20.

Effect of cropping system

Significant response was observed during both the years of experimentations due to effect of cropping system on number of branches plant^{-1} where sole groundnut exhibited a significant response and achieved highest number of branches plant^{-1} of 4.13, 7.78 and 9.69 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 4.27, 7.93 and 9.89 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. Significantly lowest was recorded at rice intercropped with groundnut with the values of 3.42, 6.58 and 8.67 plant^{-1} at 30, 60 and 90DAS, respectively during 2019 and 3.58, 6.67 and 8.84 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. The maximum pooled value of number of branches plant^{-1} recorded at 30 DAS, 60 DAS and 90 DAS were 4.20, 7.86 and

Table 4.20: Effect of cropping systems and nutrient management practices on number of branches plant^{-1} at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	4.13	4.27	4.20	7.78	7.93	7.86	9.69	9.89	9.79
C_4 - Rice + groundnut (3:1)	3.42	3.58	3.50	6.58	6.67	6.62	8.67	8.84	8.76
SEm±	0.17	0.18	0.12	0.30	0.29	0.21	0.25	0.19	0.16
CD (P=0.05)	0.54	0.57	0.37	0.95	0.93	0.62	0.80	0.60	0.47
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.73	3.83	3.78	6.93	7.07	7.00	9.00	9.17	9.08
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.57	4.70	4.63	8.13	8.27	8.20	10.10	10.30	10.20
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.03	3.23	3.13	6.47	6.57	6.52	8.43	8.63	8.53
SEm±	0.21	0.22	0.15	0.37	0.36	0.26	0.31	0.23	0.19
CD (P=0.05)	0.66	0.70	0.45	1.16	1.14	0.76	0.97	0.73	0.57
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

9.79 plant^{-1}, respectively and the lowest (3.50, 6.62 and 8.76 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded at rice intercropped with groundnut. This finding may be attributed to the lower plant population in the sole crop which significantly avoids the competition for space, moisture and nutrients.

Effect of nutrient management

The result presented in the table revealed that application of different nutrient management practices had a significant influence on number of branches plant^{-1} during both the years of experiment. During both the years, result revealed that 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed alone recorded the significantly highest number of branches plant^{-1} of 4.57, 8.13 and 10.10 plant^{-1} at 30, 60 and 90 DAS respectively during 2019 and 4.70, 8.27 and 10.30 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. Application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the minimum number of branches plant^{-1} of 3.03, 6.47 and 8.43 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 3.23, 6.57 and 8.63 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. Similar effect was also reflected in pooled data. The favourable effect of FYM on growth might be attributed to relatively readily available plant nutrients, growth enhancing substances and number of beneficial organisms like nitrogen fixing, phosphate solubilizing, cellulose decomposing and other beneficial microbes as well as antibiotics, vitamins and hormones *etc*. Thus, favourable influence of nutrients to produce larger cells with thinner cell wall and its contribution in cell division and cell elongation which improved vegetative growth and ultimately increased number of branches plant^{-1}. The findings are close proximity with the findings of Vala *et al.* (2017), Patil *et al*. (2014), Rahevar *et al*. (2015) and Sengupta *et al*. (2016).

Interaction Effect

The number of branches plant^{-1} of groundnut was not persuaded significantly by interaction effect of cropping system and nutrient management.

4.2.1.3 Dry matter (g) plant^{-1}

Data pertaining to dry matter (g) plant^{-1} due to cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.21.

Effect of cropping system

A critical examination of data presented in table revealed that there was significant variation among the treatments in both the years. During 2019, it was evident from the data that the maximum dry matter (g) plant^{-1} (1.42, 12.11 and 21.60 g at 30, 60 and 90 DAS, respectively) was obtained in sole groundnut. Significantly lowest was recorded in rice intercropped with groundnut (1.20, 8.37 and 17.13 g at 30, 60 and 90 DAS, respectively). In 2020, the highest dry matter (g) plant^{-1} received in sole groundnut (1.46, 13.06 and 23.31 g at 30, 60 and 90 DAS, respectively). The minimum dry matter (g) plant^{-1} was recorded at C_4 (Rice + groundnut with 3:1 row ratio) with values of 1.24, 9.99 and 18.80 g at 30, 60 and 90 DAS, respectively. Pooled data from both the years it was evident that highest dry matter (g) plant^{-1} was recorded in sole groundnut (1.44, 12.58 and 22.46 g at 30, 60 and 90 DAS, respectively). The lowest value was recorded in rice intercropped with groundnut (1.22, 9.18 and 17.96 g at 30, 60 and 90 DAS, respectively). Ramana *et al*. (1991) reported that the sole groundnut field showed higher dry matter accumulation at all sampling stages consistently than intercropping treatments.

Effect of nutrient management

The effect of different treatments on dry matter (g) plant^{-1} was significant. In 2019, the significantly superior dry matter (g) plant^{-1} (1.55, 12.70, 22.46 g at 30, 60 and 90 DAS, respectively) was achieved at 75% RDF along with FYM

Table 4.21: Effect of cropping systems and nutrient management practices on dry matter (g) plant^{-1} at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	1.42	1.46	1.44	12.11	13.06	12.58	21.60	23.31	22.46
C_4 - Rice + groundnut (3:1)	1.20	1.24	1.22	8.37	9.99	9.18	17.13	18.80	17.96
SEm±	0.05	0.05	0.04	0.41	0.46	0.31	0.62	0.55	0.41
CD (P=0.05)	0.17	0.15	0.11	1.31	1.46	0.92	1.94	1.74	1.22
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.25	1.28	1.26	9.94	11.18	10.56	19.05	20.87	19.96
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.55	1.59	1.57	12.70	14.15	13.42	22.46	24.51	23.48
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.14	1.18	1.16	8.08	9.25	8.66	16.58	17.78	17.18
SEm±	0.07	0.06	0.04	0.51	0.57	0.38	0.75	0.68	0.51
CD (P=0.05)	0.21	0.18	0.13	1.60	1.79	1.12	2.38	2.14	1.50
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

@ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed and lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 1.14, 8.08 and 16.58 g at 30, 60 and 90 DAS, respectively. During the second year also recorded similar result with the maximum dry matter (g) $plant^{-1}$ of 1.59, 14.15, 24.51 g at 30, 60 and 90 DAS, respectively with treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 1.18, 9.25, 17.78 g at 30, 60 and 90 DAS, respectively. Pooled data of both the years followed the similar findings with the highest dry matter (g) $plant^{-1}$ observed with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed 1.57, 13.42 and 23.48 g at 30, 60 and 90 DAS respectively, while the lowest dry matter (g) $plant^{-1}$ was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 1.16, 8.66 and 17.18 g at 30, 60 and 90 DAS, respectively. Chaithanya *et al*. (2003) observed significant and continuous increase in total dry matter production from 30 DAS to 90 DAS and at harvest due to the application of balanced quality of inorganic fertilizer and organic manure.

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.2.1.4 Number of root nodules $plant^{-1}$

The data on number of root nodules $plant^{-1}$ of groundnut was recorded at 30 days interval till up to 90 days in both the years during the *kharif* of 2019 and 2020. The mean data and pooled for both the years are presented in Table 4.22.

Table 4.22: Effect of cropping systems and nutrient management practices on number of root nodules plant^{-1} at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	24.95	27.44	26.19	46.70	49.19	47.95	53.46	55.57	54.52
C_4 - Rice + groundnut (3:1)	20.77	22.84	21.81	40.34	42.89	41.61	47.24	49.89	48.56
SEm±	0.74	0.59	0.47	0.92	0.99	0.68	1.52	1.02	0.92
CD (P=0.05)	2.33	1.85	1.39	2.91	3.11	2.00	4.79	3.21	2.70
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	21.09	24.18	22.63	42.39	44.44	43.41	49.27	51.27	50.27
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	27.91	29.45	28.68	49.10	51.36	50.23	57.10	60.25	58.68
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	19.58	21.78	20.68	39.08	42.32	40.70	44.68	46.68	45.68
SEm±	0.90	0.72	0.58	1.13	1.21	0.83	1.86	1.25	1.12
CD (P=0.05)	2.85	2.26	1.70	3.57	3.81	2.44	5.87	3.93	3.31
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect of cropping system

An inquisition of the data on number of root nodules plant^{-1} revealed that there was significant variation among the treatments in both the years. During 2019, sole groundnut (C_2) registered significantly maximum value on number of root nodules plant^{-1} of 24.95, 46.70 and 53.46 plant^{-1} at 30, 60 and 90 DAS, respectively. The corresponding values under rice intercropped with groundnut (C_4) were 20.77, 40.34 and 47.24 plant^{-1} at 30, 60 and 90 DAS, respectively. During 2020, similar trend followed significantly highest number of root nodules plant^{-1} recorded in sole groundnut (27.44, 49.19 and 55.57 plant^{-1} at 30, 60 and 90 DAS, respectively) and the lowest (22.84, 42.89 and 49.89 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with groundnut. Pooled data also revealed that there is a significant effect on number of root nodules plant^{-1} due to cropping systems. Significantly highest number of root nodules plant^{-1} (26.19, 47.95 and 54.52 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded in sole groundnut and the lowest (21.81, 41.61 and 48.56 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with groundnut. Reduced light due to shading by tall-growing cereals may be the cause of poor nodulation in intercropping groundnut. This reduced light energy affects N_2 fixation by restricting photosynthesis and the energy supply to roots, thereby reducing nodulation and nodule size. Similar finding was also observed by Nambiar *et al*. (1983).

Effect of nutrient management

Significant variations in respect to number of root nodules plant^{-1} was observed during both the years of investigation. Values of 27.91, 49.10 and 57.10 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 29.45, 49.10 and 60.25 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020 were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and were statistically superior to rest of the treatments. The lowest was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation with the values being 19.58, 39.08 and 44.68 $plant^{-1}$ at 30, 60 and 90 DAS, respectively during 2019 and 21.78, 42.32 and 46.68 at 30, 60 and 90 DAS, respectively during 2020. The pooled data of both the years also revealed a significant difference with the highest number of root nodules $plant^{-1}$ of 28.68, 50.23 and 58.68 $plant^{-1}$ at 30, 60 and 90 DAS, respectively, when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest value were recorded of 20.68, 40.70 and 45.68 $plant^{-1}$ at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. Vala *et al.* (2017) reported that application of 75% RDF + 25% N through FYM + Biofertilizer recorded significantly taller plants at harvest, higher plant spread, higher number of root nodules per plant. Similar results were observed by Karunakaran *et al*. (2010), Singh *et al*. (2011) and Vishwakarma *et al*. (2012).

Interaction Effect

Interaction effect between cropping system and various nutrient management practices found to be non-significant during both the years of experimentation.

4.2.1.5 Fresh weight of nodules $plant^{-1}$ (g)

The results recorded on the effect of cropping system and nutrient management on the nodules fresh weight $plant^{-1}$ (g) recorded at 30, 60 and 90 DAS are presented in Table 4.23.

Effect of cropping system

It was explicit from the data presented in table 4.23 that significant response was observed during both the years of experimentations due to effect of cropping system on fresh weight of nodules $plant^{-1}$ where sole groundnut produced significantly highest fresh weight of nodules $plant^{-1}$ of 0.459, 1.223

Table 4.23: Effect of cropping systems and nutrient management practices on fresh weight of nodules plant^{-1} (g) at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	0.459	0.469	0.464	1.223	1.247	1.235	1.358	1.361	1.359
C_4 - Rice + groundnut (3:1)	0.390	0.399	0.394	1.072	1.097	1.084	1.198	1.203	1.201
SEm±	0.012	0.014	0.009	0.045	0.027	0.026	0.046	0.028	0.027
CD (P=0.05)	0.039	0.045	0.028	0.140	0.086	0.077	0.146	0.088	0.080
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.433	0.438	0.436	1.113	1.113	1.113	1.232	1.235	1.233
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.500	0.508	0.504	1.292	1.307	1.299	1.415	1.422	1.418
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.340	0.355	0.348	1.038	1.095	1.067	1.187	1.190	1.188
SEm±	0.015	0.018	0.012	0.055	0.033	0.032	0.057	0.034	0.033
CD (P=0.05)	0.048	0.055	0.034	0.172	0.105	0.094	0.179	0.108	0.098
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

and 1.358 g at 30, 60 and 90 DAS, respectively during 2019 and 0.469, 1.247 and 1.361 at 30, 60 and 90 DAS, respectively during 2020. Significantly lowest was recorded at rice intercropped with groundnut with the values of 0.390, 1.072 and 1.198 g at 30, 60 and 90 DAS, respectively during 2019 and 0.399, 1.097 and 1.203 g at 30, 60 and 90 DAS, respectively during 2020. The maximum pooled value of fresh weight of nodules plant^{-1} recorded at 30, 60 and 90 DAS were 0.464, 1.235 and 1.359 g, respectively in C_2 (Sole groundnut) and significantly lowest was recorded in rice intercropped with groundnut with the values of 0.394, 1.084 and 1.201g at 30, 60 and 90 DAS, respectively. The present results were supported by the findings of Ghosh (2004) who observed that nodule number and nodule mass at pod filling stage were much lower in groundnut when cereals were used as intercrops as compared to sole groundnut.

Effect of nutrient management

The influence of nutrient management showed significant impact on fresh weight of nodules plant^{-1} (g). Out of all the nutrient management practices adoption of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed registered the significantly highest fresh weight of nodules plant^{-1} of 0.500, 1.292 and 1.415 g at 30, 60 and 90 DAS, respectively during 2019 and 0.508, 1.307 and 1.422 g at 30, 60 and 90 DAS, respectively during 2020. Application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the minimum fresh weight of nodules plant^{-1} (g), which recorded 0.340, 1.038 and 1.187 g at 30, 60 and 90 DAS respectively during 2019 and 0.355, 1.095 and 1.190 g at 30, 60 and 90 DAS respectively during 2020. Similar trend was also showed in pooled data. Thakare *et al*. (2003) in a field trial observed that increased in plant height, number of nodules, fresh weight of nodule, dry weight of shoot plant^{-1}, dry weight of root plant^{-1}, number of developed pods, number of undeveloped pods at harvest, weight of undeveloped pods and number of gynophores at harvest of groundnut when applied with 50% RDF + 5t FYM ha^{-1} + PSB + *Rhizobium*.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.2.1.6 Dry weight of nodules plant^{-1} (g)

Data pertaining to dry weight of nodules plant^{-1} (g) due to cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.24.

Effect of cropping system

Data pertaining to influence of dry weight of nodules plant^{-1} result that there was significant variation among the treatments in both the years. During 2019, it was evident from the data that the maximum dry weight (g) of nodules plant^{-1} (0.051, 0.069 and 0.080 g at 30, 60 and 90 DAS, respectively) was obtained in sole groundnut. Significantly lowest was recorded in rice intercropped with groundnut (0.044, 0.065 and 0.072 g at 30, 60 and 90 DAS, respectively). In 2020, the highest dry weight (g) of nodules plant^{-1} received in sole groundnut (0.053, 0.072 and 0.084 g at 30, 60 and 90 DAS, respectively). The minimum was recorded at C_4 (Rice + groundnut with 3:1 row ratio) with values of 0.046, 0.067 and 0.074 g at 30, 60 and 90 DAS, respectively). A further analysis of the pooled It might be due to less competition in sole crop for natural resources *i.e.* nutrient, light and space for crop growth.

Effect of nutrient management

There was marked influence of different nutrient management practices on dry weight of nodules plant^{-1}. Observation on the data showed that values of 0.057, 0.073 and 0.082 g at 30, 60 and 90 DAS, respectively during 2019 and 0.058, 0.075 and 0.086 g at 30, 60 and 90 DAS, respectively during 2020 were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and were statistically superior to rest of the

Table 4.24: Effect of cropping systems and nutrient management practices on dry weight of nodules plant^{-1} (g) at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	0.051	0.053	0.052	0.069	0.072	0.071	0.080	0.084	0.082
C_4 - Rice + groundnut (3:1)	0.044	0.046	0.045	0.065	0.067	0.066	0.072	0.074	0.073
SEm±	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001
CD (P=0.05)	0.004	0.005	0.003	0.004	0.004	0.003	0.005	0.006	0.003
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.047	0.048	0.048	0.067	0.070	0.068	0.075	0.078	0.076
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.057	0.058	0.057	0.073	0.075	0.074	0.082	0.086	0.084
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.038	0.042	0.040	0.062	0.065	0.063	0.071	0.072	0.071
SEm±	0.002	0.002	0.001	0.002	0.001	0.001	0.002	0.002	0.001
CD (P=0.05)	0.005	0.006	0.004	0.005	0.005	0.003	0.006	0.007	0.004
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

treatments. The lowest was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation. The pooled data of both the years also revealed a significant difference with the highest dry weight of nodules $plant^{-1}$ of 0.057, 0.074 and 0.084 g at 30, 60 and 90 DAS, respectively, when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest value was recorded of 0.040, 0.063 and 0.071 g at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The findings can be corroborated with the findings of Rahevar *et al*. (2015) and Sengupta *et al*. (2016).

Interaction Effect

The number of nodule dry weight of nodules $plant^{-1}$ (g) of groundnut was not persuaded significantly by interaction effect of cropping system and nutrient management.

4.2.1.7 Leaf area index

The data on leaf area index of groundnut due to different cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.25.

Effect of cropping system

Regarding the effect of cropping system, the results revealed that different cropping system significantly influence on leaf area index. During 2019, sole groundnut (C_2) registered significantly maximum value on leaf area index of 0.59, 2.31 and 2.60 at 30, 60 and 90 DAS, respectively. The corresponding values under rice intercropped with groundnut (C_4) were 0.46, 2.07 and 2.39 at 30, 60 and 90 DAS, respectively. During 2020, similar trend followed significantly highest leaf area index recorded in sole groundnut (0.59, 2.34 and 2.67 at 30, 60 and 90 DAS, respectively) and the lowest (0.48, 2.13 and 2.39 at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with

Table 4.25: Effect of cropping systems and nutrient management practices on leaf area index at different growth stages of groundnut

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	0.59	0.59	0.59	2.31	2.34	2.33	2.60	2.67	2.64
C_4 - Rice + groundnut (3:1)	0.46	0.48	0.47	2.07	2.13	2.10	2.39	2.39	2.39
SEm±	0.02	0.02	0.01	0.04	0.05	0.03	0.04	0.04	0.03
CD (P=0.05)	0.07	0.06	0.04	0.12	0.16	0.10	0.14	0.14	0.09
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.51	0.53	0.52	2.19	2.24	2.21	2.52	2.55	2.54
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.61	0.61	0.61	2.41	2.45	2.43	2.68	2.71	2.69
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.46	0.47	0.46	1.97	2.01	1.99	2.30	2.33	2.31
SEm±	0.03	0.02	0.02	0.05	0.06	0.04	0.05	0.05	0.04
CD (P=0.05)	0.08	0.08	0.05	0.15	0.20	0.12	0.17	0.17	0.11
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

groundnut. Result obtained from the pooled data of 2019 and 2020 also revealed that there was a significant effect on leaf area index due to cropping systems. Significantly highest leaf area index (0.59, 2.33 and 2.64 at 30, 60 and 90 DAS, respectively) was recorded in sole groundnut and the lowest (0.47, 2.10 and 2.39 at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with groundnut. According to the results reported by Ghosh (2004) found that a significant reduction in LAI was observed in groundnut+ pearl millet system over sole groundnut. Furthermore, Sutaria and Mehta (2000) also recorded higher LAI under sole groundnut than pearl millet +groundnut in 2:1 row ratio, while the pearl millet benefitted under intercropping system.

Effect of nutrient management

The effect of different treatments on leaf area index was significant. In 2019, the significantly superior leaf area index (0.61, 2.41 and 2.68 at 30, 60 and 90 DAS, respectively) was achieved at incorporation of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed and the lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with value of 0.46, 1.97 and 2.30 at 30, 60 and 90 DAS, respectively. During the second year also recorded similar result with the maximum leaf area index of 0.61, 2.45, 2.71 at 30, 60 and 90 DAS, respectively with treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and the lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 0.47, 2.01, 2.33 at 30, 60 and 90 DAS, respectively. Pooled data of both the years followed the similar findings with the highest leaf area index was observed with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed 0.61, 2.43 and 2.69 at 30, 60 and 90 DAS respectively, while the lowest dry matter (g) $plant^{-1}$ was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with 0.46, 1.99 and 2.31 at 30, 60 and 90 DAS, respectively. This might be due to the fact that increase in leaf area index could be attributed due to increase in cell division and leaf expansion. While more number of leaves were recorded due to beneficial influence of biofertilizers which release growth promoting substances along with enhancement of nitrogen availability. The application of chemical fertilizer in combination with organic fertilizer increased the fertilizer use efficiency of added chemical fertilizers, which helped in increasing nutrient availability and improved the physical and biological health of soil. Apart from that the organic manure also contains almost all the essential elements in variable quantities, which has synergistic effect with other essential elements for their availability. This effect might be reflected in increased plant height, spread, number of branches and leaf area in groundnut. This result was in conformity with Rayer, 1984.

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.2.1.8 Crop growth rate (g m^{-2} day^{-1})

The effects of cropping system and nutrient management on crop growth rate (g m^{-2} day^{-1}) of groundnut recorded at 30-60 and 60-90 DAS are presented in Table 4.26.

Effect of cropping system

Close scrutiny of the data recorded that there is a significant difference among cropping systems. Significantly superior crop growth rate was recorded at sole groundnut with the values of 5.94 g m^{-2} day^{-1} in 2019, 6.45 g m^{-2} day^{-1} in 2020 and 6.19 g m^{-2} day^{-1} in pooled data at 30-60 DAS. Significantly lowest (3.98, 4.86 and 4.42 g m^{-2} day^{-1} in 2019, 2020 and in pooled data, respectively) was recorded when rice intercropped with groundnut at 30-60 DAS. At 60-90 DAS there was no significant difference recorded in the response of crop growth

Table 4.26: Effect of cropping systems and nutrient management practices on crop growth rate (g m^{-2} day^{-1}) at different growth stages of groundnut

Treatments	30- 60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	5.94	6.45	6.19	5.27	5.70	5.48
C_4 - Rice + groundnut (3:1)	3.98	4.86	4.42	4.86	4.89	4.88
SEm±	0.24	0.27	0.18	0.39	0.46	0.30
CD (P=0.05)	0.77	0.84	0.53	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.83	5.50	5.17	5.06	5.38	5.22
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.20	6.98	6.59	5.42	5.76	5.59
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	3.86	4.48	4.17	4.72	4.74	4.73
SEm±	0.30	0.33	0.22	0.48	0.56	0.37
CD (P=0.05)	0.94	1.03	0.65	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

rate among cropping systems during both the years. Ghosh (2004) reported that there was 40.40% reduction in CGR in intercropped groundnut in association with pearl millet compared to sole groundnut. Nambiar *et al*. (1983) demonstrated that intercrops like pearl millet, maize and sorghum limited the light reaching the groundnut canopy by at least 33% thereby reducing photosynthesis. This restricted photosynthesis was further shown by lower CGR.

Effect of nutrient management

A reference to the data presented in Table 4.26 revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly highest crop growth rate of 6.20, 6.98 and 6.59 g m^{-2} day^{-1} during 2019, 2020 and in pooled data respectively at 30-60 DAS, while the lowest (3.86, 4.48 and 4.17 g m^{-2} day^{-1} during 2019, 2020 and in pooled data, respectively) was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) at 30-60 DAS. At 60-90 DAS there was no significant difference recorded in the response of crop growth rate to different nutrient management practices during both the years. Similar results was obtained by Patil *et al*. (2014).

Interaction Effect

Interaction effect between cropping system and various nutrient management practices found to be non-significant during both the years of experimentation.

4.2.1.9 Relative growth rate (g g^{-1} day^{-1})

The result presented in Table 4.27 showed the effects of cropping system and nutrient management practices on relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS and 60-90 DAS.

Table 4.27: Effect of cropping systems and nutrient management practices on relative growth rate (g g^{-1} day^{-1}) at different growth stages of groundnut

Treatments	30-60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	0.071	0.073	0.072	0.020	0.020	0.020
C_4 - Rice + groundnut (3:1)	0.064	0.062	0.063	0.024	0.021	0.023
SEm±	0.002	0.006	0.003	0.002	0.002	0.001
CD (P=0.05)	0.007	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.069	0.072	0.071	0.022	0.021	0.021
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.069	0.062	0.065	0.020	0.019	0.019
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	0.065	0.069	0.067	0.024	0.022	0.023
SEm±	0.003	0.007	0.004	0.002	0.002	0.002
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Effect of cropping system

The perusal of the data pertaining to relative growth rate in Table 4.27 indicated that there was a significant difference among cropping systems only during 2019. Significantly highest (0.071 g g^{-1} day^{-1}) relative growth rate was reported in sole groundnut and lowest (0.064 g g^{-1} day^{-1}) was recorded in rice intercropped with groundnut at 30-60 DAS. There was no significant difference due to cropping system in 2020 at 30-60 DAS and at 60-90 DAS during both the years. Higher relative growth rate of groundnut was observed in monoculture compared to intercropping systems might be due to no intercrop competition for light, nutrients, moisture and space.

Effect of nutrient management

There was no significant difference due to nutrient management at various growth stages during both the years of experiment.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.2.1.10 Net assimilation rate (g m^{-2} day^{-1})

The data pertaining to net assimilation rate (g m^{-2} day^{-1}) of groundnut as influenced by cropping system and nutrient management at 30-60 DAS and 60-90 DAS are presented in Table 4.28.

Effect of cropping system

There was statistical difference between values of net assimilation rate among cropping systems only during 2019. Sole groundnut (C_2) registered significantly higher net assimilation rate of 4.68 g m^{-2} day^{-1} in 2019 and pooled data recorded 4.87 g m^{-2} day^{-1} at 30-60 DAS. The corresponding values under rice intercropped with groundnut (C_4) were 3.71 in 2019 and 4.04 g m^{-2} day^{-1} in pooled data at 30-60 DAS. Data on net assimilation rate signifies that there was

Table 4.28: Effect of cropping systems and nutrient management practices on net assimilation rate (g m^{-2} day^{-1}) at different growth stages of groundnut

Treatments	30-60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	4.68	5.05	4.87	2.14	2.28	2.21
C_4 - Rice + groundnut (3:1)	3.71	4.37	4.04	2.18	2.21	2.20
SEm±	0.25	0.22	0.17	0.17	0.23	0.14
CD (P=0.05)	0.80	NS	0.50	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.20	4.64	4.42	2.14	2.24	2.19
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.66	5.25	4.96	2.14	2.21	2.17
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	3.72	4.24	3.98	2.21	2.29	2.25
SEm±	0.31	0.27	0.21	0.21	0.28	0.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

no significant difference due to cropping system in 2020 at 30-60 DAS and at 60-90 DAS during both the years. The NAR of intercropped groundnut with cereal was less. This may be attributed to the less efficient conversion of light energy into dry matter in intercropped groundnut. Similar results were observed by Reddy and Willey (1979).

Effect of nutrient management

The data on net assimilation rate clearly indicated that there was no significant variation at 30-60 DAS and 60-90 DAS among the different nutrient management practices during both the years.

Interaction Effect

Interaction effect between cropping system and various nutrient management practices found to be non-significant during both the years of experimentation.

4.2.2 Phenological parameters

4.2.2.1 Days to 50% flowering, Days to 50% maturity, Days to harvesting

The data on days to 50% flowering, 50% maturity and days to harvesting were recorded in both the cropping period of the years and which are presented in table 4.29.

Effect of cropping system

The critical analysis of the data clearly revealed that there was no significant variation in the different cropping system on 50% flowering, 50% maturity and days to harvesting.

Effect of nutrient management

There was no significant difference due to nutrient management on 50% flowering, 50% maturity and days to harvesting during both the years of experiment.

Table 4.29: Effect of cropping systems and nutrient management practices on phenological parameters of groundnut

Treatments	Days to 50% flowering			Days to 50% maturity			Days to harvesting		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	31.29	31.31	31.30	106.07	105.67	105.87	120.42	119.87	120.14
C_4 - Rice + groundnut (3:1)	30.73	30.69	30.71	105.53	105.69	105.61	120.18	120.13	120.16
SEm±	0.22	0.23	0.16	0.23	0.49	0.27	0.18	0.20	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	31.03	31.07	31.05	105.67	105.40	105.53	120.40	120.07	120.23
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	31.03	31.07	31.05	105.50	105.77	105.63	120.27	120.03	120.15
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	30.97	30.87	30.92	106.23	105.87	106.05	120.23	119.90	120.07
SEm±	0.27	0.28	0.19	0.28	0.61	0.33	0.22	0.24	0.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Interaction effect

Interaction effect of cropping system and nutrient management did not show any significant difference in both the years.

4.2.3 Yield attributes

4.2.3.1 Number of pods plant^{-1}

Data on number of pods plant^{-1} as influenced by cropping system and nutrient management practices are presented in Table 4.30.

Effect of cropping system

The variation on number of pods plant^{-1} due to cropping system was found to be significant during both years of experiment. During 2019 and 2020, the highest number of pods plant^{-1} (14.26 plant^{-1} and 16.34 plant^{-1}) was recorded in the treatment sole groundnut. The lowest (11.46 and 11.80 plant^{-1} during 2019 and 2020 respectively) number of pods plant^{-1} was recorded in C_4 (Rice + groundnut at 3:1 row ratio). Pooled result thus obtained compiled with the findings of both the years. The highest number of pods plant^{-1} (15.30 plant^{-1}) was recorded in C_2 (Sole groundnut) and lowest (11.63 plant^{-1}) was recorded at rice intercropped with groundnut. Dutta and Mondal (2000) observed that sole groundnut resulted significantly higher in yield attributes *viz*., pods plant^{-1}, seeds pod^{-1} and shelling per cent of groundnut over groundnut + maize or pigeonpea. Chandrika *et al*. (2001) reported that groundnut intercropping with pigeonpea or redgram in 7: 1 ratio significantly reduced the groundnut pod yields.

Effect of nutrient management

The variation on number of pods plant^{-1} due to different nutrient management practices found to be significant during both the years of experiment. During 2019 and 2020, the highest number of pods plant^{-1} (16.41 plant^{-1} and 17.97 plant^{-1}) was recorded in the treatment N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed), while the lowest

Table 4.30: Effect of cropping systems and nutrient management practices on yield attributes of groundnut

Treatments	Number of pods plant^{-1}			Number of seeds pod^{-1}		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	14.26	16.34	15.30	1.44	1.62	1.53
C_4 - Rice + groundnut (3:1)	11.46	11.80	11.63	1.36	1.44	1.40
SEm±	0.85	1.02	0.66	0.12	0.10	0.08
CD (P=0.05)	2.67	3.21	1.96	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	12.23	13.07	12.65	1.33	1.47	1.40
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	16.41	17.97	17.19	1.60	1.70	1.65
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	9.93	11.17	10.55	1.27	1.43	1.35
SEm±	1.04	1.25	0.81	0.15	0.12	0.09
CD (P=0.05)	3.27	3.94	2.40	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

(9.93 plant^{-1} and 11.17 plant^{-1}) was recorded in application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. Pooled result thus obtained recorded the highest number of pods plant^{-1} (17.19 plant^{-1}) with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. The lowest (10.55 plant^{-1}) was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Increased values in yield attributes of sole groundnut might have been on account of the overall improvement in vegetative growth and nodulation, which favourably influenced the flowering and fruiting and ultimately resulted into increased number of matured pods and pod weight per plant. These findings agreement with the results obtained by Chaudhary *et al*. (2015), Madhu Bala and Kedar Nath (2015) and Rahevar *et al*. 2015. Vala *et al*. 2017 reported that groundnut yield attributes such as number of mature pods plant^{-1} at harvest and pod weight plant^{-1} were improved by integrated nutrient management treatments of 75% RDF + 25% N through FYM + Biofertilizer.

Interaction effect

The interaction effects between cropping system and nutrient management practices on number of pods plant^{-1} recorded non-significant variation during both the years of experimentation.

4.2.3.2 Number of seeds pod^{-1}

The effects of cropping system and nutrient management practices on number of seeds pod^{-1} are presented in Table 4.30.

Effect of cropping system

The effect of cropping systems did not bring any significant difference in number of seeds pod^{-1} of groundnut.

Effect of nutrient management

Application of different nutrient management practices did not show any significant effect on number of seeds pod^{-1} of groundnut.

Interaction effect

The combined effect of different cropping system and nutrient management also could not bring any statistical difference on number of seeds pod^{-1} of groundnut.

4.2.3.3 Pod weight (g) plant^{-1}

Data pertaining to variation in pod weight (g) plant^{-1} due to different cropping system and nutrient management practices are presented in Table 4.31.

Effect of cropping system

Sole crop of groundnut recorded higher pod weight (g) plant^{-1} (9.86 and 10.22 g in 2019 and 2020 respectively). Significantly lowest (7.89 and 8.43 g in 2019 and 2020, respectively) pod weight (g) registered in rice+ groundnut intercropping system during both the years. Further analysis of the pooled data revealed that highest number of pod weight (g) plant^{-1} was recorded in sole groundnut with value of 10.04 g. The minimum (8.16 g) was recorded from rice intercropped with groundnut. Jat and Ahlawat (2004) noticed higher pod yield of sole groundnut which was attributed to higher pods plant^{-1} and pod weight (g) plant^{-1} compared to intercropping of groundnut+ pigeon pea system.

Effect of nutrient management

The data indicated that the effect of different treatments on pod weight (g) plant^{-1} was found to be significant. Application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed resulted in highest pod weight (g) plant^{-1} of 10.16 and 10.92g during both the years, respectively. The lowest pod weight (g) plant^{-1} was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-}

Table 4.31: Effect of cropping systems and nutrient management practices on yield attributes of groundnut

Treatments	Pod weight (g) $plant^{-1}$			1000 seed weight (g)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	9.86	10.22	10.04	388.28	389.13	388.70
C_4 - Rice + groundnut (3:1)	7.89	8.43	8.16	383.73	385.08	384.41
SEm±	0.43	0.41	0.30	2.96	3.22	2.18
CD (P=0.05)	1.37	1.31	0.89	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	8.82	8.99	8.91	386.63	388.04	387.34
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	10.16	10.92	10.54	391.89	392.49	392.19
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizerconsortium @ 20 g kg^{-1} seed	7.64	8.07	7.85	379.50	380.78	380.14
SEm±	0.53	0.51	0.37	3.62	3.94	2.68
CD (P=0.05)	1.68	1.60	1.09	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

^{1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 7.64 and 8.07g in 2019 and 2020, respectively. On further scanning of the pooled data revealed that the highest pod weight (g) plant^{-1} (10.54 g) recorded in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. The significantly lowest (7.85 g) was recorded in application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The increased in pod weight in sole groundnut, this might be due to improvement in nutritional environment which might have favourably influenced carbohydrate metabolism which in turn increased the uptake of nutrients and ultimately resulted in increased pod weight. Similar findings were reported by Kaliyarasan *et al*., 2002.

Interaction effect

During both the years of study, interaction between cropping system and nutrient management practices was found non-significant.

4.2.3.4 1000 seed weight (g)

Data on test weight as influenced by cropping system and nutrient management practices are presented in Table 4.31.

Effect of cropping system

There was no significant difference due to cropping system on 1000 seed weight (g) during both the years of experiment.

Effect of nutrient management

There was no significant difference due to nutrient management on 1000 seed weight (g) during both the years of experiment.

Interaction effect

The interaction effects between cropping system and nutrient management practices on 1000 seed weight (g) recorded non-significant variation during both the years of experimentation.

4.2.4 Yield

4.2.4.1 Seed yield (t ha^{-1})

Data pertaining to seed yield due to cropping system and nutrient management are presented in Table 4.32 and Fig 4.4.

Effect of cropping system

Adaption of cropping systems practices markedly influenced the seed yield of groundnut in both the years. Among the cropping system sole groundnut produced highest yield (1.24 and 1.27 t ha^{-1} in 2019 and 2020 respectively). The lowest seed yield was observed from C_4 (Rice+ groundnut at 3:1 row ratio) with value being 0.58 and 0.59 t ha^{-1} in 2019 and 2020 respectively. Maximum value (1.26 t ha^{-1}) of pooled was registered in C_2 (Sole groundnut). The lowest value was recorded in rice intercropped with groundnut (0.59 t ha^{-1}). Crop intensification with intercropping reduced the yield of main crop due to more interspecific competition (Singh *et al*. 2008b) and disturbance of the habitat (Banik *et al*. 2000). This was also in conformity with the finding by Singh *et al*. 2015. This result corroborates with the findings of Razzaque *et al*. (2007) who reported that less groundnut yield was obtained from intercropping system than sole crop due to shading effect of chilli on groundnut.

Effect of nutrient management

The effect of nutrient management showed significant variation in yield. It was observed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly increased the yield during both the years as well as pooled data with value of 1.04 t ha^{-1} during the first year, 1.05 t ha^{-1} during the second year and 1.05 t ha^{-1} in pooled data, respectively. The minimum value was registered at application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed during both the years and as well as in pooled data with value being 0.81 t ha^{-1} during first year, 0.83 t ha^{-1} during second year and 0.82 t ha^{-1} in pooled data, respectively. Seed yield was increased may be attributed to the reason that integrated nutrient use (organic, inorganic and bio-fertilizers) played the very important role due to their synergistic effect and also improved the soil environment, which encouraged proliferous root system resulting in better absorption of water, nutrients from lower layers and better development of plant growth leading to higher photosynthetic activity and translocation of photosynthates to the sink which in turn resulted in better development of yield attributes and finally higher seed yield. Similar results were obtained by Vala *et al*. (2017).

Interaction effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on seed yield.

4.2.4.2 Stover yield (t ha^{-1})

Data related to stover yield (t ha^{-1}) due to cropping system and nutrient management are presented in Table 4.32 and Fig. 4.5.

Effect of cropping system

The perusal of data indicated that stover yield was significantly influenced by different cropping system. Treatment C_2 (Sole groundnut) recorded highest value over rest of the treatments during both the years and even in pooled data (3.33, 3.38 and 3.36 t ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest value recorded during 2019 was 1.65 t ha^{-1}, 1.69 t ha^{-1} was in 2020 and pooled data recorded 1.67 t ha^{-1}. Alom *et al*. (2010) stated that the higher stover yield was obtained from sole groundnut than under maize + groundnut intercropping system.

Effect of nutrient management

It was apparent from the data presented in Table 4.32 that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly enhanced stover yield during both the years and similarly in

Table 4.32: Effect of cropping systems and nutrient management practices on yield of groundnut

Treatments	Seed yield (t ha^{-1})			Stover yield (t ha^{-1})			Harvest index (%)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	1.24	1.27	1.26	3.33	3.38	3.36	27.11	27.33	27.22
C_4 - Rice + groundnut (3:1)	0.58	0.59	0.59	1.65	1.69	1.67	25.83	25.93	25.88
SEm±	0.02	0.02	0.02	0.05	0.06	0.04	0.63	0.53	0.41
CD (P=0.05)	0.07	0.06	0.04	0.17	0.19	0.12	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.88	0.92	0.90	2.48	2.52	2.50	26.01	26.43	26.22
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.04	1.05	1.05	2.70	2.76	2.73	27.64	27.54	27.59
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.81	0.83	0.82	2.29	2.33	2.31	25.76	25.93	25.85
SEm±	0.03	0.02	0.02	0.07	0.07	0.05	0.77	0.65	0.51
CD (P=0.05)	0.09	0.08	0.05	0.21	0.23	0.15	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

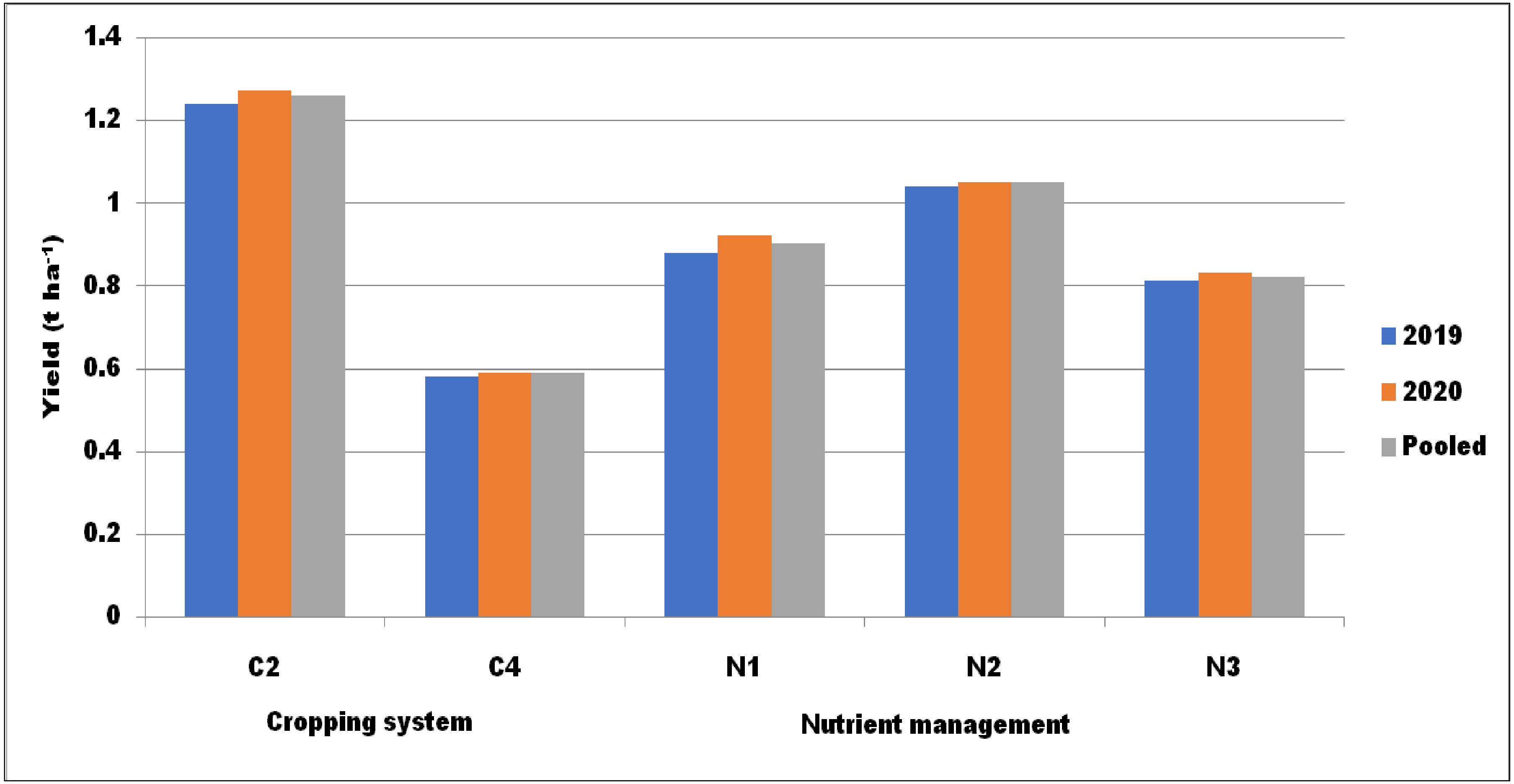


Fig 4.4: Effect of cropping system and nutrient management on seed yield of groundnut (t ha^{-1})

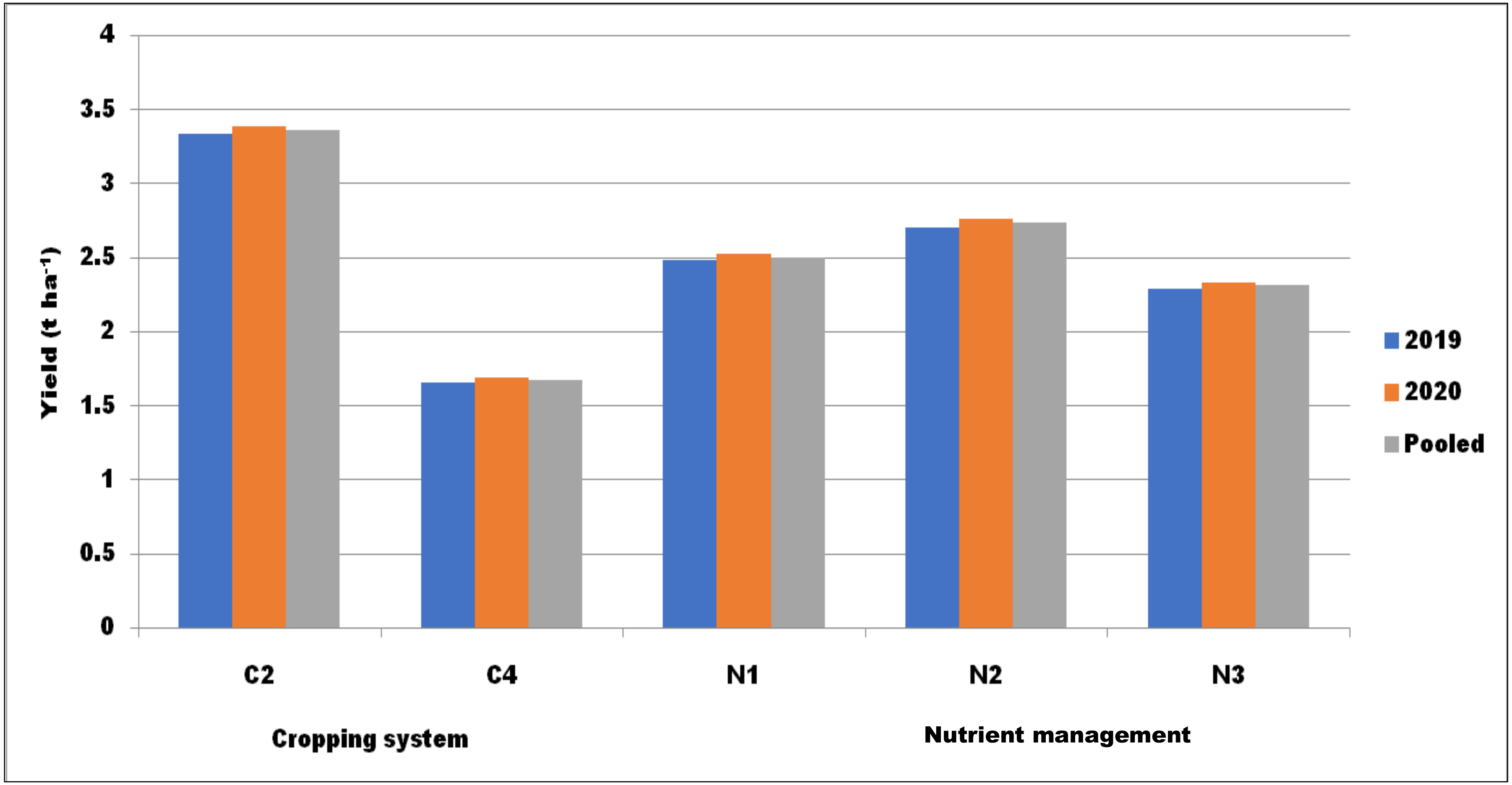


Fig 4.5: Effect of cropping system and nutrient management on stover yield of groundnut (t ha^{-1})

pooled with the value being 2.70 t ha^{-1} in 2019, 2.76 t ha^{-1} in 2020 and 2.73 t ha^{-1} in pooled data. Significantly minimum stover yield (2.29, 2.33 and 2.31 t ha^{-1} during 2019, 2020 and in pooled respectively) was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). The present findings are in close agreement with the results obtained by Zalate and Padmani (2010), Patil *et al*. (2014) and Rahevar *et al*. (2015).

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.2.4.3 Harvest index (%)

The data pertaining to harvest index due to cropping system and nutrient management practices are presented in Table 4.32.

Effect of cropping system

Application of different cropping system did not show any significant effect on harvest index of groundnut.

Effect of nutrient management

The effect of different nutrient management did not bring significant impact on the harvest index of groundnut.

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on harvest index.

4.2.5 Nutrient study

4.2.5.1 Nitrogen content in seed (%)

Data on nitrogen content in seed (%) as influenced by cropping system and nutrient management practices are presented in Table 4.33.

Effect of cropping system

Effect of cropping system could not show significant response on per cent nitrogen content in seed.

Effect of nutrient management

Different nutrient management showed significant differences in respect of nitrogen content in seed (%). The maximum nitrogen content in seed recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during both the years and similar trend followed in pooled with the values being 3.398, 3.404 and 3.401 %, respectively. The lowest value being recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (2.738, 2.744 and 2.741% during 2019, 2020 and in pooled data, respectively). Vala *et al*. (2018) reported that highest nitrogen content in seed were noticed under the treatment which constitutes 75% RDF + 25% N through FYM + Biofertilizer.

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on nitrogen content in seed (%).

4.2.5.2 Nitrogen content in stover (%)

The data pertaining to nitrogen content in stover (%) due to cropping system and nutrient management practices are presented in Table 4.33.

Effect of cropping system

Effect of cropping system could not show significant response on per cent nitrogen content in stover.

Effect of nutrient management

Close examination of the data revealed that in both the years as well as in pooled data, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer

Table 4.33: Effect of cropping systems and nutrient management practices on nitrogen content (%) in groundnut

Treatments	Nitrogen content (%)					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	3.086	3.109	3.097	1.411	1.415	1.413
C_4 - Rice + groundnut (3:1)	3.058	3.046	3.052	1.404	1.407	1.406
SEm±	0.052	0.044	0.034	0.019	0.019	0.013
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.079	3.085	3.082	1.397	1.401	1.399
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.398	3.404	3.401	1.494	1.498	1.496
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.738	2.744	2.741	1.331	1.335	1.333
SEm±	0.063	0.053	0.041	0.023	0.023	0.016
CD (P=0.05)	0.200	0.168	0.122	0.074	0.071	0.048
Interaction (C X N)	NS	NS	NS	NS	NS	NS

consortium @ 20 g kg^{-1} seed resulted in significantly highest nitrogen content in stover with the values of 1.494, 1.498 and 1.496 %, respectively. However application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed registered significantly lowest data with the values being 1.331% in 2019, 1.335% in 2020 and 1.333% in pooled data. The results of present investigation are in close agreements with the findings of Zalate and Padmani (2010).

Interaction effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.2.5.3 Phosphorous content in seed (%)

Data related to phosphorous content in seed (%) due to cropping system and nutrient management are presented in Table 4.34.

Effect of cropping system

No significant changes in seed phosphorous content was observed due to cropping system during both the years of experimentation.

Effect of nutrient management

An inference of the data presented in table revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly increased the percent phosphorous content in seed. Similar trend of effect was observed in both the year as well as pooled data with the value of 0.355, 0.358 and 0.356%, respectively. The lowest percent of phosphorous content was recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values being 0.329, 0.333 and 0.331 % during 2019, 2020 and in pooled data, respectively. These findings are in agreement with the findings of Tatpurkar *et al*. (2014).

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.2.5.4 Phosphorous content in stover (%)

The effects of cropping system and nutrient management practices on phosphorous content in stover (%) are presented in Table 4.34

Effect of cropping system

No significant differences in percent phosphorous content in stover was observed among all the treatments.

Effect of nutrient management

Nutrient management practices significantly influenced the per cent phosphorous content of stover, the highest being 0.259% in 2019, 0.264% in 2020 and 0.261% in pooled were recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). The significantly lowest value of 0.236% in 2019, 0.241% in 2020 and 0.238% in pooled data were recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). Similar findings was also observed by Vallabh and Brigendra (2015).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.2.5.5 Potassium content in seed (%)

Potassium content in seed (%) of rice differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.35.

Table 4.34: Effect of cropping systems and nutrient management practices on phosphorous content (%) in groundnut

Treatments	**Phosphorous content (%)**					
	Seed			**Stover**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	0.341	0.345	0.343	0.248	0.252	0.250
C_4 - Rice + groundnut (3:1)	0.336	0.342	0.339	0.243	0.247	0.245
SEm±	0.004	0.004	0.003	0.004	0.003	0.003
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.333	0.339	0.336	0.241	0.245	0.243
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.355	0.358	0.356	0.259	0.264	0.261
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.329	0.333	0.331	0.236	0.241	0.238
SEm±	0.005	0.004	0.003	0.005	0.004	0.003
CD (P=0.05)	0.015	0.014	0.009	0.014	0.013	0.009
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Table 4.35: Effect of cropping systems and nutrient management practices on potassium content (%) in groundnut

Treatments	**Potassium content (%)**					
	Seed			**Stover**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	1.402	1.407	1.404	2.130	2.136	2.133
C_4 - Rice + groundnut (3:1)	1.395	1.399	1.397	2.112	2.117	2.114
SEm±	0.020	0.020	0.014	0.020	0.020	0.014
CD (P=0.05)	NS	NS	NS	NS	NS	NS
B) Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.402	1.407	1.404	2.122	2.127	2.124
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.533	1.537	1.535	2.202	2.207	2.204
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.262	1.265	1.264	2.039	2.044	2.042
SEm±	0.025	0.025	0.018	0.024	0.024	0.017
CD (P=0.05)	0.078	0.078	0.052	0.076	0.075	0.050
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Effect of cropping system

The data revealed that there was no significant effect of the treatments on percent potassium content in seed during both the years.

Effect of nutrient management

An examination of the data in both the years as well as pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded highest potassium concentration in seed with the values of 1.533% in 2019, 1.537% in 2020 and a pooled value of 1.535%, while the treatments recorded lowest at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with values being 1.262, 1.265 and 1.264% during 2019, 2020 and in pooled data, respectively.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.2.5.6 Potassium content in stover (%)

The result presented in Table 4.35 showed the effects of cropping system and nutrient management practices on potassium content in stover (%).

Effect of cropping system

Effect of cropping system could not show significant response on potassium content in stover (%).

Effect of nutrient management

It was noted that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed obtained statistically superior values of 2.202, 2.207 and 2.204 % during 2019, 2020 and in pooled data respectively, while the lowest values of 2.039, 2.044 and 2.042 % during 2019, 2020 and in pooled data were recorded in N_3 treatment (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed).

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.2.5.7 Nitrogen uptake by seed (kg ha^{-1})

Data related to nitrogen uptake by seed (kg ha^{-1}) and interaction of nitrogen uptake by seed (kg ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.36 (a) and 4.36(b), respectively.

Effect of cropping system

The variations on nitrogen uptake due to cropping system were found to be significant during both the years of experiment. The highest nitrogen uptake 38.59, 39.96 and 39.27 kg ha^{-1} were recorded in treatment sole groundnut during 2019, 2020 and in pooled data, respectively. The lowest was recorded in rice intercropped with groundnut with the values of 17.82, 18.23 and 18.03 kg ha^{-1} in 2019, 2020 and in pooled data, respectively. Similar result was reported by Gao *et al*. (2019) who reported that sole maize and sole groundnut had greater N uptake than intercropped maize and groundnut, respectively.

Effect of nutrient management

The analysis of variance study of the data indicated towards a significant difference among the responses of the various nutrient management practices. Significantly highest value was recorded in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment during both the years (35.30, 35.99 and 35.64 kg ha^{-1} in 2019, 2020 and in pooled data, respectively), while the lowest was recorded with application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (22.09, 22.85 and 22.47 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). This

Table 4.36 (a): Effect of cropping systems and nutrient management practices on nitrogen uptake (kg ha^{-1}) in groundnut

Treatments	Nitrogen uptake (kg ha^{-1})					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	38.59	39.96	39.27	40.05	41.03	40.54
C_4 - Rice + groundnut (3:1)	17.82	18.23	18.03	19.65	19.77	19.71
SEm±	0.82	0.92	0.62	1.07	1.15	0.79
CD (P=0.05)	2.60	2.89	1.82	3.38	3.63	2.32
B) Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	27.23	28.45	27.84	29.22	29.76	29.49
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	35.30	35.99	35.64	35.10	35.76	35.43
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	22.09	22.85	22.47	25.23	25.67	25.45
SEm±	1.01	1.12	0.76	1.31	1.41	0.96
CD (P=0.05)	3.18	3.54	2.23	4.13	4.45	2.84
Interaction (C X N)	S	S	S	NS	NS	NS

Table 4.36 (b): Interaction effect of cropping systems and nutrient management practices on nitrogen uptake (kg ha^{-1}) in groundnut

Treatments	Nitrogen uptake (kg ha^{-1})		
	Seed		
	2019	2020	Pooled
C_2 N_1	37.65	39.09	38.37
C_4 N_1	16.80	17.80	17.30
C_2 N_2	47.92	49.35	48.64
C_4 N_2	22.67	22.64	22.65
C_2 N_3	30.19	31.44	30.81
C_4 N_3	13.99	14.26	14.12
SEm±	1.43	1.59	1.07
CD (P=0.05)	4.50	5.01	3.15

might be due to the fact that the combined application of chemical fertilizers along with enough bulk of FYM has always stimulated the uptake of nutrients because of improved root growth due to congenial soil physical condition. The improvement of N, P and K uptake might be attributed to their respective higher concentration in pod and stover and associated with higher seed and stover yields. The results of present investigations are in close agreements with the findings of Zalate and Padmini (2010), Tatpurkar *et al*. (2014) and Vallabh and Brigendra (2015).

Interaction Effect

The interaction effects between cropping system and nutrient management practice were found to be significant during both the years of investigations. The highest nitrogen uptake during both the years was associated with the interaction C_2N_2 (Sole groundnut +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 47.92 and 49.35 kg ha^{-1} during 2019 and 2020 respectively, which was followed by C_2N_1 (Sole groundnut +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 37.65, 39.09 and 38.37 kg ha^{-1} during 2019 and 2020, respectively. The significantly lowest (13.99 and 14.26 kg ha^{-1} during 2019 and 2020, respectively) was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination. The pooled data thus obtained compiled with the findings of both the years of experiment with interaction C_2N_2 giving the highest value (48.64 kg ha^{-1}) which was followed by C_2N_1 (38.37 kg ha^{-1}) treatment combination, while the lowest was obtained in C_4N_3 with a value of 14.12 kg ha^{-1}.

4.2.5.8 Nitrogen uptake by stover (kg ha^{-1})

The data pertaining to nitrogen uptake by stover (kg ha^{-1}) and interaction of nitrogen uptake by stover (kg ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.36.

Effect of cropping system

The variations on nitrogen uptake due to cropping system were found to be significant during both the years of experiment. The highest nitrogen uptake 40.05, 41.03 and 40.54 kg ha^{-1} were recorded in treatment sole groundnut during 2019, 2020 and in pooled data, respectively. The lowest was recorded in rice intercropped with groundnut with the values of 19.65, 19.77 and 19.71 kg ha^{-1} in 2019, 2020 and in pooled data, respectively.

Effect of nutrient management

Significant differences in nitrogen uptake by the crop were noticed among all the treatments, the maximum values being 35.10, 35.76, and 35.43 kg ha^{-1} during 2019, 2020 and in pooled were recorded at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment. The nitrogen uptake value was recorded low at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values being 25.23, 25.67 and 25.45 kg ha^{-1} during 2019, 2020 and in pooled data, respectively. Experiments at the wetland farm of ANGRAU Tirupati, Chaithanya *et al*. (2003) had observed that application of FYM @ 8 t ha^{-1} increased the nitrogen, phosphorus, potassium, sulphur, zinc, copper, iron and manganese uptake by groundnut seed and stover. Increase in nutrient uptake has also been observed by increasing FYM rate from 0 to 5 t ha^{-1} in the lithic ustorthent soil at Punjab Rao Krishi Vidyapith (PKV), Akola by Patil *et al*. (1998). Similar finding was reported by Dutta and Mondal (2006).

Interaction Effect

During both the years of study, cropping system and nutrient management interaction effects were found to be non-significant.

4.2.5.9 Phosphorous uptake by seed (kg ha^{-1})

The result presented in Table 4.37 (a) and 4.37 (b) showed the effects of cropping system and nutrient management practices on phosphorous uptake by seed (kg ha^{-1}) and interaction of phosphorous uptake by seed (kg ha^{-1}).

Effect of cropping system

Data on phosphorous uptake presented in Table 4.37 revealed that cropping system exerted significant influence on phosphorous uptake by seed. Highest phosphorous uptake in seed was recorded in sole groundnut (4.24, 4.41 and 4.32 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest uptake was recorded in rice intercropped with groundnut (1.95, 2.04 and 1.99 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). Higher phosphorous uptake due to higher number of branches, drymatter production, seed yield and stover yield leads to higher phosphorous uptake.

Effect of nutrient management

Significant variations in respect to phosphorous uptake in seed was observed during both the years of investigation. Values of 3.69 and 3.78 kg ha^{-1} were obtained during 2019 and 2020 respectively at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and was statistically superior to rest of the treatments. The lowest (2.65 and 2.77 kg ha^{-1}) was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation. The pooled data of both the years also revealed a significant difference with the highest phosphorous uptake by seed of 3.73 kg ha^{-1}, when the crop was applied with

Table 4.37 (a): Effect of cropping systems and nutrient management practices on phosphorous uptake (kg ha^{-1}) in groundnut

Treatments	Phosphorous uptake (kg ha^{-1})					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	4.24	4.41	4.32	7.02	7.28	7.15
C_4 - Rice + groundnut (3:1)	1.95	2.04	1.99	3.40	3.47	3.43
SEm±	0.08	0.07	0.05	0.12	0.12	0.09
CD (P=0.05)	0.25	0.22	0.16	0.39	0.39	0.26
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.94	3.11	3.03	5.05	5.19	5.12
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.69	3.78	3.73	6.10	6.30	6.20
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.65	2.77	2.71	4.48	4.63	4.56
SEm±	0.10	0.09	0.07	0.15	0.15	0.11
CD (P=0.05)	0.31	0.27	0.19	0.47	0.48	0.32
Interaction (C X N)	NS	S	S	NS	S	S

Table 4.37 (b): Interaction effect of cropping systems and nutrient management practices on phosphorous uptake (kg ha^{-1}) in groundnut

Treatments	Phosphorous uptake (kg ha^{-1})			
	Seed		Stover	
	2020	Pooled	2020	Pooled
C_2 N_1	4.24	4.15	7.01	6.93
C_4 N_1	1.98	1.90	3.38	3.31
C_2 N_2	5.17	5.10	8.57	8.34
C_4 N_2	2.39	2.37	4.03	4.06
C_2 N_3	3.81	3.72	6.27	6.18
C_4 N_3	1.73	1.70	3.00	2.94
SEm±	0.12	0.09	0.22	0.15
CD (P=0.05)	0.39	0.27	0.68	0.45

75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest (2.71 kg ha^{-1}) value was recorded when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The increase in P uptake of nutrients by groundnut seed appears to be due to cumulative effect of increased pod and stover yield and nutrient content or may be due to solubilization of fixed phosphorus by P-solubilizer due to secretion of organic acids. These results were in agreement with the findings of Ramesh *et al*. (1997) who reported improvement in uptake with the application of chemical fertilizers with FYM and biofertilizers.

Interaction Effect

The interaction effects of different treatments were found to be non significant during 2019. Significant variation was observed with the highest value of 5.17 and 5.10 kg ha^{-1} associated with the interaction of C_2N_2 (Sole groundnut with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2020 and in pooled data respectively, which was followed by C_2N_1 (Sole groundnut with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 4.24 and 4.15 kg ha^{-1} during 2020 and in pooled data, respectively. The significantly minimum (1.73 and 1.70 during 2020 and in pooled data, respectively) was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

4.2.5.10 Phosphorous uptake by stover (kg ha^{-1})

Data related to phosphorous uptake by stover (kg ha^{-1}) and their interaction effect due to cropping system and nutrient management are presented in Table 4.37 (a) and 4.37 (b).

Effect of cropping system

Data on phosphorous uptake presented in Table 4.37 revealed that cropping system exerted significant influence on phosphorous uptake by stover. Highest phosphorous uptake in stover was recorded in sole groundnut (7.02, 7.28 and 7.15 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest uptake was recorded in rice intercropped with groundnut (3.40, 3.47 and 3.43 kg ha^{-1} in 2019, 2020 and in pooled data, respectively).

Effect of nutrient management

Data tabulated in Table 4.37 indicated that nutrient management practices showed significant influence during both the years of study. The highest phosphorous uptake values of 6.10, 6.30 and 6.20 kg ha^{-1} were obtained in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during 2019, 2020 and in pooled data, respectively. The lowest (4.48, 4.63 and 4.56 kg ha^{-1} during 2019, 2020 and in pooled data, respectively) was recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. Karmakar *et al.* (2005) have observed that phosphorus, potassium and calcium uptake increased in pod and stover with application of FYM and other organic matter equivalent to 15 kg N ha^{-1} in the lateritic sandy clay loam soil at IIT, Kharagpur.

Interaction Effect

The interaction effects of different treatments were found to be non significant during 2019. Significant variation was observed with the highest value of 8.57 and 8.34 kg ha^{-1} associated with the interaction of C_2N_2 (Sole groundnut with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2020 and in pooled data respectively, which was followed by C_2N_1 (Sole groundnut with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 7.01 and 6.93 kg ha^{-1}

during 2020 and in pooled data, respectively. The significantly minimum (3.00 and 2.94 kg ha^{-1} during 2020 and in pooled data, respectively) was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

4.2.5.11 Potassium uptake by seed (kg ha^{-1})

The result presented in Table 4.38 (a) and 4.38 (b) showed the effects of cropping system and nutrient management practices on potassium uptake by seed (kg ha^{-1}) and interaction of potassium uptake by seed (kg ha^{-1}) .

Effect of cropping system

Significant differences in potassium uptake by the crop were noticed among all the treatments, the maximum being 17.50 kg ha^{-1} in 2019, 18.05 kg ha^{-1} in 2020 and 17.77 kg ha^{-1} in pooled data were observed in sole groundnut. The lowest values of 8.12, 8.37 and 8.24 kg ha^{-1} during 2019, 2020 and in pooled data, respectively was recorded in rice intercropped with groundnut. The higher K uptake may be due to higher K content, drymatter and its translocation from vegetative parts to reproductive parts in the later stages of crop growth and development stage.

Effect of nutrient management

Potassium uptake was also influenced by different nutrient management practices. Significant differences in potassium uptake by the crop were noticed among all the treatments, the maximum being 15.90, 16.21 and 16.05 kg ha^{-1} with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed during 2019, 2020 and in pooled data, respectively. The minimum being recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (10.14, 10.51 and 10.32 kg ha^{-1} during 2019, 2020 and in pooled data, respectively). Jat and Ahlawat (2010) also reported that application of FYM @ 5t ha^{-1} significantly increased the total uptake of N, P and K in groundnut. The increase in nutrient uptake by FYM could be attributed to higher yield coupled with slight improvement in nutrient content.

Interaction Effect

Potassium uptake by seed was significantly affected by the combine practice cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the uptake was highest in C_2N_2 (Sole groundnut with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (21.57 kg ha^{-1}), 2020 (22.14 kg ha^{-1}) and pooled (21.86 kg ha^{-1}) which was followed by C_2N_1 (Sole groundnut with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (17.10, 17.58 and 17.34 kg ha^{-1} during first, second and as well as in pooled data, respectively). The lowest was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (6.45, 6.59 and 6.52 kg ha^{-1} during first, second year and as well as in pooled data, respectively) among all the treatments.

4.2.5.12 Potassium uptake by stover (kg ha^{-1})

Data related to potassium uptake by stover (kg ha^{-1}) due to cropping system and nutrient management are presented in Table 4.38.

Effect of cropping system

The data on potassium uptake by stover revealed significant variation due to different cropping system during both the years of experiment. During 2019 and 2020, highest potassium uptake was recorded from sole groundnut with the values of 60.35 and 61.79 kg ha^{-1}, respectively. The statistically lowest was recorded in rice intercropped with groundnut treatment with the values 29.51 kg

Table 4.38 (a): Effect of cropping systems and nutrient management practices on potassium uptake (kg ha^{-1}) in groundnut

Treatments	**Potassium uptake (kg ha^{-1})**					
	Seed			**Stover**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	17.50	18.05	17.77	60.35	61.79	61.07
C_4 - Rice + groundnut (3:1)	8.12	8.37	8.24	29.51	29.70	29.60
SEm±	0.27	0.31	0.20	1.36	1.51	1.02
CD (P=0.05)	0.85	0.96	0.60	4.28	4.75	2.99
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	12.39	12.91	12.65	44.46	45.24	44.85
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	15.90	16.21	16.05	51.70	52.68	52.19
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	10.14	10.51	10.32	38.62	39.31	38.97
SEm±	0.33	0.38	0.25	1.67	1.85	1.24
CD (P=0.05)	1.04	1.18	0.74	5.25	5.82	3.67
Interaction (C X N)	S	S	S	NS	NS	NS

Table 4.38 (b): Interaction effect of cropping systems and nutrient management practices on potassium uptake (kg ha^{-1}) in groundnut

Treatments	Potassium uptake (kg ha^{-1})		
	Seed		
	2019	2020	Pooled
C_2 N_1	17.10	17.58	17.34
C_4 N_1	7.68	8.24	7.96
C_2 N_2	21.57	22.14	21.86
C_4 N_2	10.22	10.28	10.25
C_2 N_3	13.83	14.42	14.12
C_4 N_3	6.45	6.59	6.52
SEm±	0.47	0.53	0.35
CD (P=0.05)	1.47	1.67	1.04

ha^{-1} in 2019 and 29.70 kg ha^{-1} in 2020. The similar trend was followed in pooled data of two years.

Effect of nutrient management

Among the nutrient management, potassium uptake showed significant variation during both the years of experiment. It is indicated from the data that highest value was noticed in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment with the values 51.70 kg ha^{-1} in 2019, 52.68 kg ha^{-1} in 2020 and 52.19 kg ha^{-1} in pooled data. The statistically minimum was observed in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (38.62, 39.31 and 38.97 kg ha^{-1} in 2019, 2020 and in pooled data respectively). Mathukia *et al.* (2015) reported that application of FYM and vermicompost to groundnut significantly increased uptake of N, P and K.

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.2.6 Quality parameters

4.2.6.1 Protein content (%)

The effect of cropping system and nutrient management practices on protein content (%) are presented in Table 4.39.

Effect of cropping system

No significant differences in per cent protein content of groundnut was observed among the treatments during both the years.

Effect of nutrient management

The highest protein content was recorded at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 21.24, 21.27 and 21.26 % during 2019, 2020 and in pooled data, respectively. The lowest value of 17.11, 17.15 and 17.13 % were observed at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during 2019, 2020 and pooled data, respectively. The increased oil and protein content might be due to the role of nitrogen and Sulphur are an integral part of protein and phosphorus is structural element of certain co-enzymes involved in biosynthesis of oil and storage organs, which are proteinaceous in nature. These findings are in close conformity with those reported by Ola *et al*. (2013) and Madhu Bala and Kedar Nath (2015).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.2.6.2 Protein yield (kg ha^{-1})

The results recorded on the effect of cropping system and nutrient management on the protein yield (kg ha^{-1}) and interaction effect of protein yield (kg ha^{-1}) are presented in Table 4.39 (a) and 4.39 (b), respectively.

Effect of cropping system

The various crop management practices brought significant results on the protein yield of groundnut. Highest protein yield was recorded in sole groundnut (241.17, 249.76 and 245.46 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest protein yield was recorded in rice intercropped with groundnut (111.37, 113.96 and 112.67 kg ha^{-1} in 2019, 2020

Table 4.39 (a): Effect of cropping systems and nutrient management practices on protein content (%) and protein yield (kg ha^{-1}) in groundnut

Treatments	Protein content (%)			Protein yield (kg ha^{-1})		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	19.29	19.43	19.36	241.17	249.76	245.46
C_4 - Rice + groundnut (3:1)	19.11	19.04	19.07	111.37	113.96	112.67
SEm±	0.32	0.27	0.21	5.16	5.74	3.86
CD (P=0.05)	NS	NS	NS	16.25	18.09	11.38
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	19.24	19.28	19.26	170.17	177.81	173.99
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	21.24	21.27	21.26	220.60	224.97	222.78
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	17.11	17.15	17.13	138.05	142.81	140.43
SEm±	0.40	0.33	0.26	6.31	7.03	4.72
CD (P=0.05)	1.25	1.05	0.76	19.90	22.15	13.94
Interaction (C X N)	NS	NS	NS	S	S	S

Table 4.39 (b): Interaction effect of cropping systems and nutrient management practices on protein yield (kg ha^{-1}) in groundnut

Treatments	Protein yield (kg ha^{-1})		
	2019	**2020**	**Pooled**
C_2 N_1	235.32	244.34	239.83
C_4 N_1	105.03	111.27	108.15
C_2 N_2	299.53	308.43	303.98
C_4 N_2	141.67	141.50	141.58
C_2 N_3	188.68	196.49	192.58
C_4 N_3	87.42	89.12	88.27
SEm±	8.93	9.94	6.68
CD (P=0.05)	28.14	31.33	19.71

and in pooled data, respectively). The protein yield of groundnut was reduced probably due to intercrop competition between rice and groundnut.

Effect of nutrient management

Significant variations in respect protein yield was observed during both the years of investigation. Values of 220.60, 224.97 and 222.78 kg ha^{-1} during2019, 2020 and in pooled data, respectively were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and was statistically superior to rest of the treatments. The lowest (138.05, 142.81 and 140.43 kg ha^{-1} during 2019, 2020 and in pooled data, respectively) was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Vala *et al*. (2017) revealed that protein yield was registered higher under the treatment consist of 75% RDF + 25% N through FYM + Biofertilizer.

Interaction Effect

Protein yield was significantly affected by the combine practice cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the yield was highest in C_2N_2 (Sole groundnut +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (299.53 kg ha^{-1}), 2020 (308.43 kg ha^{-1}) and pooled (303.98 kg ha^{-1}), which was found to be followed by C_2N_1(Sole groundnut +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (235.32, 244.34 and 239.83 kg ha^{-1} during first, second year and as well as in pooled data respectively). The significantly lowest was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (87.42, 89.12 and 88.27 during first, second year and as well as in pooled data, respectively).

4.2.6.3 Oil content (%)

Oil content (%) of groundnut differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.40.

Effect of cropping system

The result revealed that different cropping system had non-significant effect on oil content (%) during both the years of experiment.

Effect of nutrient management

Oil content (%) due to nutrient management practices was found to be significant during both the years of experiment. During both the years, oil content (%) was recorded highest in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (43.36, 44.18 and 43.77 % in 2019, 2020 and in pooled data, respectively). The lowest oil content (%) values of 40.87, 41.26 and 41.07% during 2019, 2020 and in pooled data respectively was recorded in the treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Ahmed *et al*. (1997) who stated that the highest dry matter accumulation, seed yield and oil content were achievedby fertilization with farmyard manure.

Interaction effect

Interaction between cropping system and nutrient management practices did not show any differences on oil content (%) during both the experimental year.

4.2.6.4 Oil yield (kg ha^{-1})

The data obtained on oil yield (kg ha^{-1}) and interaction effect of oil yield (kg ha^{-1}) of groundnut as influenced by cropping system and nutrient management are presented in Table 4.40 (a) and 4.40 (b).

Table 4.40 (a): Effect of cropping systems and nutrient management practices on oil content (%) and oil yield (kg ha^{-1}) in groundnut

Treatments	Oil content (%)			Oil yield (kg ha^{-1})		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_2 - Sole groundnut	42.38	42.87	42.63	525.87	547.49	536.68
C_4 - Rice + groundnut (3:1)	41.91	42.61	42.26	242.82	253.62	248.22
SEm±	0.27	0.31	0.21	8.21	9.47	6.27
CD (P=0.05)	NS	NS	NS	25.86	29.83	18.48
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	42.20	42.78	42.49	373.22	392.51	382.86
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	43.36	44.18	43.77	450.52	466.15	458.33
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	40.87	41.26	41.07	329.29	343.00	336.15
SEm±	0.33	0.38	0.25	10.05	11.60	7.67
CD (P=0.05)	1.03	1.20	0.74	31.68	36.54	22.64
Interaction (C X N)	NS	NS	NS	S	NS	S

Table 4.40 (b): Interaction effect of cropping systems and nutrient management practices on oil yield (kg ha^{-1}) in groundnut

Treatments	Oil yield (kg ha^{-1})	
	2019	**Pooled**
C_2 N_1	515.00	524.69
C_4 N_1	231.43	241.04
C_2 N_2	612.35	624.78
C_4 N_2	288.69	291.88
C_2 N_3	450.26	460.57
C_4 N_3	208.33	211.73
SEm±	14.22	10.85
CD (P=0.05)	44.80	32.01

Effect of cropping system

During both the year 2019 and 2020, sole crop of groundnut recorded higher oil yield of 525.87 and 547.49 kg ha^{-1}, respectively. Rice + groundnut at 3:1 row ratio recorded significantly lower oil yield (242.82 and 253.62 kg ha^{-1}in 2019 and 2020, respectively). Pooled data of both the years revealed highest (536.68 kg ha^{-1}) oil yield in sole groundnut, while the lowest was recorded in C_4 (Rice+ groundnut with 3: 1 row ratio) with value of 248.22 kg ha^{-1}. The oil yield of groundnut was reduced probably due to intercrop competition between rice and groundnut.

Effect of nutrient management

During both the year, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly higher oil yield of 450.52, 466.15 and 458.33 kg ha^{-1} during 2019, 2020 and in pooled data, respectively, while the lowest (329.29, 343.00 and 336.15 kg ha^{-1} in 2019, 2020 and in pooled data, respectively) recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Reddy *et al*. (2005) at UAS, Bangalore observed that application of poultry manure, sewage sludge and urban garbage compost or farm yard manure resulted in higher oil content and oil yield in groundnut.

Interaction effect

The interaction effects between cropping system and nutrient management practices on oil yield was significantly affected only in the year 2019. Data shows that highest oil yield of 612.35 kg ha^{-1} was recorded in C_2N_2 (Sole groundnut +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination, which was followed by C_2N_1 (Sole groundnut +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with value of 515 kg ha^{-1} and significantly lowest was recorded in C_4N_3 (Rice intercropped with groundnut and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with value of 208.33 kg ha^{-1}. Pooled data revealed that significantly highest was observed in C_2N_2 (624.78 kg ha^{-1}) which was followed by C_2N_1 (524.69 kg ha^{-1}) recorded in sole groundnut (23.20, 39.02 and 56.18 cm at 30, 60 and 90 DAS, treatment combination and significantly lowest was recorded in C_4N_3 (211.73 kg ha^{-1}).

4.3 Soybean

4.3.1 Growth parameters

4.3.1.1 Plant height (cm)

The data on plant height of soybean was recorded at 30 days interval till up to 90 days in both the years during the *kharif* of 2019 and 2020. The mean data and pooled for both the years are presented in Table 4.41.

Effect of cropping system

There was statistical difference between plant height values of two different cropping systems during both the years of experimentation. During 2019, sole soybean (C_3) registered significantly higher plant height values of 21.73, 37.40 and 54.94 cm at 30, 60 and 90 DAS, respectively. The corresponding values under rice intercropped with soybean (C_5) were 18.91, 34.43 and 51.17 cm at 30, 60 and 90 DAS, respectively. During 2020, similar trend followed significantly highest plant height recorded in sole groundnut (23.20, 39.02 and 56.18 cm at 30, 60 and 90 DAS, respectively) and the lowest (19.55, 35.07 and 52.55 cm at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with soybean. Pooled data also revealed that there was a significant effect on plant height due to cropping systems. Significantly highest plant height (22.47, 38.21 and 55.56 cm at 30, 60 and 90 DAS, respectively) was recorded in sole soybean and the lowest (19.23, 34.75 and 51.86 cm at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with soybean. Significantly a taller plant height was observed in sole soybean than the rice intercropped with soybean at different successive growth stages. This may be due to absence of intercrop competition. The result corresponds with those of Kithan (2012), Aye (2013) and Yhokha (2015).

Effect of nutrient management

The effect of different nutrient management practices on plant height was found to be significant at all the growth stages. During 2019, significantly the highest plant height of 23.65, 40.06 and 57.21 cm at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest plant height of 17.73, 31.85 and 50.14 cm at 30, 60 and 90 DAS, respectively were recorded when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. Similarly during 2020, plant height showed significant variation among the various treatments with the highest observed in sole soybean with 25.10, 42.09 and 58.84 cm at 30, 60 and 90 DAS, respectively, while 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the lowest data on plant height at almost all the growth stages. The pooled data of both the years also revealed a significant difference with the highest plant height of 24.37, 41.07 and 58.02 cm at 30, 60 and 90 DAS, respectively, when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest plant height was recorded of 18.19, 32.19 and 50.90 cm at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. This increase in plant height might be due to greater availability of macro and micronutrients, form of organic and inorganic sources which helped in acceleration of various metabolic processes of N P and k which help in better absorption of nutrients coupled with proper distribution, these results are in conformity with the reports of Dash *et al.* (2005). Verma *et al.* (2017) revealed

Table 4.41: Effect of cropping systems and nutrient management practices on plant height (cm) at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	21.73	23.20	22.47	37.40	39.02	38.21	54.94	56.18	55.56
C_5 - Rice + soybean (3:1)	18.91	19.55	19.23	34.43	35.07	34.75	51.17	52.55	51.86
SEm±	0.74	1.12	0.67	0.92	1.01	0.68	1.15	0.95	0.75
CD (P=0.05)	2.33	3.52	1.97	2.89	3.19	2.01	3.64	3.00	2.21
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	19.59	20.39	19.99	35.84	36.52	36.18	51.82	52.59	52.21
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	23.65	25.10	24.37	40.06	42.09	41.07	57.21	58.84	58.02
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	17.73	18.65	18.19	31.85	32.54	32.19	50.14	51.67	50.90
SEm±	0.90	1.37	0.82	1.12	1.24	0.84	1.41	1.17	0.92
CD (P=0.05)	2.85	4.31	2.42	3.54	3.90	2.47	4.45	3.68	2.70
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

that all the growth parameters *viz*., plant height, dry matter, total and effectives nodules were significantly increased due to 75 % NPK + 25 % N through vermicompost + Rhizobium + PSB.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.3.1.2 Number of branches plant^{-1}

The results recorded on the effect of cropping system and nutrient management on the number of branches plant^{-1} recorded at 30, 60 and 90 DAS are presented in Table 4.42.

Effect of cropping system

Significant response was observed during both the years of experimentations due to effect of cropping system on number of branches plant^{-1} where sole soybean exhibited a significant response and achieved highest number of branches plant^{-1} of 3.47, 7.51 and 10.31 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 3.58, 7.67 and 10.51 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. Significantly lowest was recorded at rice intercropped with soybean with the values of 2.89, 6.71 and 9.36 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 3.00, 6.84 and 9.49 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. The maximum pooled value of number of branches plant^{-1} recorded at 30, 60 and 90 DAS were 3.52, 7.59 and 10.41 plant^{-1} respectively at sole soybean and the lowest (2.94, 6.78 and 9.42 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded at rice intercropped with soybean. As the competition intensifies the number of branches also tend to be reduced owing to lack of space and reduced availability of resources like nutrients and water. This was also in conformity with the finding of Rathiya and Lakpale, 2005 and Layek *et al*. (2015). The result of this findings is in agreement with the finding of Nimji (1996) who reported that pure crop of pigeon pea and soybean had more number of branches, number of pods and number of seeds per pod than intercropping system.

Effect of nutrient management

The result presented in the Table 4.42 revealed that application of different nutrient management practices had a significant influence on number of branches plant^{-1} during both the years of experiment. During both the years, result revealed that 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed alone recorded the significantly highest number of branches plant^{-1} of 3.90, 8.33 and 10.70 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 4.03, 8.40 and 10.87 plant^{-1} at 30, 60 and 90 DAS respectively during 2020. Application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the minimum number of branches plant^{-1} of 2.40, 5.90 and 9.13 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 2.53, 6.03 and 9.37 plant^{-1} at 30, 60 and 90 DAS, respectively during 2020. Similar effect was also reflected in pooled data. This increase in number of branches plant^{-1} might be due to greater availability of macro and micro nutrients from both organic and inorganic sources. Inorganic fertilizers offer nutrients to the plant which are readily soluble in soil solution and thereby instantly available to the plants. These results were conformity with Devi *et al*. (2013) and Verma *et al*. (2017). Integration of organic fertilizers with chemical fertilizers increased the availability of nutrients considerably resulting in a positive effect on growth parameters. These findings are in accordance with the results of Babalad (1999) who had observed increased plant height, the number of trifoliate leaves plant^{-1} and the number of branches plant^{-1} in soybean due to the application of organic manure and inorganic fertilizers.

Interaction Effect

The number of branches plant^{-1} of soybean was not persuaded significantly by interaction effect of cropping system and nutrient management.

Table 4.42: Effect of cropping systems and nutrient management practices number of branches plant^{-1} at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	3.47	3.58	3.52	7.51	7.67	7.59	10.31	10.51	10.41
C_5 - Rice + soybean (3:1)	2.89	3.00	2.94	6.71	6.84	6.78	9.36	9.49	9.42
SEm±	0.12	0.11	0.08	0.23	0.22	0.16	0.27	0.24	0.18
CD (P=0.05)	0.39	0.35	0.24	0.72	0.71	0.47	0.86	0.76	0.54
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.23	3.30	3.27	7.10	7.33	7.22	9.67	9.77	9.72
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.90	4.03	3.97	8.33	8.40	8.37	10.70	10.87	10.78
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	2.40	2.53	2.47	5.90	6.03	5.97	9.13	9.37	9.25
SEm±	0.15	0.14	0.10	0.28	0.27	0.20	0.33	0.30	0.22
CD (P=0.05)	0.47	0.43	0.30	0.88	0.87	0.58	1.05	0.93	0.66
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.3.1.3 Dry matter (g) plant^{-1}

Data pertaining to dry matter (g) plant^{-1} due to cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.43.

Effect of cropping system

A critical examination of data presented in table revealed that that there was significant variation among the treatments in both the years. During 2019, it was evident from the data that the maximum dry matter (g) plant^{-1} (1.35, 13.44 and 22.38 g at 30, 60 and 90 DAS, respectively) was obtained in sole soybean significantly lowest was recorded in rice intercropped with soybean (1.17, 10.02 and 18.02 g at 30, 60 and 90 DAS, respectively). In 2020, the highest dry matter (g) plant^{-1} received in sole soybean (1.43, 14.45 and 23.17 g at 30, 60 and 90 DAS, respectively). The minimum dry matter (g) plant^{-1} was recorded at C_5 (Rice + soybean with 3:1 row ratio) with value of 1.23, 11.13 and 18.56 g at 30, 60 and 90 DAS, respectively). Pooled data from both the years it was evident that highest dry matter (g) plant^{-1} was recorded in sole soybean (1.39, 13.95 and 22.78 g at 30, 60 and 90 DAS, respectively). The lowest value was recorded in rice intercropped with soybean (1.20, 10.57 and 18.29 g at 30, 60 and 90 DAS, respectively). The dry matter (g) plant^{-1} was low in intercropping systems as compared to their sole cropping which perhaps due to the fact that competition offered by cereal crop for natural resources, resulted in poor development of intercrops and also due to less space available for horizontal spread of plants and intraspecific competition for incoming sun radiation. Ahmad *et al*. (2016) reported that significant reduction in the production of soybean biomass at different intensities of intercropping was observed due to competition between the component crop for plant growth factor like moisture and nutrient *etc*. The maximum biomass was found in soybean alone due to competition free environment.

Effect of nutrient management

The effect of different treatments on dry matter (g) plant^{-1} was significant. In 2019, the significantly superior dry matter (g) plant^{-1} (1.42, 14.89, 24.97 g at 30, 60 and 90 DAS, respectively) was achieved at 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed and lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 1.12, 9.15 and 15.75 g at 30, 60 and 90 DAS, respectively. During the second year also recorded similar result with the maximum dry matter (g) plant^{-1} of 1.51, 15.86, 26.16 g at 30, 60 and 90 DAS, respectively with treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with values of 1.19, 10.35, 16.25 g at 30, 60 and 90 DAS, respectively. Pooled data of both the years followed the similar findings with the highest dry matter (g) plant^{-1} observed with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed of 1.47, 15.37 and 25.57 g at 30, 60 and 90 DAS respectively, while the lowest dry matter (g) plant^{-1} was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 1.15, 9.75 and 16.00 g at 30, 60 and 90 DAS, respectively. Application of various organic manures stimulated the plant growth, activity of soil microorganisms and higher activity of soil enzymes. The increase in accumulation of dry matter at harvest of soybean may be due to higher availability of nutrients through organic source which resulted in more synthesis of nucleic acid and amino acid, amide substances in growing region and meristematic tissue ultimately enhancing cell division and thereby increased all the growth attributes in these treatments. These results related to dry matters are in agreement with the findings of Kannan *et al*. (2013) in soybean and Pramanick *et al*. (2013) in green gram.

Table 4.43: Effect of cropping systems and nutrient management practices on dry matter (g) plant^{-1} at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	1.35	1.43	1.39	13.44	14.45	13.95	22.38	23.17	22.78
C_5 - Rice + soybean (3:1)	1.17	1.23	1.20	10.02	11.13	10.57	18.02	18.56	18.29
SEm±	0.02	0.03	0.02	0.43	0.43	0.30	0.43	0.45	0.31
CD (P=0.05)	0.08	0.09	0.06	1.36	1.35	0.90	1.36	1.40	0.92
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.24	1.29	1.26	11.16	12.16	11.66	19.89	20.19	20.04
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.42	1.51	1.47	14.89	15.86	15.37	24.97	26.16	25.57
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.12	1.19	1.15	9.15	10.35	9.75	15.75	16.25	16.00
SEm±	0.03	0.03	0.02	0.53	0.52	0.37	0.53	0.55	0.38
CD (P=0.05)	0.09	0.11	0.07	1.67	1.65	1.10	1.67	1.72	1.12
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of

4.3.1.4 Number of root nodules plant^{-1}

The data on number of root nodules plant^{-1} of soybean was recorded at 30 days interval till up to 90 days in both the years during the *kharif* of 2019 and 2020. The mean data and pooled for both the years are presented in Table 4.44.

Effect of cropping system

An inquisition of the data on number of root nodules plant^{-1} revealed that there was significant variation among the treatments in both the years. During 2019, sole soybean (C_3) registered significantly maximum value on number of root nodules plant^{-1} of 13.99, 29.93 and 37.08 plant^{-1} at 30, 60 and 90 DAS, respectively. The corresponding values under rice intercropped with soybean (C_5) were 10.04, 23.79 and 29.57 plant^{-1} at 30, 60 and 90 DAS, respectively. During 2020, similar trend followed significantly highest number of root nodules plant^{-1} recorded in sole soybean (15.10, 32.28 and 39.65 plant^{-1} at 30, 60 and 90 DAS, respectively) and the lowest (11.82, 26.25 and 32.00 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with soybean. Pooled data also revealed that there was a significant effect on number of root nodules plant^{-1} due to cropping systems. Significantly highest number of root nodules plant^{-1} (14.54, 31.10 and 38.37 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded in sole soybean and the lowest (10.93, 25.02 and 30.79 plant^{-1} at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with soybean. The competition in the rhizosphere for space, moisture and nutrients among the intercrop creates a limitation which decreased the number of root nodules. This was in conformity with the finding of Akunda (2001) and Layek *et al*. (2015). Billore *et al*. (2011) reported that nodule number and its mass were lower in intercrop soybean than sole soybean.

Effect of nutrient management

Significant variations in respect to number of root nodules plant^{-1} was observed during both the years of investigation. Values of 16.52, 33.26 and 40.02 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 18.52, 35.91 and 42.97 plant^{-1} at 30, 60 and 90 DAS respectively during 2020 were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and were statistically superior to rest of the treatments. The lowest was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation with the values being 8.97, 21.09 and 27.69 plant^{-1} at 30, 60 and 90 DAS, respectively during 2019 and 9.97, 23.33 and 30.71 at 30, 60 and 90 DAS, respectively during 2020. The pooled data of both the years also revealed a significant difference with the highest number of root nodules plant^{-1} of 17.52, 34.58 and 41.49 plant^{-1} at 30, 60 and 90 DAS respectively when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest value was recorded of 9.47, 22.21 and 29.20 plant^{-1} at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. This might be due to vigorous root system and enhances microbial activity provided with FYM. These results are in agreement with the findings of Gajbhiye and Mail (2009) in soybean and Pramanick *et al*. (2013) in green gram. Alam *et al*. (2009) reported that treatments having 75 and 50% NPK through chemical fertilizer and other rest of N either through FYM or vermicompost produced more number of total and effective root nodules plant^{-1} over 100% NPK alone. The inoculation and chemical fertilization in combination have a significant effect on the total number of nodules plant^{-1}.

Table 4.44: Effect of cropping systems and nutrient management practices on number of root nodules plant^{-1} at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	13.99	15.10	14.54	29.93	32.28	31.10	37.08	39.65	38.37
C_5 - Rice + soybean (3:1)	10.04	11.82	10.93	23.79	26.25	25.02	29.57	32.00	30.79
SEm±	0.68	0.37	0.39	1.08	0.94	0.72	1.96	1.90	1.36
CD (P=0.05)	2.15	1.18	1.15	3.41	2.97	2.12	6.16	5.99	4.02
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	10.56	11.89	11.22	26.25	28.55	27.40	32.28	33.80	33.04
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	16.52	18.52	17.52	33.26	35.91	34.58	40.02	42.97	41.49
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	8.97	9.97	9.47	21.09	23.33	22.21	27.69	30.71	29.20
SEm±	0.83	0.46	0.48	1.33	1.15	0.88	2.40	2.33	1.67
CD (P=0.05)	2.63	1.44	1.40	4.18	3.63	2.59	7.55	7.34	4.93
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Interaction Effect

Interaction effect between cropping system and various nutrient management practices found to be non-significant during both the years of experimentation.

4.3.1.5 Fresh weight of nodules plant^{-1} (g)

The results recorded on the effect of cropping system and nutrient management on the fresh weight of nodules plant^{-1} (g) recorded at 30, 60 and 90 DAS are presented in Table 4.45.

Effect of cropping system

It was explicit from the data presented in Table 4.45 that significant response was observed during both the years of experimentations due to effect of cropping system on fresh weight of nodules plant^{-1} where sole soybean produced significantly highest fresh weight of nodules plant^{-1} of 0.901, 1.604 and 1.751 g at 30, 60 and 90 DAS, respectively during 2019 and 0.910, 1.618 and 1.753 at 30, 60 and 90 DAS, respectively during 2020. Significantly lowest was recorded at rice intercropped with soybean with the values of 0.838, 1.458 and 1.597 g at 30, 60 and 90 DAS, respectively during 2019 and 0.841, 1.460 and 1.606 g at 30, 60 and 90 DAS, respectively during 2020. The maximum pooled value of fresh weight of nodules plant^{-1} recorded at 30, 60 and 90 DAS were 0.906, 1.611 and 1.752 g, respectively in C_3 (Sole soybean) and significantly lowest was recorded in rice intercropped with soybean with the values of 0.839, 1.459 and 1.601 g at 30, 60 and 90 DAS, respectively. It might be due to less competition in sole soybean for natural resources *i.e*. nutrient, light and space for crop growth

Effect of nutrient management

The influence of nutrient management showed significant impact on fresh weight of nodules plant^{-1} (g). Out of all the nutrient management practices

Table 4.45: Effect of cropping systems and nutrient management practices on fresh weight of nodules plant^{-1} (g) at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	0.901	0.910	0.906	1.604	1.618	1.611	1.751	1.753	1.752
C_5 - Rice + soybean (3:1)	0.838	0.841	0.839	1.458	1.460	1.459	1.597	1.606	1.601
SEm±	0.016	0.015	0.011	0.038	0.030	0.024	0.037	0.035	0.026
CD (P=0.05)	0.050	0.049	0.033	0.118	0.095	0.071	0.117	0.111	0.075
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.870	0.877	0.873	1.503	1.510	1.507	1.652	1.658	1.655
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.955	0.957	0.956	1.650	1.660	1.655	1.825	1.832	1.828
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.783	0.793	0.788	1.440	1.447	1.443	1.545	1.548	1.547
SEm±	0.020	0.019	0.014	0.046	0.037	0.030	0.045	0.043	0.031
CD (P=0.05)	0.062	0.060	0.040	0.145	0.116	0.087	0.143	0.136	0.092
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

adoption of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed registered the significantly highest fresh weight of nodules $plant^{-1}$ of 0.955, 1.650 and 1.825 g at 30, 60 and 90 DAS, respectively during 2019 and 0.957, 1.660 and 1.832 g at 30, 60 and 90 DAS, respectively during 2020. Application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed recorded the minimum fresh weight of nodules $plant^{-1}$(g), which recorded 0.783, 1.440 and 1.545 g at 30, 60 and 90 DAS, respectively during 2019 and 0.793, 1.447 and 1.548 g at 30, 60 and 90 DAS, respectively during 2020. Similar trend was also showed in pooled data. Similar result was reported by Durgeshwari *et al.* (2022).

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.3.1.6 Dry weight of nodules $plant^{-1}$ (g)

Data pertaining to dry weight of nodules $plant^{-1}$ (g) due to cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.46.

Effect of cropping system

Data pertaining to influence of dry weight of nodules $plant^{-1}$ result that there was significant variation among the treatments in both the years. During 2019, it was evident from the data that the maximum dry weight (g) of nodules $plant^{-1}$ (0.103, 0.162 and 0.170 g at 30, 60 and 90 DAS, respectively) was obtained in sole soybean. Significantly lowest was recorded in rice intercropped with soybean (0.096, 0.151 and 0.159 g at 30, 60 and 90 DAS, respectively). In 2020, the highest dry weight (g) of nodules $plant^{-1}$ received in sole soybean (0.105, 0.163 and 0.172 g at 30, 60 and 90 DAS, respectively). The minimum was recorded at C_5 (Rice + soybean with 3:1 row ratio) with the values of 0.097, 0.152 and 0.160 g at 30, 60 and 90 DAS, respectively). A further analysis of the pooled data of the two years revealed that highest dry weight (g) of nodules plant^{-1} was recorded in sole soybean (0.104, 0.163 and 0.171 g at 30, 60 and 90 DAS, respectively). The significantly lowest values were recorded in rice intercropped with soybean (0.096, 0.152 and 0.159 g at 30, 60 and 90 DAS, respectively). Higher values with respect to yield parameters were attributed to lack of inter space competition under sole cropping that could otherwise happen in intercropping system. These findings are in conformity with the findings of Shri *et al*. (2014).

Effect of nutrient management

There was marked influence of different nutrient management practices on dry weight of nodules plant^{-1}. Observation on the data showed that values of 0.109, 0.168 and 0.176 g at 30, 60 and 90 DAS, respectively during 2019 and 0.111, 0.170 and 0.178 g at 30, 60 and 90 DAS respectively during 2020 were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and were statistically superior to rest of the treatments. The lowest was recorded in treatment N_3 (50% RDF + FYM @ 7.5 ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation. The pooled data of both the years also revealed a significant difference with the highest dry weight of nodules plant^{-1} of 0.110, 0.169 and .177 g at 30, 60 and 90 DAS, respectively, when the crop was applied with 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest value was recorded of 0.092, 0.150 and 0.156 g at 30, 60 and 90 DAS, respectively, when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The increased in dry weight of nodules plant^{-1} might be owing to better availability of nutrients throughout the crop

Table 4.46: Effect of cropping systems and nutrient management practices on dry weight of nodules plant^{-1} (g) at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	0.103	0.105	0.104	0.162	0.163	0.163	0.170	0.172	0.171
C_5 - Rice + soybean (3:1)	0.096	0.097	0.096	0.151	0.152	0.152	0.159	0.160	0.159
SEm±	0.002	0.002	0.001	0.003	0.003	0.002	0.003	0.003	0.002
CD (P=0.05)	0.005	0.005	0.004	0.010	0.011	0.007	0.009	0.011	0.007
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.098	0.099	0.099	0.153	0.154	0.153	0.162	0.164	0.163
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.109	0.111	0.110	0.168	0.170	0.169	0.176	0.178	0.177
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.091	0.092	0.092	0.149	0.150	0.150	0.155	0.156	0.156
SEm±	0.002	0.002	0.001	0.004	0.004	0.003	0.004	0.004	0.003
CD (P=0.05)	0.006	0.007	0.004	0.012	0.013	0.008	0.012	0.013	0.008
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

growth that ultimately improved the growth and yield contributing characters of soybean. Similar findings were also observed by Konthoujam *et al*. (2013).

Interaction Effect

The number of dry weight of nodules plant^{-1} (g) of soybean was not persuaded significantly by interaction effect of cropping system and nutrient management.

4.3.1.7 Leaf area index

The data on leaf area index of soybean due to different cropping system and nutrient management recorded at 30, 60 and 90 DAS are presented in Table 4.47.

Effect of cropping system

Regarding the effect of cropping system, the results revealed that different cropping system significantly influence on leaf area index. During 2019, sole soybean (C_3) registered significantly maximum value on leaf area index of 0.60, 2.43 and 2.68 at 30, 60 and 90 DAS, respectively. The corresponding values under rice intercropped with soybean (C_5) were 0.52, 2.20 and 2.48 at 30, 60 and 90 DAS, respectively. During 2020, similar trend followed significantly highest leaf area index was recorded in sole soybean (0.61, 2.45 and 2.69 at 30, 60 and 90 DAS, respectively) and the lowest (0.54, 2.22 and 2.51 at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with soybean. Result obtained from the pooled data of 2019 and 2020 also revealed that there was a significant effect on leaf area index due to cropping systems. Significantly highest leaf area index (0.61, 2.44 and 2.68 at 30, 60 and 90 DAS, respectively) was recorded in sole soybean and the lowest (0.53, 2.21 and 2.49 at 30, 60 and 90 DAS, respectively) was recorded in rice intercropped with soybean. In all the growth stages highest leaf area index was recorded in sole soybean and lowest was in rice intercropped with soybean, which might be due to vice versa for space and light. Mandal *et al*. (2014)

reported that the results also indicated that LAI of both the intercrops (legumes) reduced under intercropping treatments.

Effect of nutrient management

The effect of different treatments on leaf area index was significant. In 2019, the significantly superior leaf area index (0.64, 2.56 and 2.77 at 30, 60 and 90 DAS, respectively) was achieved in incorporation of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed and lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with value of 0.48, 2.09 and 2.41 at 30, 60 and 90 DAS, respectively. During the second year also recorded similar result with the maximum leaf area index of 0.66, 2.56, 2.79 at 30, 60 and 90 DAS, respectively with treatment N_2 (75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) and lowest was recorded at N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 0.51, 2.10, 2.42 at 30, 60 and 90 DAS, respectively. Pooled data of both the years followed the similar findings with the highest leaf area index was observed with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed 0.65, 2.56 and 2.78 at 30, 60 and 90 DAS, respectively, while the lowest dry matter (g) $plant^{-1}$ was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with 0.49, 2.10 and 2.41 at 30, 60 and 90 DAS, respectively. The feasible reason for higher values of leaf area index could be because of the integration and availability of mineral fertilizers, organic manures along with consortia throughout the growing period of crop, this leads to ease of nitrogen availability to the crop, thus plant did not expose to nutrient stress condition at any stage. This outcome was already obtained by Devi *et al*. (2013) and Morya *et al*. (2018).

Table 4.47: Effect of cropping systems and nutrient management practices on leaf area index at different growth stages of soybean

Treatments	30 DAS			60 DAS			90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	0.60	0.61	0.61	2.43	2.45	2.44	2.68	2.69	2.68
C_5 - Rice + soybean (3:1)	0.52	0.54	0.53	2.20	2.22	2.21	2.48	2.51	2.49
SEm±	0.01	0.01	0.01	0.04	0.04	0.03	0.04	0.06	0.04
CD (P=0.05)	0.04	0.04	0.03	0.12	0.13	0.08	0.14	0.18	0.11
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.55	0.57	0.56	2.31	2.34	2.32	2.56	2.58	2.57
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.64	0.66	0.65	2.56	2.56	2.56	2.77	2.79	2.78
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.48	0.51	0.49	2.09	2.10	2.10	2.41	2.42	2.41
SEm±	0.02	0.02	0.01	0.05	0.05	0.03	0.05	0.07	0.04
CD (P=0.05)	0.05	0.05	0.03	0.15	0.16	0.10	0.17	0.22	0.13
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.3.1.8 Crop growth rate (g m^{-2} day^{-1})

The effects of cropping system and nutrient management on crop growth rate (g m^{-2} day^{-1}) of soybean recorded at 30- 60 and 60-90 DAS are presented in Table 4.48.

Effect of cropping system

Close scrutiny of the data recorded that there was a significant difference among cropping systems. Significantly superior crop growth rate was recorded at sole soybean with the values of 10.08 g m^{-2} day^{-1} in 2019, 10.85 g m^{-2} day^{-1} in 2020 and 10.46 g m^{-2} day^{-1}during pooled at 30-60 DAS. Significantly lowest (7.38, 8.25 and 7.81 g m^{-2} day^{-1} in 2019, 2020 and in pooled data, respectively) was recorded when rice intercropped with soybean at 30-60 DAS. At 60-90 DAS there was no significant difference recorded in the response of crop growth rate among cropping systems during both the years. Sole crop of soybean exhibited significantly higher CGR compared to soybean as an intercrop. Alom *el al*. (2010) reported that reduction of leaf area and availability of sunlight to underneath of canopy in intercropping situations may be the reasons for lower CGR of intercrop (legumes). Similar finding was reported by Rathiya *et al*., 2010.

Effect of nutrient management

A reference to the data presented in Table 4.48 revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly highest crop growth rate of 11.23, 11.96 and 11.59 g m^{-2} day^{-1} during 2019, 2020 and in pooled data, respectively at 30-60 DAS, while the lowest (6.69, 7.64 and 7.16 g m^{-2} day^{-1} during 2019, 2020 and in pooled

Table 4.48: Effect of cropping systems and nutrient management practices on crop growth rate (g m^{-2} day^{-1}) at different growth stages of soybean

Treatments	30- 60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	10.08	10.85	10.46	7.45	7.27	7.36
C_5 - Rice + soybean (3:1)	7.38	8.25	7.81	6.67	6.19	6.43
SEm±	0.36	0.36	0.26	0.61	0.50	0.40
CD (P=0.05)	1.15	1.14	0.76	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	8.27	9.06	8.66	7.28	6.69	6.99
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	11.23	11.96	11.59	8.40	8.59	8.49
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	6.69	7.64	7.16	5.50	4.91	5.20
SEm±	0.45	0.44	0.31	0.75	0.61	0.48
CD (P=0.05)	1.41	1.39	0.93	NS	1.92	1.43
Interaction (C X N)	NS	NS	NS	NS	NS	NS

was no significant difference recorded in the response of crop growth rate to different nutrient management practices during 2019. Data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly highest crop growth rate of 8.59 and 8.49 g m^{-2} day^{-1} during 2020 and in pooled data, respectively at 60-90 DAS, while the lowest (4.91 and 5.20 g m^{-2} day^{-1} during 2020 and in pooled data respectively) was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) at 30-60 DAS. The significant interactive effect as a consequence of organic manures and fertilizers application on crop growth rate might be due to supply of additional plant nutrients and increased availability of native soil nutrients due to increased microbial activity.

Interaction Effect

Interaction effect between cropping system and various nutrient management practices found to be non-significant during both the years of experimentation.

4.3.1.9 Relative growth rate (g g^{-1} day^{-1})

The result presented in Table 4.49 showed the effects of cropping system and nutrient management practices on relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS and 60-90 DAS.

Effect of cropping system

The perusal of the data pertaining to relative growth rate in Table 4.49 indicated that there was a significant difference among cropping systems only during 2019. Significantly highest (0.076 g $g^{-1}$$day^{-1}$ during 2019 and in pooled data) relative growth rate was reported in sole soybean and lowest (0.071 and 0.072 g g^{-1} day^{-1} during 2019 and in pooled data) was recorded in rice intercropped with soybean at 30-60 DAS. There was no significant difference due to cropping system in 2020 at 30-60 DAS and at 60-90 DAS during both the

Table 4.49: Effect of cropping systems and nutrient management practices on relative growth rate (g g^{-1} day^{-1}) at different growth stages of soybean

Treatments	30- 60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	0.076	0.077	0.076	0.017	0.016	0.017
C_5 - Rice + soybean (3:1)	0.071	0.073	0.072	0.019	0.016	0.018
SEm±	0.002	0.001	0.001	0.002	0.002	0.001
CD (P=0.05)	0.005	NS	0.003	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.073	0.074	0.074	0.019	0.017	0.018
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.078	0.078	0.078	0.018	0.017	0.017
N_3 - 50% RDF + FYM@ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	0.070	0.072	0.071	0.018	0.014	0.016
SEm±	0.002	0.002	0.001	0.003	0.002	0.002
CD (P=0.05)	0.006	NS	0.004	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

years. Higher relative growth rate of soybean was observed in monoculture compared to intercropping systems might be due to no intercrop competition for light, nutrients, moisture and space.

Effect of nutrient management

Application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly highest relative growth rate of 0.078 g g^{-1} day^{-1} during 2019 and in pooled data at 30-60 DAS, while the lowest (0.070 and 0.071 g g^{-1} day^{-1} during 2019 and in pooled data, respectively) was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) at 30-60 DAS. At 60-90 DAS there was no significant difference recorded in the response of relative growth rate to different nutrient management practices during 2019 and 2020 at 60-90 DAS. This may be due to the fact that greater availability of nutrients with the application of organic, inorganic fertilizers and biofertilizers seems to have promoted various physiological activities of plant thus growth and development of the plant.

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.3.1.10 Net assimilation rate (g m^{-2} day^{-1})

The data pertaining to net assimilation rate (g m^{-2} day^{-1}) of soybean as influenced by cropping system and nutrient management at 30-60 DAS and 60-90 DAS are presented in Table 4.50.

Effect of cropping system

There was statistical difference between values of net assimilation rate among cropping systems only at 30-60 DAS. Sole soybean (C_3) registered significantly higher net assimilation rate of 7.18, 7.51 and 7.35 g m^{-2} day^{-1} in 2019, 2020 and in pooled data, respectively at 30-60 DAS. The corresponding values under rice intercropped with soybean (C_5) were 5.86 g m^{-2} day^{-1} in 2019, 6.32 g m^{-2} day^{-1}, 6.09 g m^{-2} day^{-1} in pooled data at 30-60 DAS. Data on net assimilation rate signifies that there was no significant difference due to cropping system at 60-90 DAS during both the years of investigations. The NAR of intercropped soybean with cereal was less. This may be attributed to the less efficient conversion of light energy into dry matter in intercropped soybean.

Effect of nutrient management

Application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly highest net assimilation rate of 7.61, 7.92 and 7.76 g m^{-2} day^{-1} during 2019, 2020 and in pooled data at 30-60 DAS, while the lowest (5.64, 6.20 and 5.92 g m^{-2} day^{-1} during 2019, 2020 and in pooled data, respectively) was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) at 30-60 DAS. The data on net assimilation rate clearly indicated that there was no significant variation among the different nutrient management practices during 2019 and 2020 at 60-90 DAS. The advantage of combined application of organic manures and fertilizer is quite obvious, as these provide a steady supply of nutrients leading better growth of plants. Moreover, the increased availability of P and K in addition to other plant nutrients released by the organic manures might have contributed in enhancing the yield attributes like net assimilation rate. These finding are in close proximity with Verma *et al*. (2017).

Interaction Effect

Interaction effect between cropping system and various nutrient management practices found to be non-significant during both the years of experimentation.

Table 4.50: Effect of cropping systems and nutrient management practices on net assimilation rate (g m^{-2} day^{-1}) at different growth stages of soybean

Treatments	30- 60 DAS			60-90 DAS		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	7.18	7.51	7.35	3.00	2.83	2.92
C_5 - Rice + soybean (3:1)	5.86	6.32	6.09	2.82	2.55	2.68
SEm±	0.30	0.27	0.20	0.28	0.23	0.18
CD (P=0.05)	0.95	0.86	0.60	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.32	6.64	6.48	3.03	2.72	2.87
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	7.61	7.92	7.76	3.20	3.20	3.20
N_3 - 50% RDF + FYM@ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	5.64	6.20	5.92	2.50	2.17	2.33
SEm±	0.37	0.33	0.25	0.35	0.28	0.22
CD (P=0.05)	1.16	1.05	0.74	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

4.3.2 Phenological parameters

4.3.2.1 Days to 50% flowering, Days to 50% maturity, Days to harvesting

The data on days to 50% flowering, 50% maturity and days to harvesting were recorded in both the cropping period of the years and which are presented in Table 4.51.

Effect of cropping system

The critical analysis of the data clearly revealed that there was no significant variation in the cropping system on 50% flowering, 50% maturity and days to harvesting.

Effect of nutrient management

There was no significant difference due to nutrient management during both the years of experiment on 50% flowering, 50% maturity and days to harvesting.

Interaction effect

Interaction effect of cropping system and nutrient management did not show any significant difference in both the years.

4.3.3 Yield attributes

4.3.3.1 Number of pods plant^{-1}

Data on number of pods plant^{-1} as influenced by cropping system and nutrient management practices are presented in Table 4.52.

Table 4.51: Effect of cropping systems and nutrient management practices on phenological parameters of soybean

Treatments	Days to 50% flowering			Days to 50% maturity			Days to harvesting		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	39.38	39.22	39.30	101.42	101.27	101.34	109.98	110.18	110.08
C_5 - Rice + soybean (3:1)	39.47	38.80	39.13	101.98	101.18	101.58	110.31	110.18	110.24
SEm±	0.55	0.36	0.33	0.35	0.28	0.22	0.24	0.33	0.20
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	39.10	39.07	39.08	101.93	101.13	101.53	110.23	110.67	110.45
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	39.57	38.77	39.17	101.60	101.13	101.37	110.33	110.13	110.23
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	39.60	39.20	39.40	101.57	101.40	101.48	109.87	109.73	109.80
SEm±	0.67	0.44	0.40	0.43	0.34	0.28	0.29	0.40	0.25
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Effect of cropping system

The variation on number of pods plant^{-1} due to cropping system was found to be significant during both years of experiment. During 2019 and 2020, the highest number of pods plant^{-1} (50.95 plant^{-1} and 52.28 plant^{-1}) was recorded in the treatment sole soybean. The lowest (46.93 and 48.15 plant^{-1} during 2019 and 2020, respectively) number of pods plant^{-1} was recorded in C_5 (Rice + soybean at 3:1 row ratio). Pooled result thus obtained compiled with the findings of both the years. The highest number of pods plant^{-1} (51.61 plant^{-1}) was recorded in C_3 (Sole soybean) and lowest (47.54 plant^{-1}) was recorded at rice intercropped with soybean. Sole soybean recorded the highest number of pods plant^{-1} since it suffered from inter specific competition in the intercropping treatments.

Effect of nutrient management

The variation on number of pods plant^{-1} due to different nutrient management practices found to be significant during both the years of experiment. During 2019 and 2020, the highest number of pods plant^{-1} (55.21 plant^{-1} and 56.71 plant^{-1}) was recorded in the treatment N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed), while the lowest (43.45 plant^{-1} and 44.45 plant^{-1}) was recorded in application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. Pooled data thus obtained recorded the highest number of pods plant^{-1} (55.96 plant^{-1}) with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed.

Table 4.52: Effect of cropping systems and nutrient management practices on yield attributes of soybean

Treatments	Number of pods plant^{-1}			Number of seeds pod^{-1}		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	50.95	52.28	51.61	2.27	2.27	2.27
C_5 - Rice + soybean (3:1)	46.93	48.15	47.54	2.09	2.16	2.12
SEm±	1.04	1.01	0.72	0.10	0.06	0.06
CD (P=0.05)	3.29	3.17	2.14	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	48.17	49.50	48.84	2.20	2.20	2.20
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	55.21	56.71	55.96	2.27	2.30	2.28
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	43.45	44.45	43.95	2.07	2.13	2.10
SEm±	1.28	1.23	0.89	0.13	0.08	0.07
CD (P=0.05)	4.02	3.88	2.62	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

The lowest (43.95 plant^{-1}) was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Similarly, the integration of organic fertilizer with inorganic fertilizer increased the availability of nutrients to the plants. This may be the reason for increasing the number of pods plant^{-1}. This result was similar to the findings of Babhulkar *et al*. (2002).

Interaction effect

The interaction effects between cropping system and nutrient management practices on number of pods plant^{-1} recorded non-significant variation during both the years of experimentation.

4.3.3.2 Number of seeds pod^{-1}

The effects of cropping system and nutrient management practices on number of seeds pod^{-1} are presented in Table 4.52.

Effect of cropping system

The effect of cropping systems did not bring any significant difference in number of seeds pod^{-1} of soybean.

Effect of nutrient management

Application of different nutrient management practices did not show any significant effect on number of seeds pod^{-1} of soybean.

Interaction effect

The combined effect of different cropping system and nutrient management also could not bring any statistical difference on number of seeds pod^{-1} of soybean.

4.3.3.3 Pod weight (g) plant^{-1}

Data pertaining to variation in pod weight (g) plant^{-1} due to different cropping system and nutrient management practices are presented in Table 4.53.

Effect of cropping system

Sole crop of soybean recorded higher pod weight (g) plant^{-1} (19.27 and 20.17 g in 2019 and 2020, respectively). Significantly lowest (17.18 and 17.71 g in 2019 and 2020, respectively) pod weight (g) registered in rice+ soybean intercropping system during both the years. Further analysis of the pooled data revealed that highest number of pod weight (g) plant^{-1} was recorded in sole soybean with value of 19.72 g. The minimum (17.44 g) was recorded from rice intercropped with soybean. The decrease in intercropping soybean pod weight is due to the higher shade from rice. Shade by higher plants in intercropping decreases the rate of photosynthesis in the growth of plants below the leaf area, the lower the leaf area because not all leaves are equally efficient in absorbing solar radiation. Hence reducing pod weight. Similar finding was reported by Olufujo (1997).

Effect of nutrient management

The data indicated that the effect of different treatments on pod weight (g) plant^{-1} was found to be significant. Application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed resulted in highest pod weight (g) plant^{-1} (21.43 and 22.19 g) during both the years. The lowest pod weight (g) plant^{-1} was recorded at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 15.26 and 16.12 g in 2019 and 2020, respectively. On further scanning of the pooled data revealed that the highest pod weight (g) plant^{-1} (21.81 g) recorded in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1}. The significantly lowest (15.69 g) was recorded in application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The increased supply of multi-nutrients might have increased multi-role activities in plant and soil which in turn, resulted in greater accumulation of carbohydrates (photosythates), protein and their translocation to the reproductive organs *i.e.* yield attributes.

Table 4.53: Effect of cropping systems and nutrient management practices on yield attributes of soybean

Treatments	Pod weight (g) plant^{-1}			1000 seed weight (g)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	19.27	20.17	19.72	120.24	120.46	120.35
C_5 - Rice + soybean (3:1)	17.18	17.71	17.44	116.85	116.91	116.88
SEm±	0.61	0.60	0.43	1.56	1.61	1.12
CD (P=0.05)	1.93	1.88	1.26	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	17.98	18.51	18.24	118.76	118.80	118.78
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	21.43	22.19	21.81	121.49	121.50	121.50
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1}+biofertilizer consortium @ 20 g kg^{-1} seed	15.26	16.12	15.69	115.38	115.75	115.57
SEm±	0.75	0.73	0.52	1.91	1.97	1.37
CD (P=0.05)	2.37	2.30	1.54	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

These results corroborate the findings of many workers Dhage *et al*. (2008), Alam *et al*. (2009) and Tripathi *et al*. (2008).

Interaction effect

During both the years of study, interaction between cropping system and nutrient management practices was found non-significant.

4.3.3.4 1000 seed weight (g)

Data on test weight as influenced by cropping system and nutrient management practices are presented in Table 4.53.

Effect of cropping system

There was no significant difference due to cropping system on 1000 seed weight (g) during both the years of experiment.

Effect of nutrient management

There was no significant difference due to nutrient management on 1000 seed weight (g) during both the years of experiment.

Interaction effect

The interaction effects between cropping system and nutrient management practices on 1000 seed weight (g) recorded non-significant variation during both the years of experimentation.

4.3.4 Yield

4.3.4.1 Seed yield (t ha^{-1})

Data pertaining to seed yield due to cropping system and nutrient management are presented in Table 4.54 and Fig 4.6.

Effect of cropping system

Adaption of cropping systems practices markedly influenced the seed yield of soybean in both the years. Among the cropping system sole soybean produced highest yield (1.74 and 1.79 t ha^{-1} in 2019 and 2020, respectively). The lowest seed yield was observed from C_5 (Rice+ soybean at 3:1 row ratio) with value being 0.81 and 0.85 t ha^{-1} in 2019 and 2020, respectively. Maximum value (1.77 t ha^{-1}) of pooled was registered in C_3 (Sole soybean). The lowest value was recorded in rice intercropped with soybean (0.83 t ha^{-1}). Sole soybean recorded the highest seed yield since it suffered from inter specific competition in the intercropping treatments. Similar results was reported by Sawargi and Tripathi (1999) in rice and soybean intercropping system, Kithan (2012) in maize and soybean intercropping system, Aye (2013) in sunflower and soybean and Yhokha (2015) in soybean based intercropping. Muoneke *et al*. (2007) also reported higher seed yield of soybean in sole cropping than intercropping with cereals. Egbe *et al.* (2010) reported that the intercrop (soybean) yield get decreased in intercropping treatments as compare to sole cropping of soybean might be due to the interspecific competition among the intercrop components for light, water, air and nutrients and also the aggressive effects maize (C_4 species) on soybean, a C_3 species.

Effect of nutrient management

The effect of nutrient management on yield showed significant variation in yield. It was observed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly increased the yield during both the years as well as pooled data with value of 1.53 t ha^{-1} during the first year, 1.54 t ha^{-1} during the second year and 1.53 t ha^{-1} in pooled data, respectively. The minimum value was registered at application of 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed during both the years and as well as in pooled data with value being 1.07 t ha^{-1} during first year, 1.12 t ha^{-1} during second year and 1.10 t ha^{-1} in pooled data, respectively. The positive impact of availability of individual plant nutrients and humic substances from manure and balanced supplement of nitrogen through inorganic fertilizers might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters. The results corroborate with the findings of Konthoujam *et al*. (2013).

Interaction effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on seed yield.

4.3.4.2 Stover yield (t ha^{-1})

Data related to stover yield (t ha^{-1}) due to cropping system and nutrient management are presented in Table 4.54 and Fig 4.7.

Effect of cropping system

The perusal of data indicated that stover yield was significantly influence by different cropping system. Treatment C_3 (Sole soybean) recorded highest value over rest of the treatments during both the years and even in pooled data (3.58, 3.64 and 3.61 t ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest value recorded during 2019 was 1.74 t ha^{-1}, 1.79 t ha^{-1} was in 2020 and pooled data recorded 1.77 t ha^{-1}. The significant reduction in yield observed from the intercrop plots may be attributed to inter specific competition among the plants for space, nutrients, light, water *etc*. Pal *et al*. (1993) and Addo-Quaye *et al.* (2011) all reported reduced intercrop yield in soybean + maize or soybean + sorghum intercrop and soybean+ maize intercrop respectively, when they investigated the effect of component density on the yield of sorghum or maize intercrop with soybean or beans.

Effect of nutrient management

It is apparent from the data presented in Table 4.54 that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1}

Table 4.54: Effect of cropping systems and nutrient management practices on yield of soybean

Treatments	Seed yield (t ha^{-1})			Stover yield (t ha^{-1})			Harvest index (%)		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	1.74	1.79	1.77	3.58	3.64	3.61	32.76	32.96	32.86
C_5 - Rice + soybean (3:1)	0.81	0.85	0.83	1.74	1.79	1.77	31.62	31.95	31.78
SEm±	0.04	0.03	0.02	0.11	0.10	0.08	0.83	0.58	0.51
CD (P=0.05)	0.12	0.10	0.07	0.36	0.31	0.22	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.23	1.29	1.26	2.53	2.63	2.58	32.40	32.70	32.55
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.53	1.54	1.53	3.10	3.12	3.11	33.11	33.12	33.11
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.07	1.12	1.10	2.36	2.41	2.38	31.06	31.55	31.30
SEm±	0.05	0.04	0.03	0.14	0.12	0.09	1.02	0.71	0.62
CD (P=0.05)	0.15	0.12	0.09	0.44	0.38	0.27	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

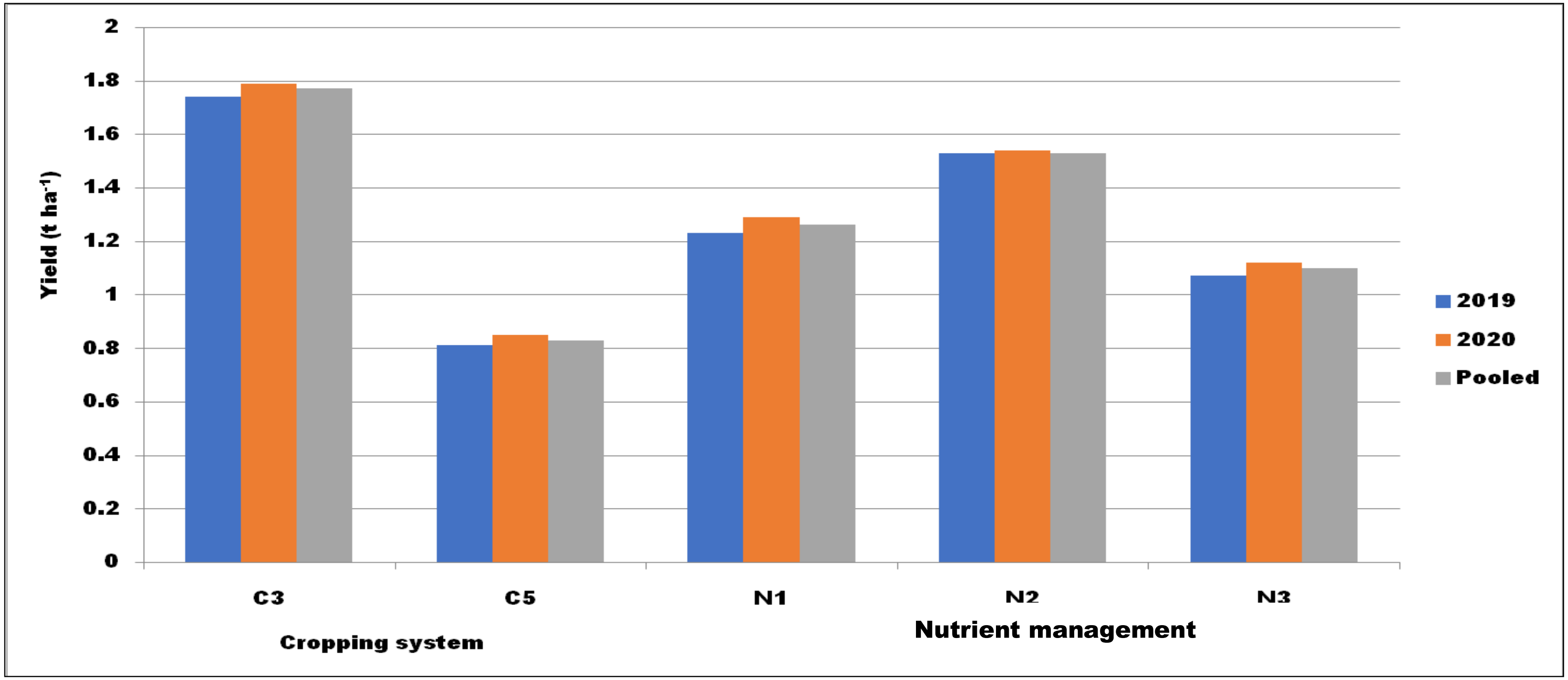


Fig 4.6: Effect of cropping system and nutrient management on seed yield of soybean (t ha^{-1})

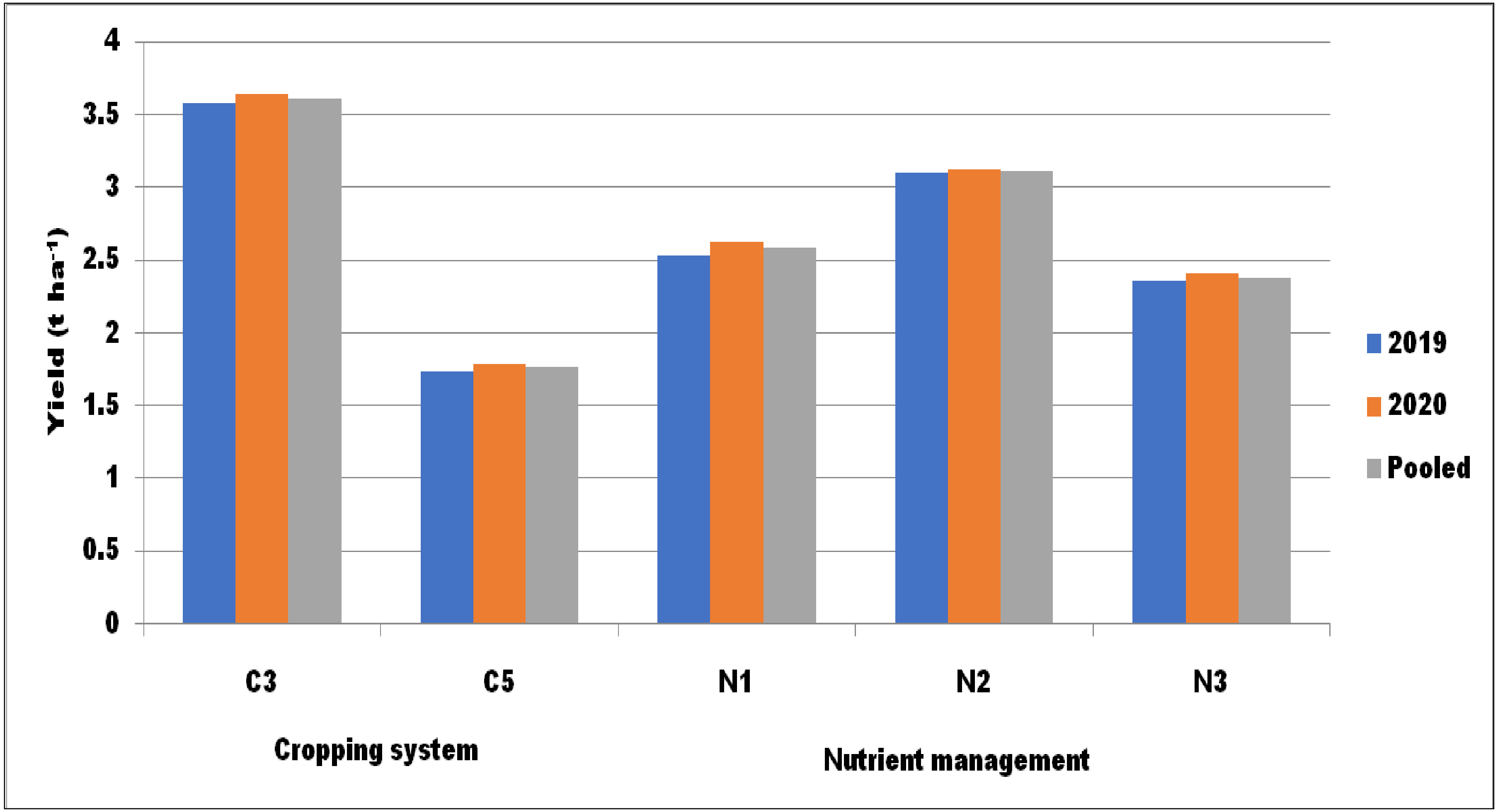


Fig 4.7: Effect of cropping system and nutrient management on stover yield of soybean (t ha^{-1})

seed significantly enhanced stover yield during both the years and similarly in pooled with the value being 3.10 t ha^{-1} in 2019, 3.12 t ha^{-1} in 2020 and 3.11 t ha^{-1} in pooled data. Significantly minimum stover yield (2.36, 2.41 and 2.38 t ha^{-1} during 2019, 2020 and in pooled data, respectively) was recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Increase in stover yield of soybean might be due to supply of essential mineral nutrients in balanced amount which resulted in better growth and development of plants. Similar results were reported by Thirumelai *et al*. (1993) and Kumar *et al*. (2009). Verma *et al.* (2017) reported that application of 75 % NPK + 25 % N through vermicompost + Rhizobium + PSB significantly enhanced seed, stover and biological yield of soybean by 17.4, 16.8 and 12.0 % over 100% NPK alone as chemical fertilizer, respectively.

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.3.4.3 Harvest index (%)

The data pertaining to harvest index due to cropping system and nutrient management practices are presented in Table 4.54

Effect of cropping system

Application of different cropping system did not show any significant effect on harvest index of soybean.

Effect of nutrient management

The effect of different nutrient management did not bring significant impact on the harvest index of soybean.

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on harvest index of soybean.

4.3.5 Nutrient study

4.3.5.1 Nitrogen content in seed (%)

Data on nitrogen content in seed (%) as influenced by cropping system and nutrient management practices are presented in Table 4.55.

Effect of cropping system

Effect of cropping system could not show significant response on per cent nitrogen content in seed.

Effect of nutrient management

Different nutrient management showed significant differences in respect of nitrogen content in seed (%). The maximum nitrogen content in seed recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during both the years and similar trend followed in pooled with the value being 6.164, 6.171 and 6.168 %, respectively. The lowest value being recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} (6.014, 6.020 and 6.017 during 2019, 2020 and in pooled data, respectively). The increased nitrogen concentration in soybean seed might be due to more uptake of nitrogen under conjoint use of organic and inorganic in form of FYM and fertilizer along with biofertilizers.

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on nitrogen content in seed (%).

Table 4.55: Effect of cropping systems and nutrient management practices on nitrogen content (%) in soybean

Treatments	Nitrogen content (%)					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	6.095	6.101	6.098	1.899	1.905	1.902
C_5 - Rice + soybean (3:1)	6.059	6.064	6.061	1.870	1.876	1.873
SEm±	0.032	0.025	0.020	0.037	0.037	0.026
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.051	6.057	6.054	1.883	1.889	1.886
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.164	6.171	6.168	1.995	2.002	1.999
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.014	6.020	6.017	1.776	1.781	1.779
SEm±	0.039	0.031	0.025	0.046	0.046	0.032
CD (P=0.05)	0.122	0.097	0.073	0.144	0.144	0.095
Interaction (C X N)	NS	NS	NS	NS	NS	NS

4.3.5.2 Nitrogen content in stover (%)

The data pertaining to nitrogen content in stover due to cropping system and nutrient management practices are presented in Table 4.55.

Effect of cropping system

Effect of cropping system could not show significant response on per cent nitrogen content in stover.

Effect of nutrient management

Close examination of the data revealed that in both the years as well as in pooled data, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed resulted in significantly highest nitrogen content in stover with the value of 1.995, 2.002 and 1.999% respectively. However application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed registered significantly lowest data with the values being 1.776 % in 2019, 1.781% in 2020 and 1.779% in pooled data. Similar findings were reported by Tumbare (2002).

Interaction effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.3.5.3 Phosphorous content in seed (%)

Data related to phosphorous content in seed (%) due to cropping system and nutrient management are presented in Table 4.56.

Effect of cropping system

No significant changes in seed phosphorous content was observed due to cropping system during both the years of experimentation.

Table 4.56: Effect of cropping systems and nutrient management practices on phosphorous content (%) in soybean

Treatments	Phosphorous content (%)					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	0.381	0.385	0.383	0.277	0.282	0.280
C_5 - Rice + soybean (3:1)	0.377	0.381	0.379	0.273	0.277	0.275
SEm±	0.003	0.003	0.002	0.003	0.003	0.002
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.381	0.385	0.383	0.277	0.281	0.279
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.395	0.399	0.397	0.292	0.295	0.293
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	0.362	0.365	0.363	0.258	0.262	0.260
SEm±	0.003	0.003	0.002	0.003	0.003	0.002
CD (P=0.05)	0.011	0.011	0.007	0.010	0.010	0.007
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Effect of nutrient management

An inference of the data presented in table revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed significantly increased the percent phosphorous content in seed. Similar trend of effect was observed in both the year as well as pooled data with the value of 0.395, 0.399 and 0.397%, respectively. The lowest percent of phosphorous content was recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values being 0.362, 0.365 and 0.363% during 2019, 2020 and in pooled data, respectively. The application of FYM along with nitrogen and phosphorus maintained the available phosphorus in soil sufficiently high perhaps owing to mineralization of organic phosphorus contributing to supply of phosphorus continuously.

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.3.5.4 Phosphorous content in stover (%)

The effects of cropping system and nutrient management practices on phosphorous content in stover (%) are presented in Table 4.56.

Effect of cropping system

No significant differences in percent phosphorous content in stover was observed among all the treatments.

Effect of nutrient management

Nutrient management practices significantly influenced the per cent phosphorous content of stover, the highest being 0.292% in 2019, 0.295% in 2020 and 0.293 % in pooled were recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). The significantly lowest value of 0.258% in 2019, 0.262% in 2020 and 0.260% in pooled data were recorded in treatment N_2 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). The results obtained are in conformity with those of Jagtap (2001).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.3.5.5 Potassium content in seed (%)

Potassium content in seed (%) of rice differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.57.

Effect of cropping system

The data revealed that there was no significant effect of the treatments on percent potassium content in seed during both the years.

Effect of nutrient management

An examination of the data in both the years as well as pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded highest potassium concentration in seed with the values of 1.745% in 2019, 1.751% in 2020 and a pooled value of 1.748%, while the treatments recorded lowest at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with values being 1.453, 1.458 and 1.456 % during 2019, 2020 and in pooled data, respectively. The increased potassium concentration in soybean seed might be due to more uptake of potassium under collective use of organic and inorganic in form of FYM and fertilizer along with biofertilizers.

Table 4.57: Effect of cropping systems and nutrient management practices on potassium content (%) in soybean

Treatments	Potassium content (%)					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	1.601	1.605	1.603	2.463	2.468	2.466
C_5 - Rice + soybean (3:1)	1.591	1.597	1.594	2.453	2.458	2.456
SEm±	0.022	0.018	0.014	0.031	0.031	0.022
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.590	1.595	1.592	2.506	2.512	2.509
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.745	1.751	1.748	2.643	2.647	2.645
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.453	1.458	1.456	2.225	2.230	2.228
SEm±	0.027	0.022	0.018	0.038	0.038	0.027
CD (P=0.05)	0.086	0.069	0.052	0.120	0.118	0.079
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.3.5.6 Potassium content in stover (%)

The result presented in Table 4.57 showed the effects of cropping system and nutrient management practices on potassium content in stover (%)

Effect of cropping system

Effect of cropping system could not show significant response on potassium content in stover (%).

Effect of nutrient management

It was noted that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} obtained statistically superior values of 2.643, 2.647 and 2.645% during 2019, 2020 and in pooled data, respectively, while the lowest values of 2.225, 2.230 and 2.228 during 2019, 2020 and in pooled data were recorded in N_3 treatment (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed).

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.3.5.7 Nitrogen uptake by seed (kg ha^{-1})

Data related to nitrogen uptake by seed (kg ha^{-1}) and interaction of nitrogen uptake by seed (kg ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.58 (a) and 4.58 (b), respectively.

Effect of cropping system

The variations on nitrogen uptake due to cropping system were found to be significant during both the years of experiment. The highest nitrogen uptake 106.30, 109.35 and 107.82 kg ha^{-1} were recorded in treatment sole soybean during 2019, 2020 and in pooled data, respectively. The lowest was recorded in rice intercropped with soybean with the values of 49.13, 51.35 and 50.24 kg ha^{-1} in 2019, 2020 and in pooled data, respectively. Singh *et al*. (2008a) reported that sole soybean removed significantly higher amount of N which might be attributed to cumulative effect of the highest biomass production under this treatment.

Effect of nutrient management

The analysis of variance study of the data indicated towards a significant difference among the responses of the various nutrient management practices. Significantly highest value was recorded in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment during both the years (94.06, 95.17 and 94.61 kg ha^{-1} in 2019, 2020 and in pooled data, respectively), while the lowest was recorded with application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (64.38, 67.57 and 65.98 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). Bonde and Gawande (2017) reported that the highest N uptake by soybean was recorded with the application of 75% NP + 4t FYM + 25 kg S ha^{-1} or 5 kg Zn ha^{-1}.

Interaction Effect

The interaction effects between cropping system and nutrient management practice were found to be significant only during 2019. The highest nitrogen uptake was associated with the interaction C_3N_2 (Sole soybean +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 127.59 and 128.14 kg ha^{-1} during 2019 and in pooled data, respectively, which was followed by C_3N_1 (Sole soybean +100%

RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 103.57 and 105.23 kg ha^{-1} during 2019 and in pooled data, respectively. The significantly lowest (41.02 and 41.85 kg ha^{-1} during 2019 and in pooled data, respectively) was recorded in C_5N_3 (Rice intercropped with soybean and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

4.3.5.8 Nitrogen uptake by stover (kg ha^{-1})

The data pertaining to nitrogen uptake by stover (kg ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.58.

Effect of cropping system

The variations on nitrogen uptake due to cropping system were found to be significant during both the years of experiment. The highest nitrogen uptake 68.39, 69.76 and 69.08 kg ha^{-1} were recorded in treatment sole soybean during 2019, 2020 and in pooled data respectively. The lowest was recorded in rice intercropped with soybean with the values of 32.72, 33.81 and 33.26 kg ha^{-1} in 2019, 2020 and in pooled data, respectively.

Effect of nutrient management

Significant differences in nitrogen uptake by the crop were noticed among all the treatments, the maximum values being 61.99, 62.63 and 62.31 kg ha^{-1} during 2019, 2020 and in pooled were recorded at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment. The nitrogen uptake value was recorded low at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values being 41.95, 43.00 and 42.48 kg ha^{-1} during 2019, 2020 and in pooled data, respectively. Bandopadhyay *et al.* (2016) also reported similar findings.

Table 4.58 (a): Effect of cropping systems and nutrient management practices on nitrogen uptake (kg ha^{-1}) in soybean

Treatments	**Nitrogen uptake (kg ha^{-1})**					
	Seed			**Stover**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	106.30	109.35	107.82	68.39	69.76	69.08
C_5 - Rice + soybean (3:1)	49.13	51.35	50.24	32.72	33.81	33.26
SEm±	1.97	1.76	1.32	2.60	2.34	1.75
CD (P=0.05)	6.22	5.56	3.90	8.19	7.38	5.16
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	74.71	78.31	76.51	47.72	49.72	48.72
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	94.06	95.17	94.61	61.99	62.63	62.31
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	64.38	67.57	65.98	41.95	43.00	42.48
SEm±	2.42	2.16	1.62	3.18	2.87	2.14
CD (P=0.05)	7.61	6.81	4.78	10.03	9.04	6.32
Interaction (C X N)	S	NS	S	NS	NS	NS

Table 4.58 (b): Interaction effect of cropping systems and nutrient management practices on nitrogen uptake (kg ha^{-1}) in soybean

Treatments	Nitrogen uptake (kg ha^{-1})	
	Seed	
	2019	Pooled
C_3 N_1	103.57	105.23
C_5 N_1	45.85	47.78
C_3 N_2	127.59	128.14
C_5 N_2	60.53	61.09
C_3 N_3	87.74	90.10
C_5 N_3	41.02	41.85
SEm±	3.42	2.29
CD (P=0.05)	10.77	6.76

Interaction Effect

During both the years of study, cropping system and nutrient management interaction effects were found to be non-significant.

4.3.5.9 Phosphorous uptake by seed (kg ha^{-1})

The result presented in Table 4.59 (a) and 4.59 (b) showed the effects of cropping system and nutrient management practices on phosphorous uptake by seed (kg ha^{-1}) and interaction of phosphorous uptake by seed (kg ha^{-1}) .

Effect of cropping system

Data on phosphorous uptake presented in Table 4.59 revealed that cropping system exerted significant influence on phosphorous uptake by seed. Highest phosphorous uptake in seed was recorded in sole soybean (6.67, 6.93 and 6.80 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest uptake was recorded in rice intercropped with soybean (3.07, 3.24 and 3.16 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). Similar was reported by Kaparwan *et al*. (2021) who had reported that sole chickpea has higher phosphorous uptake then intercropping in chickpea and mustard intercropping system.

Effect of nutrient management

Significant variations in respect to phosphorous uptake in seed was observed during both the years of investigation. Values of 6.04 and 6.16 kg ha^{-1} were obtained during 2019 and 2020, respectively at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and was statistically superior to rest of the treatments. The lowest (3.87 and 4.11 kg ha^{-1}) was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during both the years of investigation. The pooled data of both the years also revealed a significant difference with the highest phosphorous uptake by seed of 6.10 kg ha^{-1}, when the crop was applied with

Table 4.59 (a): Effect of cropping systems and nutrient management practices on phosphorous uptake (kg ha^{-1}) in soybean

Treatments	**Phosphorous uptake (kg ha^{-1})**					
	Seed			**Stover**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	6.67	6.93	6.80	10.00	10.33	10.17
C_5 - Rice + soybean (3:1)	3.07	3.24	3.16	4.78	4.99	4.88
SEm±	0.14	0.13	0.10	0.36	0.32	0.24
CD (P=0.05)	0.43	0.42	0.28	1.13	0.99	0.71
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.71	4.98	4.84	7.03	7.41	7.22
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	6.04	6.16	6.10	9.08	9.26	9.17
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	3.87	4.11	3.99	6.07	6.30	6.18
SEm±	0.17	0.16	0.12	0.44	0.39	0.29
CD (P=0.05)	0.53	0.52	0.35	1.39	1.22	0.86
Interaction (C X N)	S	NS	S	NS	NS	NS

Table 4.59 (b): Interaction effect of cropping systems and nutrient management practices on phosphorous uptake (kg ha^{-1}) in soybean

Treatments	Phosphorous uptake (kg ha^{-1})	
	Seed	
	2019	Pooled
C_3 N_1	6.52	6.66
C_5 N_1	2.89	3.02
C_3 N_2	8.22	8.28
C_5 N_2	3.87	3.92
C_3 N_3	5.28	5.46
C_5 N_3	2.46	2.52
SEm±	0.24	0.17
CD (P=0.05)	0.74	0.49

75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. The lowest (3.99 kg ha^{-1}) value was recorded when the crop was applied with 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed. It might be due to addition of FYM, which played important role in solublization of insoluble phosphorus and potash, led to higher availability of plant nutrients. The availability of nitrogen and phosphorus increased by addition of FYM thus total uptake of NPK increased. Similar results was supported by Singh *et al*. (2020).

Interaction Effect

The interaction effects of different treatments were found to be non significant during 2020. Significant variation was observed with the highest value of 8.22 and 8.28 kg ha^{-1} associated with the interaction of C_3N_2 (Sole soybean with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 and in pooled data, respectively, which was followed by C_3N_1 (Sole soybean with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination with the values of 6.52 and 6.66 kg ha^{-1} during 2019 and in pooled data, respectively. The significantly minimum (2.46 and 2.52 during 2019 and in pooled data, respectively) was recorded in C_5N_3 (Rice intercropped with soybean and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

4.3.5.10 Phosphorous uptake by stover (kg ha^{-1})

Data related to phosphorous uptake by stover (kg ha^{-1}) due to cropping system and nutrient management are presented in Table 4.59.

Effect of cropping system

Data on phosphorous uptake by stover presented in Table 4.59 revealed that cropping system exerted significant influence on phosphorous uptake by stover. Highest phosphorous uptake in stover was recorded in sole soybean (10.00, 10.33 and 10.17 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest uptake was recorded in rice intercropped with soybean (4.78, 4.99 and 4.88 kg ha^{-1} in 2019, 2020 and in pooled data, respectively).

Effect of nutrient management

Data tabulated in Table 4.59 indicated that nutrient management practices showed significant influence during both the years of study. The highest phosphorous uptake values of 9.08, 9.26 and 9.17 kg ha^{-1} were obtained in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during 2019, 2020 and in pooled data, respectively. The lowest (6.07, 6.30 and 6.18 kg ha^{-1} during 2019, 2020 and in pooled data, respectively) was recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. Sarawgi *et al.* (2008) reported that application of NP + FYM + PSB also enhanced the utilization of P by soybean crop. Similar result was recorded by Kumari *et al.* (2017).

Interaction Effect

During both the years of study, cropping system and nutrient management interaction effects were found to be non-significant.

4.3.5.11 Potassium uptake by seed (kg ha^{-1})

The result presented in Table 4.60 (a) and 4.60 (b) showed the effects of cropping system and nutrient management practices on potassium uptake by seed (kg ha^{-1}) and interaction of potassium uptake by seed (kg ha^{-1}).

Effect of cropping system

Significant differences in potassium uptake by the crop were noticed among all the treatments, the maximum being 28.15 kg ha^{-1} in 2019, 29.00 kg ha^{-1} in 2020 and 28.57 kg ha^{-1} in pooled data were observed in sole soybean. The lowest values of 13.04, 13.65 and 13.34 kg ha^{-1} during 2019, 2020 and in pooled data, respectively was recorded in rice intercropped with soybean. This might be due to significant higher uptake of nutrient by seed and stover because of their higher seed and stover yield as a consequence of increased total dry matter in sole soybean.

Effect of nutrient management

Potassium uptake was also influenced by different nutrient management practices. Significant differences in potassium uptake by the crop were noticed among all the treatments, the maximum being 26.59, 27.00 and 26.80 kg ha^{-1} with the application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed during 2019, 2020 and in pooled data, respectively. The minimum being recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (15.57, 16.37 and 15.97 during 2019, 2020 and in pooled data, respectively). Mohanty *et al*. (2012) reported that integrated fertilizer management ensured higher absorption of NPK because of increased cation exchange capacity in roots.

Interaction Effect

Potassium uptake by seed was significantly affected by the combine practice of cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the yield was highest in C_3N_2 (Sole soybean with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (36.03 kg ha^{-1}), 2020 (36.51 kg ha^{-1}) and pooled (36.27 kg ha^{-1}) which was followed by C_3N_1 (Sole soybean with 100% RDF along with FYM @ 2.5 t ha^{-1}

Table 4.60 (a): Effect of cropping systems and nutrient management practices on potassium uptake (kg ha^{-1}) in soybean

Treatments	Potassium uptake (kg ha^{-1})					
	Seed			Stover		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	28.15	29.00	28.57	89.04	90.67	89.86
C_5 - Rice + soybean (3:1)	13.04	13.65	13.34	43.01	44.40	43.70
SEm±	0.49	0.41	0.32	3.72	3.28	2.48
CD (P=0.05)	1.55	1.28	0.94	11.71	10.35	7.31
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	19.62	20.59	20.11	63.52	66.08	64.80
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	26.59	27.00	26.80	82.11	82.80	82.46
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	15.57	16.37	15.97	52.45	53.73	53.09
SEm±	0.60	0.50	0.39	4.55	4.02	3.04
CD (P=0.05)	1.90	1.56	1.15	14.34	12.67	8.96
Interaction (C X N)	S	S	S	NS	NS	NS

Table 4.60 (b): Interaction effect of cropping systems and nutrient management practices on potassium uptake (kg ha^{-1}) in soybean

Treatments	Potassium uptake (kg ha^{-1})		
	Seed		
	2019	2020	Pooled
C_3 N_1	27.19	28.07	27.63
C_5 N_1	12.06	13.11	12.59
C_3 N_2	36.03	36.51	36.27
C_5 N_2	17.15	17.49	17.32
C_3 N_3	21.22	22.40	21.81
C_5 N_3	9.92	10.34	10.13
SEm±	0.85	0.70	0.55
CD (P=0.05)	2.69	2.21	1.63

and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (27.19, 28.07 and 27.63 kg ha^{-1} during first, second year and as well as in pooled data, respectively). The lowest was recorded in C_5N_3 (Rice intercropped with soybean and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (9.92, 10.34 and 10.13 kg ha^{-1} during first, second and as well as in pooled data, respectively) among all the treatments.

4.3.5.12 Potassium uptake by stover (kg ha^{-1})

Data related to potassium uptake by stover (kg ha^{-1}) due to cropping system and nutrient management are presented in Table 4.60.

Effect of cropping system

The data on potassium uptake by stover revealed significant variation due to different cropping system during both the years of experiment. During 2019 and 2020, highest potassium uptake was recorded from sole soybean with the values of 89.04 and 90.67 kg ha^{-1}, respectively. The statistically lowest was recorded in rice intercropped with soybean treatment with the values 43.01 kg ha^{-1} in 2019 and 44.40 kg ha^{-1} in 2020. The similar trend was followed in pooled data of two years.

Effect of nutrient management

Among the nutrient management, potassium uptake by stover showed significant variation during both the years of experiment. It is indicated from the data that highest value was noticed in N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment with the values 82.11 kg ha^{-1} in 2019, 82.80 kg ha^{-1} in 2020 and 82.46 kg ha^{-1} in pooled data. The statistically minimum was observed in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (52.45, 53.73 and 53.09 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). This increase in K uptake may be attributed to increased seed and straw production. Similar result was reported by Sharma *et al*. (2019) and Arbad and Ismail (2011).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.3.6 Quality parameters

4.3.6.1 Protein content (%)

The effect of cropping system and nutrient management practices on protein content (%) are presented in Table 4.61.

Effect of cropping system

No significant differences in per cent protein content of soybean was observed among the treatments during both the years.

Effect of nutrient management

The highest protein content was recorded at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) with the values of 38.53, 38.57 and 38.55 % during 2019, 2020 and in pooled data, respectively. The lowest value of 37.59, 37.62 and 37.61 % were observed at N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) during 2019, 2020 and pooled data, respectively. As nitrogen increased, the protein content also increased. Application of organic manures in the form of FYM with inorganic fertilizers along with biofertilizer accelerated availability of nitrogen which increased the protein content in grain of soybean. Similar findings were also reported by Jagtap (2001) and Tumbare (2002). Application of FYM along with inorganic fertilizer increased protein content in grain of soybean. Similar results were also reported by Alam *et al*. (2009).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.3.6.2 Protein yield (kg ha^{-1})

The results recorded on the effect of cropping system and nutrient management on the protein yield (kg ha^{-1}) and interaction effect of protein yield (kg ha^{-1}) are presented in Table 4.61 (a) and 4.61 (b), respectively.

Effect of cropping system

The various crop management practices brought significant results on the protein yield of soybean. Highest protein yield was recorded in sole soybean (664.36 and 683.42 and 673.89 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest protein yield was recorded in rice intercropped with soybean (307.07, 320.93 and 314.00 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The protein yield of soybean was reduced probably due to intercrop competition between rice and soybean.

Effect of nutrient management

Significant variations in respect protein yield was observed during both the years of investigation. Values of 587.87, 594.80 and 591.33 kg ha^{-1} during 2019, 2020 and in pooled data respectively were obtained at N_2 (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and was statistically superior to rest of the treatments. The lowest (402.36, 422.33 and 412.35 kg ha^{-1} during 2019, 2020 and in pooled data, respectively) was recorded in treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium@ 20 g kg^{-1} seed). The protein yield of seed increased with the increase in nitrogen

Table 4.61 (a): Effect of cropping systems and nutrient management practices on protein content (%) and protein yield (kg ha^{-1}) in soybean

Treatments	Protein content (%)			Protein yield (kg ha^{-1})		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	38.09	38.13	38.11	664.36	683.42	673.89
C_5 - Rice + soybean (3:1)	37.87	37.90	37.88	307.07	320.93	314.00
SEm±	0.20	0.16	0.13	12.33	11.02	8.27
CD (P=0.05)	NS	NS	NS	38.85	34.74	24.40
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	37.82	37.86	37.84	466.92	489.41	478.17
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	38.53	38.57	38.55	587.87	594.80	591.33
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	37.59	37.62	37.61	402.36	422.33	412.35
SEm±	0.24	0.19	0.15	15.10	13.50	10.13
CD (P=0.05)	0.76	0.61	0.46	47.59	42.54	29.88
Interaction (C X N)	NS	NS	NS	S	NS	S

Table 4.61 (b): Interaction effect of cropping systems and nutrient management practices on protein yield (kg ha^{-1}) in soybean

Treatments	Protein yield (kg ha^{-1})	
	2019	**Pooled**
C_3 N_1	647.31	657.68
C_5 N_1	286.54	298.65
C_3 N_2	797.41	800.86
C_5 N_2	378.32	381.80
C_3 N_3	548.37	563.14
C_5 N_3	256.35	261.55
SEm±	21.36	14.32
CD (P=0.05)	67.30	42.26

levels from organic sources. This finding is closely associated with Alam *et al*. (2009), Sonkamble *et al*. (2010) and Chaturvedi *et al*. (2010).

Interaction Effect

Protein yield was significantly affected by the combine practice of cropping system and nutrient management during 2019 and in pooled data. The perusal of the data revealed that the protein yield was highest in C_3N_2 (Sole soybean +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (797.41 kg ha^{-1}) and pooled (800.86 kg ha^{-1}), which was found to be followed by C_3N_1 (Sole soybean +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (647.31 and 657.68 kg ha^{-1} during first year and as well as in pooled data, respectively). The significantly lowest was recorded in C_5N_3 (Rice intercropped with soybean and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (256.35 and 261.55 during first year and as well as in pooled data, respectively).

4.3.6.3 Oil content (%)

Oil content (%) of soybean differed significantly due to different cropping system and nutrient management practices which are presented in Table 4.62.

Effect of cropping system

The result revealed that different cropping system had non-significant effect on oil content (%) during both the years of experiment.

Effect of nutrient management

Oil content (%) due to nutrient management practices was found to be significant during both the years of experiment. During both the years, oil content (%) was recorded highest in application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (21.38, 21.44 and

21.41% in 2019, 2020 and in pooled data, respectively). The lowest oil content (%) values of 18.62, 18.82 and 18.72% during 2019, 2020 and in pooled data respectively was recorded in the treatment N_3 (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). This increase may be due to mineralization of organic nutrients of FYM as well as microbial activity due to available organic carbon. The mineralization of organics enhanced oil content due to synthesis of fatty acids and their etherification by accelerating biochemical reaction in glyoxylate cycle. Similar results were observed by Shubhangi and Kachhave (2008) and Alam *et al*. (2009).

Interaction effect

Interaction between cropping system and nutrient management practices did not show any differences on oil content (%) during both the experimental year.

4.3.6.4 Oil yield (kg ha^{-1})

The data obtained on oil yield (kg ha^{-1}) and interaction effect of oil yield (kg ha^{-1}) of soybean as influenced by cropping system and nutrient management are presented in Table 4.62 (a) and 4.62 (b).

Effect of cropping system

During both the year 2019 and 2020, sole crop of soybean recorded higher oil yield of 353.26 and 366.21 kg ha^{-1}, respectively. Rice + soybean at 3:1 row ratio recorded significantly lower oil yield (161.18 and 168.66 kg ha^{-1} in 2019 and 2020, respectively). Pooled data of both the years revealed highest (359.74 kgha^{-1}) oil yield in sole soybean, while the lowest was recorded in C_5 (Rice+ soybean with 3: 1 row ratio) with value of 164.92 kg ha^{-1}. The oil yield of soybean was reduced probably due to intercrop competition between rice and soybean.

Effect of nutrient management

During both the year, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded significantly higher oil yield of 327.23, 331.56 and 329.39 kg ha^{-1} during 2019, 2020 and in pooled data, respectively, while the lowest (200.13, 212.98 and 206.55 kg ha^{-1} in 2019, 2020 and in pooled data, respectively) recorded in N_3 treatment (50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed). Increase in oil yield might be due to the balanced nutrition of the crop. The macro and micro nutrients supplied through chemical fertilizer and organic manures helped in synthesis of fatty acids and their esterification by accelerating biochemical reactions in glyoxylate cycle. Similar results were observed by Singh and Rai (2004).

Interaction effect

Oil yield was significantly affected by the combine practice cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the yield was highest in C_3N_2 (Sole soybean +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 (446.43 kg ha^{-1}), 2020 (450.75 kg ha^{-1}) and pooled (448.59 kg ha^{-1}), which was found to be followed by C_3N_1 (Sole soybean +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (338.86, 352.75 and 345.80 kg ha^{-1} during first, second year and as well as in pooled data, respectively). The significantly lowest was recorded in C_5N_3 (Rice intercropped with soybean and application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination (125.75, 130.83 and 128.29 during first, second year and as well as in pooled data, respectively).

Table 4.62 (a): Effect of cropping systems and nutrient management practices on oil content (%) and oil yield (kg ha^{-1}) in soybean

Treatments	Oil content (%)			Oil yield (kg ha^{-1})		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_3 - Sole soybean	20.13	20.34	20.23	353.26	366.21	359.74
C_5 - Rice + soybean (3:1)	19.73	19.78	19.76	161.18	168.66	164.92
SEm±	0.28	0.31	0.21	7.39	6.54	4.94
CD (P=0.05)	NS	NS	NS	23.29	20.61	14.56
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	19.79	19.92	19.86	244.32	257.76	251.04
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	21.38	21.44	21.41	327.23	331.56	329.39
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	18.62	18.82	18.72	200.13	212.98	206.55
SEm±	0.35	0.38	0.26	9.05	8.01	6.04
CD (P=0.05)	1.10	1.21	0.76	28.53	25.24	17.83
Interaction (C X N)	NS	NS	NS	S	S	S

Table 4.62 (b): Interaction effect of cropping systems and nutrient management practices on oil yield (kg ha^{-1}) in soybean

Treatments	Oil yield (kg ha^{-1})		
	2019	2020	Pooled
C_3 N_1	338.86	352.75	345.80
C_5 N_1	149.78	162.78	156.28
C_3 N_2	446.43	450.75	448.59
C_5 N_2	208.02	212.37	210.19
C_3 N_3	274.50	295.12	284.81
C_5 N_3	125.75	130.83	128.29
SEm±	12.80	11.33	8.55
CD (P=0.05)	40.35	35.70	25.22

4.4 Competition studies

Competition studies worked out for different rice based intercropping systems and nutrient management practices are presented in the Table 4.63.

4.4.1 Land equivalent ratio

As per the pooled data, the highest LER was recorded from rice+ soybean (3:1) intercropping system with the value of 1.44 which meant that there was 44% yield advantage of intercropping over sole cropping followed by rice + groundnut (3:1) as 1.32 *i.e.* 32% yield advantage of intercropping over sole cropping. Intercropping systems gave higher land utilization as compared to sole crop. This might be perhaps due to biological feasibility of the component crop in intercropping system which enhanced better resource use efficiency in intercropping. Higher LER in intercropping treatments compared with monocropping of rice ascribed to better resources utilization (land, light) and added resources (fertilizer, water). Similar findings were also obtained by Mahapatra (1987) who reported that higher LER can be obtained from intercropping system than sole crop. The LERs for all types of intercrops were higher than sole crop, thus indicating that intercropping rice crop with leaf vegetables was more beneficial than sole rice production. Higher LER could be due to better use of natural resources as previously indicated by Jabbar *et al*. (2009) and Udhaya and Kuzhanthaivel (2015).

The pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest LER as 1.43 *i.e*. 43 % yield advantage of intercropping over sole cropping followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 1.40 *i.e.* 40% yield advantage of intercropping over sole cropping. Application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded lower value of LER as 1.31 *i.e*. 31% yield advantage of intercropping over sole cropping.

4.4.2 Price equivalent ratio

The data pertaining to price equivalent ratio due to cropping system and nutrient management practices are presented in Table 4.63.

Intercropping of rice with soybean had recorded higher values for price equivalent ratio (1.40) which was followed by rice+ groundnut (3:1) intercropping system (1.30). This increase was attributed to the additional yield advantage of intercropping system as well as higher market price of the groundnut and soybean than that of the rice alone.

The pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest PER as 1.38 followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 1.37. Application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded lower value of PER as 1.30.

4.4.3 Relative crowding coefficient

Data related to relative crowding coefficient due to cropping system and nutrient management are presented in Table 4.63.

Pooled data showed that among cropping system, rice + soybean (3:1) recorded the highest RCC value of 31.65 followed by rice + groundnut (3:1) as 10.36. As the value of RCC was more than 1, there was yield advantage in the intercropping. The product of the component crops were greater than one. All the intercropping systems had yield advantage. Shahid and Saeed (1997), Ahmad (1990) and Bhatti *et al*. (2006) had also been reported for grain yield advantage over their respective monoculture as determined on the basis of "RCC".

Table 4.63: Effect of cropping systems and nutrient management practices on competitive indices in rice based intercropping system (pooled data of two years)

Treatments	Land equivalent ratio	Price equivalent ratio	Relative crowding coefficient	Competition ratio		Monetary advantage (Rs. ha^{-1})
Cropping system (C)				**CR Rice**	**CR Intercrop**	
C_1 - Sole rice	-	-	-	-	-	-
C_2- Sole groundnut	-	-	-	-	-	-
C_3- Sole soybean	-	-	-	-	-	-
C_4 - Rice + groundnut (3:1)	1.32	1.30	10.36	0.46	1.67	20056.53
C_5 - Rice + soybean (3:1)	1.44	1.40	31.65	0.69	1.46	28536.67
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.40	1.37	24.53	0.45	1.48	24697.85
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.43	1.38	27.32	0.67	1.50	30416.33
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	1.31	1.30	11.18	0.60	1.71	17775.61

As per pooled data, the nutrient management treatment of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest RCC as 27.32 followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 24.53. The lowest RCC was recorded in 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 11.18. As the value of RCC was more than 1, all the treatment showed yield advantage in the present intercropping system.

4.4.4 Competition ratio

The result presented in Table 4.63 showed the effects of cropping system and nutrient management practices on competition ratio of rice based intercropping system.

Among the cropping systems, higher competitive ratio of rice was recorded with rice + soybean (3:1) as 0.69 followed rice + groundnut (3:1) with value of 0.46. Whereas in case of intercrop higher competitive ratio of intercrop was recorded with rice + groundnut (3:1) as 1.67, followed rice + soybean (3:1) with value of 1.46. So, intercrop appeared to be more competitive and rice was found to be less competitive with respect to utilization of available resources. The competition ratio value of rice was less compared to the associated crops, which indicated that groundnut in the intercropping system is less competitive than the associated cereals. According to Willey and Rao (1980), CR gives a better measure of competitive ability of the crops and is also advantageous as an index over RCC and aggressivity. It is thus apparent from the data regarding CR that rice in each intercropping system was the dominated crop. Among the intercrops, groundnut and soybean proved to be better competitive when grown in association with rice. As reported earlier by Shahid and Saeed (1997), lentil was a better competitor than other crops when grown in association with wheat. Singh *et al*, (2017) also reported that competition ratio of intercrop is higher compared to sole crop, when barley is intercropped with Indian mustard and chickpea.

Pooled data of competitive ratio in rice indicated that among nutrient management treatments, application 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded a higher value of competitive ratio as 0.67 which was closely followed by 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 0.60. The lowest competitive ratio (0.45) was recorded under adoption of 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. Whereas pooled data of competitive ratio in intercrop indicated that among nutrient management treatments, application 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} recorded a higher value of competitive ratio as 1.71 which was followed by 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 1.50. The lowest competitive ratio was recorded under adoption of 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as 1.48.

4.4.5 Monetary advantage (Rs. ha^{-1})

The data pertaining to monetary advantage (Rs. ha^{-1}) due to cropping system and nutrient management practices are presented in Table 4.63.

Intercropping of rice with soybean had recorded higher values for monetary advantage (Rs. 28536.67 ha^{-1}) which was followed by rice+ groundnut (3:1) intercropping system (Rs. 20056.53 ha^{-1}). When monetary advantage was considered, rice+soybean association gave maximum monetary advantage which might be due to higher LER, RCC and less CR value.

The pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest monetary advantage as Rs. 30416.33 ha^{-1} followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as Rs. 24697.85

ha^{-1}. Application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded lower value of monetary advantage as Rs. 17775.61 ha^{-1}.

4.5 PHYSICO CHEMICAL PROPERTIES OF SOIL

4.5.1 Soil pH

The data pertaining to soil pH due to cropping system and nutrient management practices are presented in Table 4.64.

Effect of cropping system

Application of different cropping system did not show any significant effect on soil pH.

Effect of nutrient management

The effect of different nutrient management did not bring significant impact on soil pH.

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on soil pH.

4.5.2 Organic carbon (%)

The data on organic carbon was recorded in both the cropping period of the years and which are presented in Table 4.64.

Effect of cropping system

The critical analysis of the data clearly revealed that there was no significant variation in the different intercropping treatments.

Table 4.64: Effect of cropping systems and nutrient management practices on pH and organic carbon (%) content after harvest of rice based intercropping system

Treatments	**pH**			**Organic carbon (%)**		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	4.98	4.97	4.97	1.25	1.27	1.26
C_2 - Sole groundnut	5.01	4.98	4.99	1.29	1.32	1.30
C_3 - Sole soybean	4.95	4.83	4.89	1.30	1.32	1.31
C_4 - Rice + groundnut (3:1)	4.97	4.96	4.97	1.28	1.30	1.29
C_5 - Rice + soybean (3:1)	5.02	4.94	4.98	1.30	1.31	1.30
SEm±	0.03	0.06	0.03	0.02	0.02	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.98	4.96	4.97	1.30	1.30	1.30
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.99	4.90	4.94	1.30	1.33	1.31
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	4.98	4.95	4.97	1.25	1.29	1.27
SEm±	0.03	0.04	0.03	0.02	0.01	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (C X N)	NS	NS	NS	NS	NS	NS

Effect of nutrient management

There was no significant difference due to nutrient management at various growth stages during both the years of experiment.

Interaction effect

Interaction effect of cropping system and nutrient management did not show any significant difference in both the years.

4.5.3 Available nitrogen (kg ha^{-1}) in soil after harvest

Data on available nitrogen (kg ha^{-1}) in soil after harvest as influenced by cropping system and nutrient management practices are presented in Table 4.65.

Effect of cropping system

Data on available nitrogen (kg ha^{-1}) in soil after harvest is presented in Table 4.65 revealed that cropping system exerted significant influence on available nitrogen (kg ha^{-1}). Highest available nitrogen was recorded in sole soybean (287, 290.12 and 288.56 kg ha^{-1} in 2019, 2020 and in pooled data respectively). Among intercropping highest was recorded in rice intercropped with soybean (274.71, 278 and 276.35 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). The significantly lowest available nitrogen was recorded in sole rice (262.17, 264.73 and 263.45 kg ha^{-1} in 2019, 2020 and in pooled data, respectively). Intercropping significantly increased the available soil N content. Singh *et al*. (2008a) reported that maximum values of available soil N, P and K were recorded after harvest of maize + soybean, followed by maize+ cowpea, maize + greengram and minimum was after the harvest of maize + frenchbean at all the proportions of sowing. These results are in conformity with the findings of Padhi and Panigrahi (2006).

Effect of nutrient management

Different nutrient management showed significant differences in respect of available nitrogen in soil after harvest. The maximum available nitrogen in soil after harvest recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during both the years and similar trend followed in pooled with the values being 280.82, 284.26 and 282.54, kg ha^{-1} respectively. The lowest values being recorded in application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed (269.75, 272.66 and 271.20 kg ha^{-1} during 2019, 2020 and in pooled data, respectively). The increase in available N in soil by INM might be owing to the fact that mixing of nitrogen fertilizer and FYM have reduced the nitrogen losses, improved fertilizer use efficiency and thus increased the availability of nitrogen. Similar finding was reported by Seth *et al*. (2016).

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on available nitrogen (kg ha^{-1}) in soil after harvest.

4.5.4 Available phosphorous (kg ha^{-1}) in soil after harvest

The data pertaining to available phosphorous (kg ha^{-1}) in soil after harvest due to cropping system and nutrient management practices are presented in Table 4.65.

Effect of cropping system

Effect of cropping system could not show significant response on available phosphorous (kg ha^{-1}) in soil after harvest.

Effect of nutrient management

Close examination of the data revealed that in both the years as well as pooled data, application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed resulted in significantly highest available phosphorous in soil after harvest with the value of 22.59, 23.61 and 23.10 kg ha^{-1}, respectively. However application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed registered significantly lowest data during both the years of investigation. The addition of organic matter in soil might have decreased the phosphate fixation due to the formulation of phosphor humic complexes that easily assimilated by plants which ultimately increased the available P in soil. Similar finding was reported by Seth *et al.* (2016). Sharma and Sharma (2004) recorded the increase in organic carbon and available N, P and K contents in soil due to combined application to FYM and inorganic fertilizers.

Interaction effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.5.5 Available potassium (kg ha^{-1}) in soil after harvest

Data related to available potassium (kg ha^{-1}) in soil after harvest due to cropping system and nutrient management practices are presented in Table 4.65.

Effect of cropping system

No significant changes in available potassium (kg ha^{-1}) in soil after harvest was observed during both the years of experimentation.

Effect of nutrient management

An inference of the data presented in Table 4.65 revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-}

Table 4.65: Effect of cropping systems and nutrient management practices on available NPK (kg ha^{-1}) content of soil after harvest of rice based intercropping system

Treatments	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})			Available Potassium (kg ha^{-1})		
Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	262.17	264.73	263.45	20.58	21.14	20.86	142.85	145.01	143.93
C_2- Sole groundnut	280.89	284.17	282.53	21.54	22.43	21.99	145.73	147.24	146.48
C_3- Sole soybean	287.00	290.12	288.56	21.96	23.14	22.55	146.05	148.18	147.12
C_4 - Rice + groundnut (3:1)	269.07	271.78	270.42	20.83	21.41	21.12	143.08	145.16	144.12
C_5 - Rice + soybean (3:1)	274.71	278.00	276.35	21.26	21.84	21.55	144.93	146.96	145.95
SEm±	2.60	2.73	1.89	0.48	0.55	0.37	1.52	1.56	1.09
CD (P=0.05)	7.53	7.91	5.34	NS	NS	NS	NS	NS	NS
Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	273.74	276.35	275.05	21.75	22.27	22.01	144.22	146.28	145.25
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	280.82	284.26	282.54	22.59	23.61	23.10	149.41	151.77	150.59
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	269.75	272.66	271.20	19.36	20.10	19.73	139.95	141.49	140.72
SEm±	2.01	2.12	1.46	0.37	0.43	0.28	1.18	1.21	0.84
CD (P=0.05)	5.83	6.13	4.14	1.08	1.24	0.81	3.41	3.50	2.39
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

^{1} seed significantly increased the available potassium in soil after harvest. Similar trend of effect was observed in both the year as well as pooled data with the value of 149.41, 151.77 and 150.59 kg ha^{-1}, respectively. The lowest available potassium in soil after harvest was recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) during both the years. The increase in available K in soil might be owing to the fact that addition of organic matter in soil have increased the cation- exchange capacity, reduced the leaching losses which ultimately increased the availability of K in soil. Thus the combined application of organic and inorganic manures significantly increased the available N, P and K status of soil. Similar finding was reported by Seth *et al*. (2016).

Interaction Effect

The interaction effect of different cropping system and nutrient management practices had no significant effect on available potassium (kg ha^{-1}) in soil after harvest.

4.5.6 Soil bacteria (No. x 10^{6} cfu g^{-1} soil)

The result presented in Table 4.66 showed the effects of cropping system and nutrient management practices on soil bacteria (No. x 10^{6} cfu g^{-1} soil)

Effect of cropping system

Data on soil bacteria (No. x 10^{6} cfu g^{-1} soil) is presented in Table 4.66 revealed that cropping system exerted significant influence on soil bacteria. Highest soil bacteria was recorded in sole soybean (40.61 x 10^{6} cfu g^{-1} soil in 2019, 41.11 x 10^{6} cfu g^{-1} soil 2020 and 40.86 x 10^{6} cfu g^{-1} soil in pooled data, respectively). Among intercropping highest was recorded in rice intercropped with soybean (35.43 x 10^{6} cfu g^{-1} soil in 2019, 35.77 x 10^{6} cfu g^{-1} soil 2020 and 35.60 x 10^{6} cfu g^{-1} soil in 2019, 2020 and in pooled data, respectively).The significantly lowest available nitrogen was recorded in sole rice (23.51 x 10^{6} cfu g^{-1} soil in 2019, 23.79 x 10^{6} cfu g^{-1} soil 2020 and 23.65 x 10^{6} cfu g^{-1} soil in 2019, 2020 and in pooled data, respectively). Rekha, *et al.* (2018) reported that among the intercropping systems, intercropping of paired rows of aerobic rice with soybean witnessed significantly higher population of bacteria, fungi and actinomycetes.

Effect of nutrient management

Nutrient management practices significantly influenced the soil bacteria (No. x 10^6 cfu g^{-1} soil) the highest being 37.25 x 10^6 cfu g^{-1} soil in 2019, 37.72 x 10^6 cfu g^{-1} soil in 2020 and 37.49 x 10^6 cfu g^{-1} soil in pooled were recorded at N_2 treatment (75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). The significantly lowest value of 30.81 x 10^6 cfu g^{-1} soil in 2019, 31.27 x 10^6 cfu g^{-1} soil in 2020 and 31.04 x 10^6 cfu g^{-1} soil in pooled data was recorded in treatment N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed).Farmyard manure is being used as major source of organic manure in field crops and its role in crop production cannot be overlooked. In addition to supplying all essential nutrients, it increases the activities of bacteria or microbes in soil (Sutaliya and Singh, 2005).

Interaction Effect

The data revealed that there was no significant interaction effect of the cropping system and nutrient management during both the years of experimentation.

4.5.7 Soil fungi (No. x 10^3 cfu g^{-1} soil)

The effects of cropping system and nutrient management practices on soil fungi (No. x 10^3 cfu g^{-1} soil) are presented in Table 4.66.

Effect of cropping system

Significant differences in soil fungi were noticed among all the treatments, the maximum being in 43.57 x 10^3 cfu g^{-1} soil 2019, 43.71 x 10^3 cfu g^{-1} soil in 2020 and 43.64 x 10^3 cfu g^{-1} soil in pooled data were observed in sole soybean. Among intercropping highest was recorded in rice intercropped with soybean (39.20 x 10^3 cfu g^{-1} soil in 2019, 39.65 x 10^3 cfu g^{-1} soil 2020 and 39.43 x 10^3 cfu g^{-1} soil in 2019, 2020 and in pooled data, respectively). The lowest values of 26.43 x 10^3 cfu g^{-1} soil , 26.54 x 10^3 cfu g^{-1} soil and 26.48 x 10^3 cfu g^{-1} soil kg ha^{-1} during 2019, 2020 and in pooled data, respectively were recorded in sole rice. Changes in soil fungal abundance as a result of intercropping have been an area of great concern. Lian *et al.* (2018) reported that one of the possible explanations for the increasing fungal abundance observed in intercropping could be related to the greater quantity and types of root exudates in intercropping system and these exudates provide more energy and nutrition for fungi. In addition, they had also reported all changes in the soil physicochemical properties caused by intercropping, such as the increase of soil nutrient contents, provided substrates for microbial growth or improved micro-environments for microbial habitats, which eventually resulted in an increase in the soil fungal abundance.

Effect of nutrient management

An examination of the data in both the years as well as pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded highest soil fungi (No.x 10^3 cfu g^{-1} soil) with the values of 39.77 x 10^3 cfu g^{-1} soil in 2019, 40.11 x 10^3 cfu g^{-1} soil in 2020 and a pooled value of 39.94 x 10^3 cfu g^{-1} soil, while the treatments recorded lowest value at N_3 (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). Kalaiyarasi (2009) found that application of FYM and biofertilizers along with the recommended chemical fertilizer enhanced the microbial consortia. Chandrakumar *et al.* (2008) reported that application of organic manures favoured the microbial population, which in turn helped to release bounded or unavailable form of nutrients to available form.

Table 4.66: Effect of cropping systems and nutrient management practices on soil microbial population after harvest of rice based intercropping system

Treatments	Bacteria (No. x 10^6 cfu g^{-1} soil)			Fungi (No. x 10^3 cfu g^{-1} soil)			Actinomycetes (No. x 10^5 cfu g^{-1} soil)		
A) Cropping system (C)	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
C_1 - Sole rice	23.51	23.79	23.65	26.43	26.54	26.48	1.51	1.52	1.52
C_2- Sole groundnut	37.20	38.05	37.62	39.71	40.08	39.90	1.83	1.84	1.84
C_3- Sole soybean	40.61	41.11	40.86	43.57	43.71	43.64	1.87	1.88	1.87
C_4 - Rice + groundnut (3:1)	33.05	33.28	33.17	37.32	37.47	37.40	1.76	1.78	1.77
C_5 - Rice + soybean (3:1)	35.43	35.77	35.60	39.20	39.65	39.43	1.81	1.83	1.82
SEm±	0.57	0.51	0.38	0.64	0.61	0.44	0.05	0.04	0.03
CD (P=0.05)	1.66	1.49	1.09	1.84	1.76	1.25	0.13	0.13	0.09
B) Nutrient management (N)									
N_1- 100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	33.81	34.21	34.01	37.01	37.29	37.15	1.78	1.80	1.79
N_2 - 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	37.25	37.72	37.49	39.77	40.11	39.94	1.87	1.89	1.88
N_3 - 50% RDF + FYM @ 7.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed	30.81	31.27	31.04	34.96	35.06	35.01	1.61	1.62	1.62
SEm±	0.44	0.40	0.30	0.49	0.47	0.34	0.04	0.03	0.02
CD (P=0.05)	1.29	1.15	0.84	1.43	1.36	0.97	0.10	0.10	0.07
Interaction (C X N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Interaction Effect

Interactive effects of cropping system and nutrient management found non-significant during both the years of experimentation.

4.5.8 Soil actinomycetes (No. x 10^5 cfu g^{-1} soil)

Data on soil actinomycetes (No. x 10^5 cfu g^{-1} soil) as influenced by cropping system and nutrient management practices are presented in Table 4.66.

Effect of cropping system

The variations on soil actinomycetes (No. x 10^5 cfu g^{-1} soil) due to cropping system were found to be significant during both the years of experiment. The highest soil actinomycetes of 1.87 x 10^5 cfu g^{-1} soil, 1.88 x 10^5 cfu g^{-1} soil and 1.87 x 10^5 cfu g^{-1} soil were recorded in treatment sole soybean during 2019, 2020 and in pooled data, respectively. Among intercropping highest was recorded in rice intercropped with soybean (1.81 x 10^5 cfu g^{-1} soil in 2019, 1.83 x 10^5 cfu g^{-1} soil 2020 and 1.82 x 10^5 cfu g^{-1} soil in 2019, 2020 and in pooled data, respectively). The lowest was recorded in sole rice with the values of 1.51 x 10^5 cfu g^{-1}, 1.52 x 10^5 cfu g^{-1} and 1.52 x 10^5 cfu g^{-1} kg ha^{-1} in 2019, 2020 and in pooled data, respectively. Microbe number of rhizosphere soil in the intercropping pattern increased significantly as compared to monoculture rice. Li *et al*. (2013) reported that actinomycetes population increased to 73%, when sugarcane intercropped with soybean.

Effect of nutrient management

It was noted that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed obtained statistically superior values of 1.87 x 10^5 cfu g^{-1} soil, 1.89 x 10^5 cfu g^{-1} soil and 1.88 x 10^5 cfu g^{-1} soil during both the years and in pooled data, respectively, while the lowest was recorded in N_3 treatment (50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed). Singh *et al*. (2006) reported that soil analysis for microbial population count at rice harvest stage showed an increase in microbial (actinomycetes, bacteria and fungi) population and soil enzymatic activity under Integrated Plant Nutrient Supply (IPNS) compared to sole chemical fertilizer application.

Interaction effect

During both the years of study interaction between cropping system and nutrient management practices were found non-significant.

4.6 ECONOMIC ANALYSIS

Data on economics analysis are presented in Table 4.67.

4.6.1 Cost of cultivation (Rs. ha^{-1})

As per the pooled data, the highest (Rs. 31,087 ha^{-1}) cost of cultivation was recorded from rice+ groundnut (3:1) intercropping system followed by rice + soybean (3:1) with the value of Rs. 30907 ha^{-1}. The lowest (Rs. 30,522 ha^{-1}) was recorded in sole rice. The highest cost of cultivation (Rs. ha^{-1}) in the intercropping treatment might be due to high expenditure involved through the use of seed for the treatment.

The pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest cost of cultivation of Rs. 31,714 ha^{-1} followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed with the value of Rs. 30,001 ha^{-1}. Application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded lower value of cost of cultivation as Rs. 30,542 ha^{-1}. This might be due to additional cost of fertilizer and FYM.

Table 4.67: Effect of cropping systems and nutrient management practices on economics of rice based intercropping system

Treatments	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B:C ratio		
Cropping system	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
C_1	30522	30522	30522	66648.38	66772.21	66710.30	36126.38	36250.21	36188.30	1.19	1.19	1.19
C_2	30907	30907	30907	70964.44	72917.78	71941.11	40057.44	42010.78	41034.11	1.30	1.36	1.33
C_3	30405	30405	30405	73271.11	75243.33	74257.22	42865.78	44838.00	43851.89	1.40	1.47	1.43
C_4	31087	31087	31087	90515.56	91401.11	90958.33	59428.56	60314.11	59871.33	1.90	1.93	1.92
C_5	30840	30840	30840	98514.65	100250.99	99382.82	67674.32	69410.66	68542.49	2.21	2.26	2.23
Nutrient management												
N_1	30001	30001	30001	79184.94	80975.96	80080.45	49183.94	50974.96	50079.45	1.63	1.69	1.66
N_2	31714	31714	31714	90299.55	91008.68	90654.12	58585.55	59294.68	58940.12	1.86	1.89	1.87
N_3	30542	30542	30542	70463.99	71966.61	71215.30	39921.99	41424.61	40673.30	1.31	1.36	1.33

4.6.2 Gross return (Rs. ha^{-1})

Among the intercropping systems under study, rice intercropped with soybean (3:1) recorded highest gross returns (Rs. 99,382.82 ha^{-1}) followed by rice + groundnut (3:1) intercropping system (Rs. 90,958.33 ha^{-1}). However, lowest gross return was noticed in sole rice (Rs. 66,710.30 ha^{-1}). Rice yield and additional yield of intercrop, which in turn increased gross and net returns.

The pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest gross return as Rs. 90,654.12 ha^{-1} followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as Rs. 80,080.45 ha^{-1}. Application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded lower value of gross return as Rs. 71,215.30 ha^{-1}. The result is in close proximity to those obtained by Mohanty *et al*. (2014) and Sharma *et al*. (2018).

4.6.3 Net returns (Rs. ha^{-1})

Intercropping of rice with soybean (3:1) had recorded higher values for net return (Rs. 68,542.49 ha^{-1}) which was followed by rice+ groundnut (3:1) intercropping system (Rs. 59,871.33 ha^{-1}). The lowest net return was registered in sole rice (Rs. 36,188.30 ha^{-1}). The higher output of intercropping system compared to the mono cropping system may have caused from complementary and effective usage of growth resource by the component crops. These results are in line with those of Jabbar *et al*. (2005), Li *et al*. (2006) and Hussainy *et al*. (2020) who also reported higher net monetary returns from intercropping over monocropping of rice. All the intercropping systems gave substantially high net income over monocropping.

The pooled data revealed that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest net return as Rs. 58,940.12 ha^{-1} followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed as Rs. 50,079.45 ha^{-1}. Application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded lower value of net return as Rs. 40,673.30 ha^{-1}. The maximum net income is due to higher gross income. Similar observations were also noted earlier by Sai Ram *et al*. (2020).

4.6.4 B:C ratio

Among the cropping systems, highest B:C ratio was recorded with rice + soybean (3:1) as 2.23 followed rice + groundnut (3:1) with value of 1.92. The minimum (1.19) B:C ratio was observed in sole rice. B:C ratio increased in intercropping system due to the additional yield of intercrop. Generally, intercropping was economically efficient as compared to sole crops. Similar findings was reported by Laskar *et al*. (2005). Similar results were also reported in pea-maize intercropping systems by Yang *et al*. (2018).

Pooled data of B:C ratio indicated that among nutrient management treatments, application 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded higher B:C ratio of 1.87, which was followed by 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed with the value of 1.66. The lowest (1.33) B:C ratio was recorded under adoption of 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed. The maximum benefit cost ratio was owing to higher grain yield and in turn higher gross and net returns. The result is in close proximity with Baishya *et al*. (2015) and Mondal *et al*. (2015).

Plate 1: General view of the experimental field

Plate 2: Seed treatment with biofertlizer

Plate 3: Sole crops at seedling stage

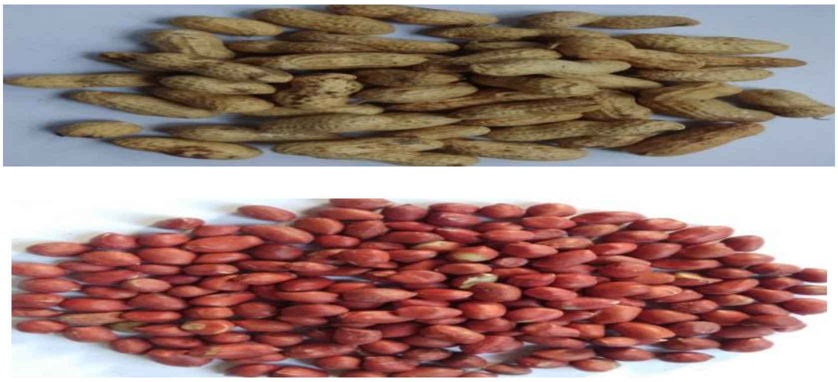
Plate 4: Rice based intercropping system at seedling stage

Plate 5: Sole crops at maturity stage

Plate 6: Rice + groundnut intercropping system

Plate 7: Rice + soybean intercropping system

Rice : Sahbhagi dhan



Groundnut: ICGS 76

Soybean : JS 9752

Plate 8: Harvested crops

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An investigation entitled "Integrated nutrient management in upland rice-based intercropping system under foothill condition of Nagaland" was carried out in the Experimental Farm of ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema during the two consecutive *kharif* seasons of 2019 and 2020 with the following objectives:

1. To study the comparative performance of rice – based intercropping system
2. To study the suitable integrated nutrient management practice for rice based intercropping system
3. To study the effect of integrated nutrient management and intercropping systems on soil fertility status
4. To study the economics of the treatments.

The experiment was laid out in Randomized Block Design with two factors (cropping system and nutrient management) comprising fifteen treatment combinations and replicated three times. The relevant field experimental results were presented and discussed in the preceding chapters and their summary and conclusion were given as under:

5.1 Summary

5.1.1 Effect of cropping system on rice based intercropping with groundnut and soybean

a) Growth and phenological parameters

i. Rice

- Sole rice registered higher growth parameters *viz*., plant height (cm), number of leaves plant^{-1}, dry matter (g) plant^{-1}, leaf area index and crop growth rate (g m^{-2} day^{-1}), which was at par with rice intercropped with soybean (3:1) at 30, 60 and 90 DAS during both the years and pooled data. There was no significant difference between different cropping system on relative growth rate (g g^{-1} day^{-1}) and net assimilation rate (g m^{-2} day^{-1}) of rice at 30-60 DAS and 60-90 DAS during both the years and pooled data.

- There was no significant difference between different cropping system on days to 50% flowering, days to 50% maturity and days to harvesting of rice during both the years.

ii. Groundnut/Soybean

- Significantly the highest plant height (cm), number of branches $plant^{-1}$, dry matter (g) $plant^{-1}$, number of root nodules $plant^{-1}$, fresh weight of nodules $plant^{-1}$ (g), dry weight of nodules $plant^{-1}$(g) and leaf area index were recorded under sole groundnut and sole soybean in rice + groundnut and rice + soybean intercropping system, respectively at 30, 60 and 90 DAS during both the years and pooled data. Crop growth rate (g m^{-2} day^{-1}) was recorded highest under sole groundnut at 30-60 DAS and there was no significant difference among cropping system on crop growth rate (g m^{-2} day^{-1}) at 60-90 DAS during both the years and in pooled data. Relative growth rate (g g^{-1} day^{-1}) and net assimilation rate (g m^{-2} day^{-1}) were recorded highest under sole groundnut only during 2019 at 30-60 DAS. Crop growth rate (g m^{-2} day^{-1}) and net assimilation rate (g m^{-2} day^{-1}) were registered highest under sole soybean only at 30-60 DAS during both the years and in pooled data. Relative growth rate (g g^{-1} day^{-1}) was recorded highest under sole soybean only at 30-60 DAS during 2019 and in pooled data.

- There was no significant difference between cropping system on days to 50% flowering, days to 50% maturity and days to harvesting of groundnut and soybean during both the years of experimentation.

b) Yield attributes and crop yield

i. Rice

- Different cropping system influenced yield attributes and grain yield of rice. Sole rice performed better in terms of number of panicles m^{-2}, weight of panicle (g), number of grains $panicle^{-1}$, filled grain %, grain yield (t ha^{-1}) and straw yield (t ha^{-1}), which was at par with rice + soybean (3:1) intercropping system during both the years and in pooled data.
- The different treatment showed no significant effect on panicle length (cm), test weight (g) and harvest index (%) of rice during both the years.
- Highest rice equivalent yield (t ha^{-1}) was recorded in rice intercropped with soybean (3:1), which was followed by rice intercropped with groundnut (3:1) during both the years and in pooled data.

ii. Groundnut/Soybean

- Sole groundnut and sole soybean produced significantly higher number of pods $plant^{-1}$, pod weight (g) $plant^{-1}$, seed yield (t ha^{-1}) and stover yield (t ha^{-1}) in rice + groundnut and rice + soybean intercropping system, respectively during both the years and in pooled data.
- There was no significant effect on number of seeds pod^{-1}, test weight (g) and harvest index (%) of groundnut among cropping system during both the years.

c) Nutrient study and quality parameters

i. Rice

- There was no significant effect on N, P and K content (%) in seed and stover of rice due to different cropping system during both the years.
- The highest nitrogen and potassium uptake (kg ha^{-1}) in seed and stover was registered in sole rice followed by rice intercropped with soybean (3:1). But in case of phosphorous highest uptake in seed was obtained in sole rice followed by rice intercropped with soybean (3:1). However, there was no significant effect on phosphorous uptake in stover of rice due to different cropping system during both the years.
- There was no significant effect on protein content (%) of rice due to different cropping system during both the years.
- The highest protein yield (kg ha^{-1}) was registered in sole rice followed by rice intercropped with soybean (3:1) during both the years and pooled data.

ii. Groundnut/Soybean

- There was no significant effect on NPK content (%) in seed and stover of groundnut and soybean due to different cropping system during both the years.
- The significantly highest N, P and K uptake (kg ha^{-1}) in seed and stover was registered in sole groundnut and sole soybean in rice + groundnut and rice + soybean intercropping system, respectively during both the years.
- There was no significant effect on protein and oil content (%) of groundnut and soybean due to different cropping system during both the years.

- The significantly highest protein and oil yields (kg ha^{-1}) were registered in sole groundnut and sole soybean in rice + groundnut and rice + soybean intercropping system, respectively during both the years.

5.1.2 Effect of nutrient management on rice based intercropping with groundnut and soybean

a) Growth and phenological parameters

i. Rice

- Application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @20 g kg^{-1} seed resulted in significantly highest plant height (cm), number of leaves $plant^{-1}$, dry matter (g) $plant^{-1}$, leaf area index at 30, 60 and 90 DAS during both the years and pooled data. Crop growth rate (g m^{-2} day^{-1}) was highest with the application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed at 30-60 DAS during both the years and in pooled data and at 60-90 DAS during 2019 and in pooled data. However, relative growth rate (g g^{-1} day^{-1}) and net assimilation rate (g $m^{-2}day^{-1}$) were not significantly affected by different nutrient management practices at 30-60 and 60-90 DAS during both the years and pooled data.
- The nutrient management failed to produce any significant variation on days to 50% flowering, days to 50% maturity and days to harvesting during both the years.

ii. Groundnut/Soybean

- There was no any significant variation in days to 50% flowering, days to 50% maturity and days to harvesting due to different nutrient management practices during both the years.
- In case of groundnut and soybean crop the highest values of growth parameters *viz*., plant height (cm), number of branches $plant^{-1}$, dry

matter (g) plant^{-1}, number of root nodules plant^{-1}, fresh weight of nodules plant^{-1} (g), dry weight of nodules plant^{-1}(g) and leaf area index were realized in treatment 75% RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed in rice+groundnut and rice+soybean intercropping system, respectively during both the years and in pooled data. In case of groundnut, crop growth rate (g m^{-2} day^{-1}) was highest with the application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed at 30-60 DAS during both the years and in pooled data. However, relative growth rate (g g^{-1} day^{-1}) and net assimilation rate (g m^{-2}day^{-1}) were not significantly affected by different nutrient management practices at 30-60 and 60-90 DAS during both the years and pooled data. In case of soybean, crop growth rate (g m^{-2} day^{-1}) was highest with the application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed at 30-60 DAS during both the years and in pooled data and at 60-90 DAS during 2020 and in pooled data. Relative growth rate (g g^{-1} day^{-1}) was highest with the application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed at 30-60 DAS during 2019 and in pooled data. However, net assimilation rate (g m^{-2} day^{-1}) was highest with the application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed at 30-60 DAS during both the years and in pooled data.

b) Yield attributes and crop yield

i. Rice

- Application of 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed number of panicles m^{-2}, panicle length (cm), weight of panicle (g), number of grains panicle^{-1}, filled grain %, grain yield (t ha^{-1}), straw yield (t ha^{-1}) and rice equivalent yield (t ha^{-1}) were recorded highest under 75 % RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed during both the years and in pooled data.

- The different treatment showed no significant effect on test weight (g) and harvest index (%) of rice during both the years and pooled data.

ii. Groundnut/Soybean

- Significantly highest number of pods $plant^{-1}$, pod weight (g) $plant^{-1}$, seed yield (t ha^{-1}) and stover yield (t ha^{-1}) were observed with application of 75% RDF+ FYM @ 5 t ha^{-1} + biofertilizer consortium @20 g kg^{-1} seed in rice+groundnut and rice+soybean intercropping system, respectively in both the years of study and in pooled data.
- Number of seeds pod^{-1}, test weight (g) and harvest index (%) were found to be non-significant due to different nutrient management practices during both the years.

c) Nutrient study and quality parameters

i. Rice

- The highest N, P and K content and uptake in seed and stover was registered in plot supplied with 75% RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed during both the years.
- The quality parameters *viz*., protein content (%) and protein yield (kg ha^{-1}) performed highest with the application of 75% RDF+ FYM @5t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed during both the years and in pooled data.

ii. Groundnut/Soybean

- The significantly highest N, P and K content (%) and uptake (kg ha^{-1}) in seed and stover, protein content (%), oil content (%), protein yield (kg ha^{-1}) and oil yield (kg ha^{-1}) was registered with the application of 75%

RDF+ FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed in rice+groundnut and rice+soybean intercropping system, respectively during both the years.

5.1.3 Interaction effect of cropping system and nutrient management on rice based intercropping with groundnut and soybean

i. Rice

- The interaction effect between cropping system and nutrient management at 30 and 60 DAS during both the years failed to show any significant variation on plant height (cm). However after 90 DAS, significantly highest plant height was recorded in C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019.
- The interaction effects between cropping system and nutrient management practices on panicle weight (g) and grain yield (t ha^{-1}) were significantly affected in both the years of experiment. The highest panicle was registered at C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination which was statistically at par with C_5N_2 (Rice + soybean (3:1) + 75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.
- Rice equivalent yield (t ha^{-1}) was significantly affected by the combine practice of cropping system and nutrient management during both the year and in pooled data. The data revealed that the rice equivalent yield (t ha^{-1}) was highest in C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination, which was followed by C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20

g kg^{-1} seed) treatment combination during both the years and in pooled data.

- The interaction effects between cropping system and nutrient management practice was found to be significant in 2019 in case of nitrogen and potassium uptake (kg ha^{-1}) in seed and protein yield (kg ha^{-1}). But it showed non-significant effect during 2020. The highest nitrogen and potassium uptake (kg ha^{-1}) in seed and protein yield (kg ha^{-1}) in 2019 was associated with the interaction C_1N_2 (Sole rice +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) which was followed by C_5N_2 (Rice intercropped with soybean and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) and C_4N_2 (Rice intercropped with groundnut and application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed)

ii. Groundnut

- The interaction effects between cropping system and nutrient management practice were found to be significant during both the years of investigations in case of nitrogen uptake (kg ha^{-1}) in seed. The highest nitrogen uptake (kg ha^{-1}) during both the years was associated with the interaction C_2N_2 (Sole groundnut +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 and 2020 respectively, which was followed by C_2N_1 (Sole groundnut +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.
- The interaction effects of different treatments were found to be non significant during 2019 in case of phosphorous uptake (kg ha^{-1}) in seed and stover. Significant variation was observed with the highest values associated with the interaction of C_2N_2 (Sole groundnut with application

of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2020 and in pooled data respectively, which was followed by C_2N_1 (Sole groundnut with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

- Potassium uptake (kg ha^{-1}) by seed was significantly affected by the combine practice of cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the potassium uptake (kg ha^{-1}) was highest in C_2N_2 (Sole groundnut with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination, which was followed by C_2N_1 (Sole groundnut with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination
- Protein yield (kg ha^{-1}) was significantly affected by the combine practice cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the protein yield (kg ha^{-1}) was highest in C_2N_2 (Sole groundnut +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during both the years, which was found to be followed by C_2N_1 (Sole groundnut +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.
- The interaction effects between cropping system and nutrient management practices on oil yield (kg ha^{-1}) was significantly affected only in the year 2019. Data shows that highest oil yield (kg ha^{-1}) was recorded in C_2N_2 (Sole groundnut +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination, which

was followed by C_2N_1 (Sole groundnut +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

iii. Soybean

- The interaction effects between cropping system and nutrient management practice were found to be significant only during 2019 in case of nitrogen uptake (kg ha^{-1}) in seed and stover. The highest nitrogen uptake was associated with the interaction C_3N_2 (Sole soybean +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019 and in pooled data respectively, which was followed by C_3N_1 (Sole soybean +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.
- Potassium uptake (kg ha^{-1}) by seed was significantly affected by the combine practice of cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the potassium uptake (kg ha^{-1}) was highest in C_3N_2 (Sole soybean with application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during both the years which was followed by C_3N_1 (Sole soybean with 100% RDF along with FYM @ 2.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.
- Protein yield (kg ha^{-1}) was significantly affected by the combine practice of cropping system and nutrient management during 2019 and in pooled data. The perusal of the data revealed that the protein yield (kg ha^{-1}) was highest in C_3N_2 (Sole soybean +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during 2019, which was found to be followed by C_3N_1(Sole soybean

+100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

- Oil yield (kg ha^{-1}) was significantly affected by the combine practice of cropping system and nutrient management during both the year and in pooled data. The perusal of the data revealed that the oil yield (kg ha^{-1}) was highest in C_3N_2 (Sole soybean +75% RDF + FYM @ 5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination during both the years, which was found to be followed by C_3N_1(Sole soybean +100% RDF + FYM @ 2.5 t ha^{-1} + biofertilizer consortium @ 20 g kg^{-1} seed) treatment combination.

5.2 Competitive studies of rice based intercropping with groundnut and soybean as influenced by cropping system and nutrient management

a**) Effect of cropping system**

- Intercropping of rice with soybean had recorded higher values for land equivalent ratio, price equivalent ratio, relative crowding coefficient and monetary advantage (Rs. ha^{-1}).
- Among the cropping systems, higher competitive ratio of rice was recorded with rice + soybean (3:1) followed rice + groundnut (3:1). Whereas in case of intercrop higher competitive ratio of intercrop was recorded with rice + groundnut (3:1), followed rice + soybean (3:1).

b) Effect of nutrient management

- The application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} recorded the highest land equivalent ratio, price equivalent ratio, relative crowding coefficient and monetary advantage (Rs. ha^{-1}).
- Competitive ratio in rice indicated that among nutrient management treatments, application 75% RDF along with FYM @ 5 t ha^{-1} and

biofertilizer consortium @ 20 g kg^{-1} recorded a higher value of competitive ratio. Whereas pooled data of competitive ratio in intercrop indicated that among nutrient management treatments, application of 50% RDF along with FYM @ 7.5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} recorded a higher value of competitive ratio.

5.3 Physico chemical properties of soil in rice based intercropping with groundnut and soybean as influenced by cropping system and nutrient management

a) Effect of cropping system

- Application of different cropping system did not show any significant effect on soil pH and organic carbon (%) during both the years and in pooled data.
- Highest available nitrogen (kg ha^{-1}) was recorded in sole soybean during both the years and in pooled data. Among intercropping highest was recorded in rice intercropped with soybean during both the years and in pooled data.
- Effect of cropping system could not show significant response on available phosphorous and potassium (kg ha^{-1}) in soil after harvest.
- Highest soil bacteria, actinomycetes and fungi were recorded in sole soybean. Among intercropping highest was recorded in rice intercropped with soybean during both the years.

b) Effect of nutrient management

- The effect of different nutrient management did not bring significant impact on soil pH and organic carbon during both the years.
- The maximum available nitrogen, phosphorous and potassium (kg ha^{-1}) in soil after harvest recorded at N_2 treatment (75% RDF along with

FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1}) during both the years and in pooled data.

- It was noted that application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} obtained statistically superior values of soil bacteria, actinomycetes and fungi during both the years.

5.4 Economic analysis of rice based intercropping with groundnut and soybean as influenced by cropping system and nutrient management

a) Effect of cropping system

- The highest cost of cultivation (Rs. ha^{-1}) was recorded from rice+ groundnut (3:1) intercropping system followed by rice + soybean (3:1)
- Among the intercropping systems under study, rice intercropped with soybean (3:1) recorded highest gross returns (Rs. ha^{-1}), net return (Rs. ha^{-1}) and B:C ratio followed by rice + groundnut (3:1) intercropping system.

b) Effect of nutrient management

- Application of 75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded the highest cost of cultivation (Rs. ha^{-1}), gross return (Rs. ha^{-1}), net return (Rs. ha^{-1}) and B:C ratio.

5.5 Conclusion

- Among intercropping systems rice+ soybean intercropping system was found to be most suitable than rice+ groundnut intercropping. This system recorded highest grain yield (2.98 t ha^{-1}) of rice and the highest rice equivalent yield (4.63 t ha^{-1}).
- Among the different doses of nutrient management applied, N_2-75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed found to be most suitable as it recorded maximum production

(3.15 t ha^{-1} rice and 1.53 t ha^{-1} seed yield of soybean) under the rainfed condition of Nagaland.

- In respect of land equivalent ratio, price equivalent ratio, relative crowding coefficient and monetary advantage (Rs. ha^{-1}), rice + soybean (3:1) intercropping system was found to be the most beneficial.
- Rice + soybean intercropping system recorded higher B:C ratio (2.23) compared to rice+ groundnut (1.92). Among the different nutrient management, N_2-75% RDF along with FYM @ 5 t ha^{-1} and biofertilizer consortium @ 20 g kg^{-1} seed recorded maximum B:C ratio of 1.87.

Legume intercropping in rice can play and fulfil the diversified needs of concerned growers. Interventions with biologically and economically feasible cropping system can be easily made and practiced especially by small farmers in the rainfed areas of Nagaland. Therefore, in the current scenario of growing population pressure, changing climate and the needs to produce diverse products from the ever shrinking land holdings, inclusion of legume (especially soybean) in the rice culture system can be a very useful management strategy not only to meet the food requirements but also to increase profitability for farmers, sustainability of agriculture and conservation of soil health.

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APPENDIX-A

Calendar of agronomic management practices performed during the investigation period during 2019 and 2020

Sl. No.	Operations	Date	
		2019	2020
1	First ploughing	13/5/19	20/5/20
2	Second ploughing	17/5/19	25/5/20
3	Layout	23/5/19	29/5/20
4	Application of FYM	27/5/19	3/6/20
5	Fertilizer application	18/6/19	25/6/20
6	Seed treatment with biofertilizer + Sowing of seeds	19/6/19	26/6/20
7	Thinning	1/7/19	8/7/20
8	Gap filling	2/7/19	10/7/20
9	First hand weeding	15/7/19	23/7/20
10	Observation at 30 DAS	19/7/19	26/7/20
11	Second dose of urea application	16/7/19	25/7/20
12	Third dose of urea application	9/8/19	14/8/20
13	Second hand weeding	14/8/19	19/8/20
14	Observation at 60 DAS	19/8/19	26/8/20
15	Observation at 90 DAS	19/9/19	26/9/20
16	Complete harvesting		
	Rice	18/10/19	26/10/20
	Groundnut	17/10/19	24/10/20
	Soybean	7/10/19	15/10/20
17	Threshing and drying	28/10/19	2/11/20

APPENDIX-B

Cost of cultivation (Rs. ha^{-1})

A. Common cost of cultivation

Sl. No.	Operations	Quantity (Unit ha^{-1})	Rate (Rs. ha^{-1})	Cost (Rs. ha^{-1})
1.	Field preparation			
	a. Primary tillage	1	1500	1500
	b. Secondary tillage	1	1500	1500
	c. Preparation of layout	10	282	2820
2.	Sowing	10	282	2820
3.	Gap filling, weeding and intercultural operation	10	282	2820
4.	Application of manures and fertilizers	8 labours	282	2256
5.	Harvesting, threshing and winnowing	10 labours	282	2820
6.	Drying and bagging	8 labours	282	2256
Total				18792

B. Cost of variable inputs

Sl. No.	Inputs	Quantity (kg ha^{-1})	Rate (Rs. ha^{-1})	Cost (Rs. ha^{-1})	
1.	**Seed**				
	C_1-Rice seed	80	20	1600	
	C_2-Groundnut seed	70	55	3850	
	C_3-Soybean seed	60	40	2400	
	C_4- Rice seed Groundnut seed	60 35	20 55	1200 1925	Total 3125
	C_5- Rice seed Soybean seed	60 30	20 40	1200 1200	Total 2400
2.	**Seed treatment with biofertilizer consortium**				
	C_1	1.6	50	80	
	C_2	1.4	50	70	
	C_3	1.2	50	60	
	C_4	(1.2+0.7)=1.9	50	95	
	C_5	(1.2+0.6)=1.8	50	90	
3.	**Nutrient management**				
N_1	**Rice**				
	Urea	130	10	1300	
	SSP	187	15	2805	
	MOP	33	25	825	
	FYM	2.5 t	1000	2500	
	Total			7430	
N_2	Urea	98	10	980	
	SSP	141	15	2115	
	MOP	25	25	625	
	FYM	5 t	1000	5000	
	Total			8720	
N_3	Urea	65	10	650	
	SSP	94	15	1410	
	MOP	17	25	425	
	FYM	7.5 t	1000	7500	
	Total			9985	
N_1	**Groundnut**				
	Urea	43	10	430	
	SSP	250	15	3750	
	MOP	50	25	1250	
	FYM	2.5t	1000	2500	
	Total			7930	
N_2	Urea	33	10	330	

	SSP	188	15	2820
	MOP	38	25	950
	FYM	5 t	1000	5000
			Total	9100
N_3	Urea	22	10	220
	SSP	125	15	1875
	MOP	25	25	625
	FYM	7.5 t	1000	7500
			Total	10220
N_1	**Soybean**			
	Urea	43	10	430
	SSP	375	15	5625
	MOP	69	25	1725
	FYM	2.5 t	1000	2500
			Total	10280
N_2	Urea	33	10	330
	SSP	281	15	4215
	MOP	50	25	1250
	FYM	5t	1000	5000
			Total	10795
N_3	Urea	22	10	220
	SSP	188	15	2820
	MOP	33	25	825
	FYM	7.5 t	1000	7500
			Total	11365

APPENDIX- C

ANOVA-1: Analysis of variance on plant height (cm) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of plant height					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	2.91	15.48	0.23	2.79	397.83	166.35
Factor C	2	216.18	209.06	569.07	546.11	726.14	724.71
Factor N	2	552.45	564.78	1001.06	1038.74	1071.34	970.47
C X N	4	5.57	14.61	39.41	51.66	436.30	343.16
Error	16	358.67	282.61	792.77	807.29	485.28	854.38

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	40.70	58.64	28.22
Replication	4	18.39	3.06	564.21
Factor C	2	422.228	1114.77	1449.38
Year X Factor C	2	3.00	0.399	1.43
Factor N	2	1,115.80	2039.39	2039.92
Year X Factor N	2	1.4	0.413	1.86
Factor C X Factor N	4	18.51	89.80	773.12
Year X C X N	4	1.67	1.26	6.37
Error	32	641.28	1600.01	1339.63

ANOVA-2: Analysis of variance on number of leaves plant^{-1} of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of number of leaves plant^{-1}					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.04	0.90	2.14	3.97	33.55	42.29
Factor C	2	12.85	16.33	315.62	159.13	226.86	238.73
Factor N	2	34.67	28.05	155.58	309.25	790.14	802.80
C X N	4	3.31	2.94	10.07	7.36	30.85	46.44
Error	16	18.71	16.39	99.72	124.68	279.12	160.31

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	6.37	9.39	5.32
Replication	4	0.94	6.10	75.84
Factor C	2	28.69	314.69	465.49
Year X Factor C	2	0.49	0.012	0.10
Factor N	2	62.53	624.43	1591.91
Year X Factor N	2	0.19	0.43	1.03
Factor C X Factor N	4	6.10	17.25	75.73
Year X C X N	4	0.16	0.19	1.56
Error	32	35.1	224.41	439.43

ANOVA-3: Analysis of variance on dry matter (g) plant^{-1} of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of dry matter (g) plant^{-1}**					
		30 DAS		**60 DAS**		**90 DAS**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	0.02	0.00	0.62	0.51	52.74	48.14
Factor C	2	0.12	0.13	19.20	20.21	138.24	145.88
Factor N	2	2.07	1.65	206.05	208.32	486.97	475.11
C X N	4	0.01	0.00	2.95	3.06	47.14	44.66
Error	16	0.24	0.26	16.67	19.37	98.80	130.11

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.18	15.43	10.99
Replication	4	0.12	1.13	100.89
Factor C	2	0.25	39.38	284.02
Year X Factor C	2	0.00	0.03	0.10
Factor N	2	3.68	414.34	961.77
Year X Factor N	2	0.04	0.03	0.32
Factor C X Factor N	4	0.01	5.78	91.64
Year X C X N	4	0.00	0.24	0.17
Error	32	0.51	36.05	228.91

ANOVA-4: Analysis of variance on leaf area index of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of leaf area index of rice					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.02	0.01	0.33	0.00	0.67	0.01
Factor C	2	0.09	0.08	0.59	0.80	0.75	0.70
Factor N	2	0.42	0.43	4.30	4.24	2.52	2.26
C X N	4	0.03	0.01	0.22	0.17	0.21	0.22
Error	16	0.07	0.05	0.82	0.63	1.30	0.62

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.00	0.02	0.01
Replication	4	0.03	0.33	0.69
Factor C	2	0.17	1.39	1.45
Year X Factor C	2	0.00	0.01	0.00
Factor N	2	0.85	8.52	4.76
Year X Factor N	2	0.00	0.02	0.01
Factor C X Factor N	4	0.04	0.38	0.42
Year X C X N	4	0.00	0.02	0.00
Error	32	0.12	1.45	1.91

ANOVA-5: Analysis of variance on crop growth rate (g m^{-2} day^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of crop growth rate (g m^{-2} day^{-1})			
		30-60 DAS		60-90 DAS	
		2019	2020	2019	2020
Replication	2	1.20	1.32	125.07	112.79
Factor C	2	45.30	47.96	151.45	159.79
Factor N	2	464.68	480.14	165.26	150.79
C X N	4	7.30	8.09	80.61	90.65
Error	16	44.80	52.56	322.02	379.67

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	34.21	1.05
Replication	4	2.53	237.86
Factor C	2	93.15	310.82
Year X Factor C	2	0.11	0.41
Factor N	2	944.75	315.52
Year X Factor N	2	0.07	0.53
Factor C X Factor N	4	14.73	169.96
Year X C X N	4	0.66	1.30
Error	32	97.36	701.69

ANOVA-6: Analysis of variance on relative growth rate (g g^{-1} day^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of relative growth rate (g g^{-1} day^{-1})			
		30-60 DAS		60-90 DAS	
		2019	2020	2019	2020
Replication	2	0.03	0.00	0.00	0.00
Factor C	2	0.04	0.00	0.00	0.00
Factor N	2	0.03	0.00	0.00	0.00
C X N	4	0.07	0.00	0.00	0.00
Error	16	0.28	0.00	0.00	0.00

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	0.01	0.00
Replication	4	0.04	0.00
Factor C	2	0.02	0.00
Year X Factor C	2	0.02	0.00
Factor N	2	0.02	0.00
Year X Factor N	2	0.02	0.00
Factor C X Factor N	4	0.04	0.00
Year X C X N	4	0.04	0.00
Error	32	0.28	0.00

ANOVA-7: Analysis of variance on net assimilation rate (g m^{-2} day^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of net assimilation rate (g m^{-2} day^{-1})			
		30-60 DAS		60-90 DAS	
		2019	2020	2019	2020
Replication	2	7.91	0.07	10.12	17.81
Factor C	2	1.07	2.35	5.06	3.62
Factor N	2	2.91	7.30	19.48	6.86
C X N	4	0.96	1.38	13.36	7.88
Error	16	33.82	32.92	58.44	56.26

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	7.62	0.41
Replication	4	7.97	27.93
Factor C	2	3.24	7.20
Year X Factor C	2	0.18	1.48
Factor N	2	9.58	23.66
Year X Factor N	2	0.62	2.68
Factor C X Factor N	4	2.04	20.53
Year X C X N	4	0.30	0.71
Error	32	66.70	114.71

ANOVA-8: Analysis of variance on phenological parameters of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of phenological parameters					
		Days to 50% flowering		Days to 50% maturity		Days to harvesting	
		2019	2020	2019	2020	2019	2020
Replication	2	1.53	3.40	1.50	0.50	1.41	1.30
Factor C	2	0.17	0.33	0.57	0.73	0.52	0.89
Factor N	2	0.33	1.08	3.80	4.38	0.07	0.18
C X N	4	0.41	2.87	1.69	0.68	3.26	2.01
Error	16	20.15	21.32	13.43	12.75	7.26	7.82

ANOVA Pooled				
Source of variance	**df**	**Days to 50% flowering**	**Days to 50% maturity**	**Days to harvesting**
Years	1	0.71	0.24	0.69
Replication	4	4.90	2.07	2.74
Factor C	2	0.48	1.29	1.26
Year X Factor C	2	0.04	-0.05	0.15
Factor N	2	1.11	8.19	0.11
Year X Factor N	2	0.32	-0.05	0.15
Factor C X Factor N	4	2.37	1.96	4.91
Year X C X N	4	0.91	0.47	0.39
Error	32	41.49	26.09	15.04

ANOVA-9: Analysis of variance on yield attributes of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of yield attributes**					
		Number of panicles m^{-2}		**Panicle length (cm)**		**Weight of $panicle^{-1}$**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	450.64	731.31	0.49	1.17	0.35	0.13
Factor C	2	2278.51	2614.26	3.06	2.31	3.62	3.91
Factor N	2	5130.65	7290.61	68.92	53.21	3.61	4.13
C X N	4	815.61	993.38	0.89	0.67	1.07	1.19
Error	16	2283.89	2574.30	38.36	62.42	1.04	1.41

ANOVA Pooled				
Source of variance	**df**	**Number of panicles m^{-2}**	**Panicle length (cm)**	**Weight of $panicle^{-1}$**
Years	1	138.24	4.97	0.09
Replication	4	1181.95	1.66	0.48
Factor C	2	4810.83	4.99	7.53
Year X Factor C	2	81.94	0.38	0.00
Factor N	2	12298.16	121.41	7.73
Year X Factor N	2	123.08	0.71	0.10
Factor C X Factor N	4	1584.02	1.00	2.25
Year X C X N	4	224.99	0.56	0.02
Error	32	4858.20	100.78	2.44

ANOVA-10: Analysis of variance on yield attributes of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of yield attributes**					
		Number of grains panicle^{-1}		**Filled grain %**		**Test weight (g)**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	450.64	731.31	1.98	1.74	0.05	0.15
Factor C	2	2278.51	2614.26	200.59	202.61	0.32	0.40
Factor N	2	5130.65	7290.61	298.92	300.73	0.27	0.29
C X N	4	815.61	993.38	20.96	21.27	0.14	0.10
Error	16	2283.89	2574.30	266.18	265.61	29.79	29.85

ANOVA Pooled				
Source of variance	**df**	**Number of grains panicle^{-1}**	**Filled grain %**	**Test weight (g)**
Years	1	138.24	1.90	0.42
Replication	4	1181.95	3.68	0.2
Factor C	2	4810.83	403.28	0.708
Year X Factor C	2	81.94	-0.07	0.01
Factor N	2	12298.16	599.72	0.56
Year X Factor N	2	123.08	-0.07	0.00
Factor C X Factor N	4	1584.02	42.14	0.21
Year X C X N	4	224.99	0.09	0.04
Error	32	4858.20	531.83	59.64

ANOVA-11: Analysis of variance on yield (t ha^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of yield**			
		Grain yield (t ha^{-1})		**Straw yield (t ha^{-1})**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.09	0.01	0.03	0.00
Factor C	2	0.95	0.98	1.28	1.34
Factor N	2	1.37	1.36	2.08	2.19
C X N	4	0.41	0.41	0.32	0.96
Error	16	0.38	0.49	2.56	1.49

ANOVA Pooled			
Source of variance	**df**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**
Years	1	0.00	0.04
Replication	4	0.10	0.03
Factor C	2	1.92	2.62
Year X Factor C	2	0	0.00
Factor N	2	2.73	4.27
Year X Factor N	2	0	0.00
Factor C X Factor N	4	0.813	1.18
Year X C X N	4	0	0.11
Error	32	0.872	4.05

ANOVA-12: Analysis of variance on rice equivalent yield (t ha^{-1}) and harvest index (%) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		Rice equivalent yield (t ha^{-1})		**Harvest index (%)**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.06	0.02	3.96	0.00
Factor C	2	11.26	12.34	9.72	8.55
Factor N	2	3.60	3.45	10.44	8.67
C X N	4	0.88	0.85	14.16	3.44
Error	16	0.61	0.60	76.34	75.35

ANOVA Pooled			
Source of variance	**df**	**Rice equivalent yield (t ha^{-1})**	**Harvest index (%)**
Years	1	0.04	0.35
Replication	4	0.08	3.95
Factor C	2	23.59	18.22
Year X Factor C	2	0.01	0.03
Factor N	2	7.04	19.07
Year X Factor N	2	0.01	0.04
Factor C X Factor N	4	1.73	14.82
Year X C X N	4	0.01	2.79
Error	32	1.21	151.71

ANOVA-13: Analysis of variance on N content in grain and straw (%) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		N content in grain (%)		**N content in straw (%)**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.02	0.01	0.00	0.00
Factor C	2	0.00	0.00	0.00	0.00
Factor N	2	0.03	0.03	0.07	0.07
C X N	4	0.00	0.00	0.00	0.00
Error	16	0.03	0.04	0.00	0.00

ANOVA Pooled			
Source of variance	**df**	**N content in grain (%)**	**N content in straw (%)**
Years	1	0.00	0.00
Replication	4	0.03	0.00
Factor C	2	0.00	0.00
Year X Factor C	2	0.00	0.00
Factor N	2	0.06	0.14
Year X Factor N	2	0.00	0.00
Factor C X Factor N	4	0.00	0.00
Year X C X N	4	0.00	0.00
Error	32	0.07	0.00

ANOVA-14: Analysis of variance on P content in grain and straw (%) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		P content in grain (%)		**P content in straw (%)**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.00	0.00	0.00	0.00
Factor C	2	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00
C X N	4	0.00	0.00	0.00	0.00
Error	16	0.00	0.00	0.00	0.00

ANOVA Pooled			
Source of variance	df	P content in grain (%)	P content in straw (%)
Years	1	1.95	0.00
Replication	4	2.20	0.00
Factor C	2	38.09	0.00
Year X Factor C	2	0.06	0.00
Factor N	2	568.81	0.00
Year X Factor N	2	0.11	0.00
Factor C X Factor N	4	11.03	0.00
Year X C X N	4	1.03	0.00
Error	32	28.02	0.00

ANOVA-15: Analysis of variance on K content in grain and straw (%) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		K content in grain (%)		K content in straw (%)	
		2019	2020	2019	2020
Replication	2	0.00	0.00	0.00	0.00
Factor C	2	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.05	0.05
C X N	4	0.00	0.00	0.00	0.00
Error	16	0.01	0.01	0.03	0.02

ANOVA Pooled			
Source of variance	df	K content in grain (%)	K content in straw (%)
Years	1	0.00	0.00
Replication	4	0.00	0.00
Factor C	2	0.00	0.00
Year X Factor C	2	0.00	0.00
Factor N	2	0.01	0.10
Year X Factor N	2	0.00	0.00
Factor C X Factor N	4	0.00	0.00
Year X C X N	4	0.00	0.00
Error	32	0.01	0.04

ANOVA-16: Analysis of variance on N uptake in grain and straw (kg ha^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		N uptake in grain (kg ha^{-1})		N uptake in straw (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	54.65	18.07	1.47	0.73
Factor C	2	156.79	165.72	19.68	18.47
Factor N	2	359.89	365.35	276.49	292.43
C X N	4	54.33	56.38	2.85	9.21
Error	16	58.94	81.22	18.68	9.35

ANOVA Pooled			
Source of variance	df	N uptake in grain (kg ha^{-1})	N uptake in straw (kg ha^{-1})
Years	1	1.17	1.95
Replication	4	72.72	2.20
Factor C	2	322.43	38.09
Year X Factor C	2	0.09	0.06
Factor N	2	725.24	568.81
Year X Factor N	2	-0.003	0.11
Factor C X Factor N	4	110.66	11.03
Year X C X N	4	0.05	1.03
Error	32	140.16	28.02

ANOVA-17: Analysis of variance on P uptake in grain and straw (kg ha^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		P uptake in grain (kg ha^{-1})		P uptake in straw (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	1.80	0.98	1.08	1.01
Factor C	2	7.06	7.83	3.22	3.23
Factor N	2	15.09	15.84	16.60	17.79
C X N	4	1.32	1.65	0.52	1.97
Error	16	5.93	7.71	13.48	9.54

ANOVA Pooled			
Source of variance	df	P uptake in grain (kg ha^{-1})	P uptake in straw (kg ha^{-1})
Years	1	0.33	1.61
Replication	4	2.77	2.10
Factor C	2	14.88	6.43
Year X Factor C	2	0.01	0.02
Factor N	2	30.93	34.37
Year X Factor N	2	0.01	0.02
Factor C X Factor N	4	2.95	2.17
Year X C X N	4	0.01	0.32
Error	32	13.63	23.02

ANOVA-18: Analysis of variance on K uptake in grain and straw (kg ha^{-1}) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		K uptake in grain (kg ha^{-1})		K uptake in straw (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	3.97	2.62	3.27	0.68
Factor C	2	9.64	10.75	197.11	195.75
Factor N	2	28.38	28.42	747.09	791.47
C X N	4	3.15	2.88	43.32	123.99
Error	16	3.67	6.41	273.74	316.56

ANOVA Pooled			
Source of variance	df	K uptake in grain (kg ha^{-1})	K uptake in straw (kg ha^{-1})
Years	1	0.31	9.35
Replication	4	6.59	3.96
Factor C	2	20.37	392.79
Year X Factor C	2	0.02	0.05
Factor N	2	56.80	1538.18
Year X Factor N	2	0.00	0.38
Factor C X Factor N	4	6.02	153.58
Year X C X N	4	0.01	13.73
Error	32	10.08	590.28

ANOVA-19: Analysis of variance on protein content (%) of rice in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		Protein content (%)		Protein yield (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	0.60	0.38	2134.72	705.81
Factor C	2	0.03	0.04	6124.66	6473.56
Factor N	2	1.07	1.11	14058.29	14271.40
C X N	4	0.00	0.00	2122.21	2202.25
Error	16	1.20	1.39	2302.31	3172.68

ANOVA Pooled			
Source of variance	df	Protein content (%)	Protein yield (kg ha^{-1})
Years	1	0.01	45.76
Replication	4	0.98	2840.75
Factor C	2	0.07	12594.68
Year X Factor C	2	0.00	3.49
Factor N	2	2.18	28329.43
Year X Factor N	2	0.00	0.16
Factor C X Factor N	4	0.00	4322.92
Year X C X N	4	0.00	1.67
Error	32	2.60	5474.75

GROUNDNUT

ANOVA-20: Analysis of variance on plant height (cm) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of plant height (cm)					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.25	5.10	20.19	25.00	41.58	56.08
Factor C	1	21.56	34.69	15.55	24.95	49.83	36.44
Factor N	2	92.25	116.99	125.48	158.12	129.41	175.66
C X N	2	0.28	5.09	0.81	0.32	13.85	6.21
Error	10	26.41	11.63	25.19	35.05	51.95	63.97

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	6.65	2.59	11.49
Replication	4	5.35	45.19	97.66
Factor C	1	47.49	36.12	126.19
Year X Factor C	1	1.90	0.37	0.20
Factor N	2	58.76	62.79	55.03
Year X Factor N	2	1.21	0.44	1.44
Factor C X Factor N	2	160.99	224.35	227.01
Year X C X N	2	0.52	1.14	1.54
Error	20	38.04	60.24	115.92

ANOVA-21: Analysis of variance on number of branches plant^{-1} of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of number of branches plant^{-1}**					
		30 DAS		**60 DAS**		**90 DAS**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	1.15	0.88	0.99	0.52	2.48	1.65
Factor C	1	2.28	2.14	6.48	7.22	4.70	4.91
Factor N	2	7.07	6.52	8.87	9.16	8.62	8.69
C X N	2	0.35	0.34	0.16	0.09	0.62	0.55
Error	10	2.66	2.93	8.13	7.83	5.73	3.25

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.19	0.13	0.32
Replication	4	2.04	1.51	4.14
Factor C	1	2.67	4.41	3.87
Year X Factor C	1	0.01	0.01	0.01
Factor N	2	4.16	6.50	2.14
Year X Factor N	2	0.01	0.00	0.00
Factor C X Factor N	2	11.85	21.06	22.08
Year X C X N	2	0.00	0.05	0.00
Error	20	5.59	15.96	8.98

ANOVA-22: Analysis of variance on dry matter (g) plant^{-1} of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares dry matter (g) plant^{-1}					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.03	0.05	11.60	0.59	40.78	24.02
Factor C	1	0.21	0.21	62.79	42.38	89.96	91.80
Factor N	2	0.55	0.56	64.74	73.14	104.46	136.18
C X N	2	0.03	0.03	7.64	10.67	20.16	14.11
Error	10	0.26	0.21	15.48	19.35	34.09	27.59

ANOVA Pooled				
Source of variance	df	30 DAS	60 DAS	90 DAS
Years	1	0.01	14.80	25.76
Replication	4	0.08	12.20	64.80
Factor C	1	0.27	84.02	151.50
Year X Factor C	1	0.00	0.01	0.686
Factor N	2	0.39	28.744	20.04
Year X Factor N	2	0.00	0.20	3.42
Factor C X Factor N	2	0.92	146.62	280.95
Year X C X N	2	0.00	1.10	0.08
Error	20	0.46	34.83	61.68

ANOVA-23: Analysis of variance on number of root nodules plant^{-1} of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of number of root nodules plant^{-1}					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	4.72	0.57	45.57	12.26	34.14	20.48
Factor C	1	78.29	95.27	182.40	179.05	174.10	145.41
Factor N	2	236.47	184.48	313.32	267.67	473.79	571.98
C X N	2	5.29	13.11	37.95	54.81	44.63	26.92
Error	10	49.01	30.90	76.83	87.81	207.93	93.51

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	46.63	57.14	51.08
Replication	4	5.28	57.83	54.64
Factor C	1	91.17	61.97	353.82
Year X Factor C	1	4.42	1.58	0.64
Factor N	2	146.78	353.09	318.37
Year X Factor N	2	3.53	1.73	1.62
Factor C X Factor N	2	365.97	614.97	760.06
Year X C X N	2	1.04	1.87	2.31
Error	20	79.91	164.65	301.42

ANOVA-24: Analysis of variance on fresh weight of nodules plant^{-1} (g) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of fresh weight of nodules plant^{-1} (g)**					
		30 DAS		**60 DAS**		**90 DAS**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	0.01	0.00	0.05	0.02	0.06	0.02
Factor C	1	0.02	0.02	0.10	0.10	0.12	0.11
Factor N	2	0.08	0.07	0.20	0.17	0.18	0.18
C X N	2	0.01	0.01	0.03	0.03	0.02	0.00
Error	10	0.01	0.02	0.18	0.07	0.19	0.07

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.00	0.00	0.00
Replication	4	0.02	0.07	0.08
Factor C	1	0.09	0.12	0.09
Year X Factor C	1	0.00	0.00	0.00
Factor N	2	0.03	0.06	0.08
Year X Factor N	2	0.00	0.00	0.00
Factor C X Factor N	2	0.09	0.45	0.43
Year X C X N	2	0.00	0.00	0.00
Error	20	0.03	0.25	0.26

ANOVA-25: Analysis of variance on dry weight of nodules plant^{-1} (g) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of dry weight of nodules plant^{-1} (g)					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.00	0.00	0.00	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00	0.00	0.00
C X N	2	0.00	0.00	0.00	0.00	0.00	0.00
Error	10	0.00	0.00	0.00	0.00	0.00	0.00

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.00	0.00	0.00
Replication	4	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00
Year X Factor C	1	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00
Year X Factor N	2	0.00	0.00	0.00
Factor C X Factor N	2	0.00	0.00	0.00
Year X C X N	2	0.00	0.00	0.00
Error	20	0.00	0.00	0.00

ANOVA-26: Analysis of variance on leaf area index of groundnut at 30 DAS in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of leaf area index					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.00	0.02	0.09	0.10	0.16	0.08
Factor C	1	0.06	0.03	0.28	0.20	0.19	0.34
Factor N	2	0.07	0.06	0.57	0.58	0.44	0.44
C X N	2	0.00	0.00	0.08	0.08	0.01	0.02
Error	10	0.01	0.03	0.14	0.23	0.17	0.17

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.00	0.02	0.01
Replication	4	0.03	0.19	0.25
Factor C	1	0.06	0.74	0.56
Year X Factor C	1	0.00	0.00	0.00
Factor N	2	0.05	0.29	0.14
Year X Factor N	2	0.00	0.00	0.01
Factor C X Factor N	2	0.15	0.76	0.72
Year X C X N	2	0.00	0.00	0.01
Error	20	0.08	0.37	0.34

ANOVA-27: Analysis of variance on crop growth rate (g m^{-2} day^{-1}) of groundnut at 30-60 DAS in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of crop growth rate (g m^{-2} day^{-1})**			
		30-60 DAS		**60-90 DAS**	
		2019	**2020**	**2019**	**2020**
Replication	2	3.80	0.12	2.74	5.27
Factor C	1	17.20	11.32	0.75	2.91
Factor N	2	16.53	18.84	1.47	3.17
C X N	2	2.15	2.99	2.72	0.27
Error	10	5.31	6.43	13.91	18.69

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	4.30	0.47
Replication	4	3.92	8.01
Factor C	1	23.25	2.98
Year X Factor C	1	0.00	0.26
Factor N	2	6.95	0.31
Year X Factor N	2	0.06	0.72
Factor C X Factor N	2	38.42	6.78
Year X C X N	2	0.34	0.25
Error	20	11.73	32.60

ANOVA-28: Analysis of variance on relative growth rate (g g^{-1} day^{-1}) of groundnut at 30-60 DAS in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of relative growth rate (g g^{-1} day^{-1})			
		30-60 DAS		60-90 DAS	
		2019	2020	2019	2020
Replication	2	0.00	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.00	0.00	0.00	0.00

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	0.00	0.00
Replication	4	0.00	0.00
Factor C	1	0.00	0.00
Year X Factor C	1	0.00	0.00
Factor N	2	0.00	0.00
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.00	0.00
Year X C X N	2	0.00	0.00
Error	20	0.00	0.00

ANOVA-29: Analysis of variance on net assimilation rate (g m^{-2} day^{-1}) of groundnut at 30-60 DAS in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of net assimilation rate (g m^{-2} day^{-1})			
		30-60 DAS		60-90 DAS	
		2019	2020	2019	2020
Replication	2	1.35	0.01	0.08	1.71
Factor C	1	4.24	2.11	0.01	0.02
Factor N	2	2.65	3.14	0.02	0.02
C X N	2	0.56	0.90	0.52	0.04
Error	10	5.75	4.40	2.73	4.71

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	2.40	0.07
Replication	4	1.36	1.79
Factor C	1	4.73	0.01
Year X Factor C	1	0.01	0.03
Factor N	2	0.37	0.22
Year X Factor N	2	0.16	0.26
Factor C X Factor N	2	8.15	0.02
Year X C X N	2	0.19	0.10
Error	20	10.15	7.44

ANOVA-30: Analysis of variance on phenological parameters of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of phenological parameters**					
		Days to 50% flowering		**Days to 50% maturity**		**Days to harvesting**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	0.11	0.52	5.88	3.86	0.65	0.37
Factor C	1	1.39	1.74	1.28	0.00	0.27	0.32
Factor N	2	0.02	0.16	1.77	0.72	0.09	0.09
C X N	2	1.08	1.14	1.96	3.95	0.08	1.85
Error	10	4.40	4.68	4.79	22.04	2.92	3.60

ANOVA Pooled				
Source of variance	**df**	**Days to 50% flowering**	**Days to 50% maturity**	**Days to harvesting**
Years	1	0.01	0.11	0.93
Replication	4	0.63	9.78	0.97
Factor C	1	0.49	0.06	0.21
Year X Factor C	1	-0.00	0.04	0.71
Factor N	2	0.21	6.97	0.68
Year X Factor N	2	1.76	0.26	0.72
Factor C X Factor N	2	2.68	1.03	0.13
Year X C X N	2	0.39	1.32	0.93
Error	20	9.01	26.79	0.58

ANOVA-31: Analysis of variance on yield attributes of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of of yield attributes			
		Number of pods plant^{-1}		Number of seeds pod^{-1}	
		2019	2020	2019	2020
Replication	2	26.59	19.46	0.00	0.01
Factor C	1	35.20	92.84	0.04	0.14
Factor N	2	129.48	147.62	0.37	0.25
C X N	2	2.81	27.90	0.55	0.59
Error	10	64.74	93.58	1.28	0.84

ANOVA Pooled			
Source of variance	df	Number of pods plant^{-1}	Number of seeds pod^{-1}
Years	1	13.21	0.16
Replication	4	46.05	0.01
Factor C	1	43.06	0.07
Year X Factor C	1	0.62	0.00
Factor N	2	69.48	1.14
Year X Factor N	2	12.61	0.02
Factor C X Factor N	2	294.46	0.70
Year X C X N	2	15.63	0.02
Error	20	158.32	2.12

ANOVA-32: Analysis of variance on yield attributes of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of of yield attributes			
		Pod weight (g) plant^{-1}		Test weight (g)	
		2019	2020	2019	2020
Replication	2	3.65	3.04	325.54	189.04
Factor C	1	17.34	14.49	92.84	73.71
Factor N	2	19.15	25.41	464.33	419.76
C X N	2	3.98	4.24	70.46	136.97
Error	10	17.01	15.47	786.28	931.82

ANOVA Pooled			
Source of variance	df	Pod weight (g) plant^{-1}	Test weight (g)
Years	1	1.83	11.21
Replication	4	6.69	514.96
Factor C	1	10.19	240.96
Year X Factor C	1	0.08	2.30
Factor N	2	8.70	217.96
Year X Factor N	2	0.11	9.60
Factor C X Factor N	2	65.10	786.46
Year X C X N	2	0.43	0.81
Error	20	32.48	1717.81

ANOVA-33: Analysis of variance on yield (t ha^{-1}) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of yield (t ha^{-1})					
		Seed yield (t ha^{-1})		Stover yield (t ha^{-1})		Harvest index (%)	
		2019	2020	2019	2020	2019	2020
Replication	2	0.00	0.00	0.03	0.05	7.09	2.71
Factor C	1	1.97	2.08	12.57	12.94	7.44	8.87
Factor N	2	0.17	0.15	0.49	0.55	12.44	8.12
C X N	2	0.02	0.02	0.05	0.12	0.14	0.77
Error	10	0.05	0.03	0.27	0.31	35.86	25.67

ANOVA Pooled				
Source of variance	df	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Years	1	0.01	0.02	0.24
Replication	4	0.01	0.08	9.80
Factor C	1	0.84	4.94	3.18
Year X Factor C	1	0.00	0.01	0.03
Factor N	2	0.11	0.39	5.15
Year X Factor N	2	0.00	0.01	0.80
Factor C X Factor N	2	3.45	21.36	28.58
Year X C X N	2	0.00	0.00	0.05
Error	20	0.08	0.58	61.53

ANOVA-34: Analysis of variance on N content in seed and stover (%) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		N content in seed (%)		N content in stover (%)	
		2019	2020	2019	2020
Replication	2	0.09	0.12	0.01	0.01
Factor C	1	0.00	0.02	0.00	0.00
Factor N	2	1.31	1.31	0.08	0.08
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.24	0.17	0.03	0.03

ANOVA Pooled			
Source of variance	df	N content in seed (%)	N content in stover (%)
Years	1	0.00	0.00
Replication	4	0.14	0.01
Factor C	1	113.98	23.85
Year X Factor C	1	0.00	0.00
Factor N	2	0.46	0.03
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	1.64	0.12
Year X C X N	2	0.00	0.00
Error	20	0.48	0.07

ANOVA-35: Analysis of variance on P content in seed and stover (%) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		P content in seed (%)		P content in stover (%)	
		2019	2020	2019	2020
Replication	2	0.00	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.00	0.00	0.00	0.00

ANOVA Pooled			
Source of variance	**df**	**P content in seed (%)**	**P content in stover (%)**
Years	1	0.00	0.00
Replication	4	0.00	0.00
Factor C	1	1.40	0.74
Year X Factor C	1	0.00	0.00
Factor N	2	0.00	0.00
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.00	0.00
Year X C X N	2	0.00	0.00
Error	20	0.00	0.00

ANOVA-36: Analysis of variance on K content in seed and stover (%) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		K content in seed (%)		**K content in stover (%)**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.03	0.03	0.01	0.01
Factor C	1	0.00	0.00	0.00	0.00
Factor N	2	0.22	0.22	0.08	0.08
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.04	0.04	0.03	0.03

ANOVA Pooled			
Source of variance	**df**	**K content in seed (%)**	**K content in stover (%)**
Years	1	0.00	0.00
Replication	4	0.06	0.03
Factor C	1	0.08	0.03
Year X Factor C	1	0.00	0.00
Factor N	2	0.11	0.06
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.25	0.08
Year X C X N	2	0.00	0.00
Error	20	0.07	0.07

ANOVA-37: Analysis of variance on N uptake in seed and stover (kg ha^{-1}) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		N uptake in seed (kg ha^{-1})		N uptake in stover (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	4.85	14.12	10.91	10.25
Factor C	1	1940.95	2124.27	1872.21	2033.19
Factor N	2	531.90	522.20	295.83	309.21
C X N	2	61.53	68.56	16.24	38.42
Error	10	61.25	75.91	103.31	119.44

ANOVA Pooled			
Source of variance	**df**	**N uptake in seed (kg ha^{-1})**	**N uptake in stover (kg ha^{-1})**
Years	1	4.80	1.80
Replication	4	12.64	14.10
Factor C	1	11198.84	11902.80
Year X Factor C	1	3.81	2.72
Factor N	2	256.04	137.42
Year X Factor N	2	0.18	1.46
Factor C X Factor N	2	3641.80	3409.16
Year X C X N	2	1.35	1.56
Error	20	143.48	229.81

ANOVA-38: Analysis of variance on P uptake in seed and stover (kg ha^{-1}) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		P uptake in seed (kg ha^{-1})		P uptake in stover (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	0.03	0.11	0.23	0.30
Factor C	1	23.59	25.33	59.07	65.39
Factor N	2	3.42	3.17	8.06	8.65
C X N	2	0.39	0.39	0.50	1.30
Error	10	0.58	0.45	1.35	1.40

ANOVA Pooled			
Source of variance	**df**	**P uptake in seed (kg ha^{-1})**	**P uptake in stover (kg ha^{-1})**
Years	1	0.10	0.17
Replication	4	0.10	0.35
Factor C	1	130.97	365.46
Year X Factor C	1	0.06	0.15
Factor N	2	1.50	3.71
Year X Factor N	2	0.01	0.06
Factor C X Factor N	2	43.49	109.77
Year X C X N	2	0.01	0.08
Error	20	1.07	2.92

ANOVA-39: Analysis of variance on K uptake in seed and stover (kg ha^{-1}) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		K uptake in seed (kg ha^{-1})		**K uptake in stover (kg ha^{-1})**	
		2019	**2020**	**2019**	**2020**
Replication	2	1.31	3.91	25.60	15.03
Factor C	1	396.16	421.47	5821.57	6047.14
Factor N	2	101.05	98.27	485.52	526.16
C X N	2	11.88	12.48	50.72	95.09
Error	10	6.57	8.44	177.57	213.20

ANOVA Pooled			
Source of variance	**df**	**K uptake in seed (kg ha^{-1})**	**K uptake in stover (kg ha^{-1})**
Years	1	1.46	11.47
Replication	4	5.22	40.61
Factor C	1	264.51	2817.54
Year X Factor C	1	0.16	2.74
Factor N	2	70.52	392.71
Year X Factor N	2	0.15	3.68
Factor C X Factor N	2	705.86	9808.97
Year X C X N	2	0.11	0.57
Error	20	15.01	390.789

ANOVA-40: Analysis of variance on protein content (%) and protein yield (kg ha^{-1}) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		Protein content (%)		Protein yield (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	3.34	4.63	189.27	551.65
Factor C	1	0.14	0.69	75818.21	82979.49
Factor N	2	51.07	51.01	20777.40	20398.48
C X N	2	0.00	0.10	2403.57	2677.96
Error	10	9.45	6.69	2392.58	2965.11

ANOVA Pooled			
Source of variance	df	Protein content (%)	Protein yield (kg ha^{-1})
Years	1	0.01	187.34
Replication	4	5.32	493.98
Factor C	1	4452.16	437454.70
Year X Factor C	1	0.02	148.70
Factor N	2	18.03	10001.75
Year X Factor N	2	0.03	7.05
Factor C X Factor N	2	64.11	142257.75
Year X C X N	2	0.12	52.66
Error	20	18.79	5604.59

ANOVA-41: Analysis of variance on oil content (%) and oil yield (kg ha^{-1}) of groundnut in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		Oil content (%)		Oil yield (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	4.85	7.05	455.31	1857.09
Factor C	1	0.99	0.32	360536.92	388626.91
Factor N	2	18.61	25.51	45204.28	46076.27
C X N	2	0.12	0.06	5009.64	5830.27
Error	10	6.42	8.77	6063.43	8067.32

ANOVA Pooled			
Source of variance	**df**	**Oil content (%)**	**Oil yield (kg ha^{-1})**
Years	1	2.13	1576.67
Replication	4	7.93	1541.98
Factor C	1	21627.69	2029940.29
Year X Factor C	1	1.06	1008.42
Factor N	2	5.89	21208.99
Year X Factor N	2	0.09	49.802
Factor C X Factor N	2	28.31	647865.98
Year X C X N	2	0.29	178.13
Error	20	19.16	14900.92

Soybean

ANOVA-42: Analysis of variance on plant height (cm) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of plant height (cm)**					
		30 DAS		**60 DAS**		**90 DAS**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	86.63	29.88	81.40	97.02	112.08	89.59
Factor C	1	35.84	59.95	39.78	70.17	64.22	59.37
Factor N	2	109.85	133.72	202.43	276.06	163.60	182.44
C X N	2	4.03	5.43	20.68	24.71	7.34	30.98
Error	10	49.10	112.09	75.65	92.02	119.82	81.71

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	10.04	11.54	15.48
Replication	4	116.51	178.41	201.68
Factor C	1	41.24	148.68	79.36
Year X Factor C	1	0.23	1.63	0.00
Factor N	2	108.51	30.43	108.88
Year X Factor N	2	0.69	3.36	8.17
Factor C X Factor N	2	196.55	445.98	311.34
Year X C X N	2	1.62	3.73	0.20
Error	20	161.19	167.68	201.53

ANOVA-43: Analysis of variance on number of branches plant^{-1} of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of number of branches plant^{-1}					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.06	0.34	0.02	0.11	0.33	0.28
Factor C	1	1.50	1.50	2.88	3.04	4.11	4.70
Factor N	2	6.78	6.75	17.76	16.86	7.61	7.24
C X N	2	0.30	0.16	0.12	0.40	1.02	0.62
Error	10	1.36	1.10	4.68	4.53	6.63	5.24

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.11	0.19	0.25
Replication	4	0.40	0.13	0.61
Factor C	1	4.55	10.89	2.25
Year X Factor C	1	0.00	0.01	0.00
Factor N	2	2.11	12.09	2.94
Year X Factor N	2	0.04	0.02	0.05
Factor C X Factor N	2	10.30	18.01	20.05
Year X C X N	2	0.00	0.06	0.02
Error	20	2.46	9.21	11.87

ANOVA-44: Analysis of variance on dry matter (g) plant^{-1} of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares dry matter (g) plant^{-1}					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.01	0.04	0.52	2.56	5.29	15.99
Factor C	1	0.15	0.17	52.63	49.70	85.33	95.77
Factor N	2	0.28	0.32	101.91	94.49	256.09	299.25
C X N	2	0.02	0.02	6.86	8.91	7.10	5.88
Error	10	0.05	0.07	16.83	16.51	16.84	17.88

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.04	10.00	3.97
Replication	4	0.05	3.08	21.28
Factor C	1	0.24	77.59	126.30
Year X Factor C	1	0.00	0.04	0.03
Factor N	2	0.14	69.01	212.07
Year X Factor N	2	0.00	0.08	1.06
Factor C X Factor N	2	0.58	167.68	409.22
Year X C X N	2	0.00	0.12	0.76
Error	20	0.13	33.34	34.72

ANOVA-45: Analysis of variance on number of root nodules plant^{-1} of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of number of root nodules plant^{-1}					
		30 DAS		60 DAS		90 DAS	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	1.15	3.21	21.18	12.22	71.94	69.85
Factor C	1	70.21	48.51	169.59	163.32	253.88	263.27
Factor N	2	190.28	241.63	447.86	479.47	465.76	488.15
C X N	2	5.55	2.38	34.20	2.02	12.18	16.02
Error	10	41.81	12.56	105.61	79.78	344.17	325.38

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	18.78	51.91	56.20
Replication	4	4.36	33.39	141.78
Factor C	1	64.16	210.88	252.38
Year X Factor C	1	0.00	1.05	1.78
Factor N	2	140.23	366.23	377.72
Year X Factor N	2	0.06	6.82	1.81
Factor C X Factor N	2	350.95	708.32	864.65
Year X C X N	2	3.17	3.15	0.94
Error	20	54.36	185.4	669.56

ANOVA-46: Analysis of variance on fresh weight of nodules plant^{-1} (g) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of fresh weight of nodules plant^{-1} (g)					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.00	0.01	0.06	0.04	0.00	0.00
Factor C	1	0.02	0.02	0.10	0.11	0.00	0.00
Factor N	2	0.09	0.08	0.14	0.14	0.00	0.00
C X N	2	0.00	0.00	0.03	0.02	0.00	0.00
Error	10	0.02	0.02	0.13	0.08	0.00	0.00

ANOVA Pooled				
Source of variance	df	30 DAS	60 DAS	90 DAS
Years	1	0.00	0.00	0.00
Replication	4	0.01	0.10	0.07
Factor C	1	0.07	0.14	0.17
Year X Factor C	1	0.00	0.00	0.00
Factor N	2	0.04	0.04	0.10
Year X Factor N	2	0.00	0.00	0.00
Factor C X Factor N	2	0.10	0.37	0.43
Year X C X N	2	0.00	0.00	0.00
Error	20	0.04	0.21	0.24

ANOVA-47: Analysis of variance on dry weight of nodules plant^{-1} (g) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of dry weight of nodules plant^{-1} (g)					
		30 DAS		60 DAS		90 DAS	
		2019	2020	2019	2020	2019	2020
Replication	2	0.00	0.00	0.00	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00	0.00	0.00
C X N	2	0.00	0.00	0.00	0.00	0.00	0.00
Error	10	0.00	0.00	0.00	0.00	0.00	0.00

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.00	0.00	0.00
Replication	4	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00
Year X Factor C	1	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00
Year X Factor N	2	0.00	0.00	0.00
Factor C X Factor N	2	0.00	0.00	0.00
Year X C X N	2	0.00	0.00	0.00
Error	20	0.00	0.00	0.00

ANOVA-48: Analysis of variance on leaf area index of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of leaf area index**					
		30 DAS		**60 DAS**		**90 DAS**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
Replication	2	0.00	0.00	0.06	0.04	0.12	0.01
Factor C	1	0.03	0.02	0.23	0.22	0.18	0.15
Factor N	2	0.08	0.07	0.66	0.63	0.40	0.42
C X N	2	0.00	0.01	0.04	0.08	0.02	0.02
Error	10	0.01	0.02	0.14	0.15	0.18	0.29

ANOVA Pooled				
Source of variance	**df**	**30 DAS**	**60 DAS**	**90 DAS**
Years	1	0.00	0.00	0.00
Replication	4	0.01	0.10	0.13
Factor C	1	0.03	0.70	0.34
Year X Factor C	1	0.00	0.00	0.00
Factor N	2	0.05	0.30	0.23
Year X Factor N	2	0.00	0.00	0.00
Factor C X Factor N	2	0.13	0.85	0.63
Year X C X N	2	0.00	0.00	0.00
Error	20	0.03	0.29	0.47

ANOVA-49: Analysis of variance on crop growth rate (g m^{-2} day^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of crop growth rate (g m^{-2} day^{-1})**			
		30-60 DAS		**60-90 DAS**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.29	1.47	6.10	13.56
Factor C	1	32.76	30.55	2.73	5.20
Factor N	2	63.57	58.16	25.69	40.59
C X N	2	4.26	5.87	15.36	12.10
Error	10	11.96	11.72	34.00	22.35

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	6.07	0.95
Replication	4	1.76	19.66
Factor C	1	48.03	4.10
Year X Factor C	1	0.02	0.09
Factor N	2	43.77	57.63
Year X Factor N	2	0.07	0.40
Factor C X Factor N	2	103.16	38.44
Year X C X N	2	0.12	1.02
Error	20	23.69	56.35

ANOVA-50: Analysis of variance on relative growth rate (g g^{-1} day^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of relative growth rate (g g^{-1} day^{-1})**			
		30-60 DAS		**60-90 DAS**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.00	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.00	0.00	0.00	0.00

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	0.00	0.00
Replication	4	0.00	0.00
Factor C	1	0.00	0.00
Year X Factor C	1	0.00	0.00
Factor N	2	0.00	0.00
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.00	0.00
Year X C X N	2	0.00	0.00
Error	20	0.00	0.00

ANOVA-51: Analysis of variance on net assimilation rate (g m^{-2} day^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of net assimilation rate (g m^{-2} day^{-1})			
		30-60 DAS		60-90 DAS	
		2019	2020	2019	2020
Replication	2	0.05	0.08	2.08	2.65
Factor C	1	7.89	6.39	0.16	0.36
Factor N	2	11.96	9.57	1.61	3.19
C X N	2	0.72	1.82	2.29	2.67
Error	10	8.19	6.72	7.17	4.56

ANOVA Pooled			
Source of variance	**df**	**30-60 DAS**	**60-90 DAS**
Years	1	1.40	0.42
Replication	4	0.13	4.73
Factor C	1	8.56	0.08
Year X Factor C	1	0.05	0.00
Factor N	2	9.61	7.25
Year X Factor N	2	0.13	0.12
Factor C X Factor N	2	19.89	2.71
Year X C X N	2	0.13	0.13
Error	20	14.91	11.72

ANOVA-52: Analysis of variance on phenological parameters of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of phenological parameters					
		Days to 50% flowering		Days to 50% maturity		Days to harvesting	
		2019	2020	2019	2020	2019	2020
Replication	2	1.19	0.22	0.05	0.19	1.99	1.08
Factor C	1	0.04	0.80	1.39	0.04	0.50	0.00
Factor N	2	0.94	0.59	0.49	0.28	0.72	2.63
C X N	2	0.40	0.59	0.46	0.87	0.76	0.85
Error	10	26.78	11.84	11.07	7.09	5.13	9.74

ANOVA Pooled				
Source of variance	**df**	**Days to 50% flowering**	**Days to 50% maturity**	**Days to harvesting**
Years	1	1.52	2.03	-0.04
Replication	4	1.40	0.20	3.13
Factor C	1	0.81	-0.02	1.16
Year X Factor C	1	0.32	0.23	0.11
Factor N	2	0.34	0.60	0.70
Year X Factor N	2	0.25	0.06	1.78
Factor C X Factor N	2	0.73	1.32	0.98
Year X C X N	2	0.92	1.37	0.75
Error	20	38.63	18.19	14.80

ANOVA-53: Analysis of variance on yield attributes of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of of yield attributes			
		Number of pods plant^{-1}		Number of seeds pod^{-1}	
		2019	2020	2019	2020
Replication	2	35.48	44.02	0.12	0.08
Factor C	1	72.56	76.63	0.14	0.06
Factor N	2	420.23	455.52	0.12	0.08
C X N	2	0.41	0.75	0.02	0.00
Error	10	97.89	91.10	0.94	0.37

ANOVA Pooled			
Source of variance	**df**	**Number of pods plant^{-1}**	**Number of seeds pod^{-1}**
Years	1	14.69	0.01
Replication	4	79.51	0.21
Factor C	1	195.43	0.13
Year X Factor C	1	0.70	0.03
Factor N	2	220.65	0.04
Year X Factor N	2	0.39	0.01
Factor C X Factor N	2	608.55	0.23
Year X C X N	2	0.38	0.00
Error	20	188.99	1.31

ANOVA-54: Analysis of variance on yield attributes of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares of of yield attributes**			
		Pod weight (g) plant^{-1}		**Test weight (g)**	
		2019	**2020**	**2019**	**2020**
Replication	2	2.06	12.32	237.15	130.80
Factor C	1	19.65	27.32	51.75	56.92
Factor N	2	114.88	112.52	112.47	99.20
C X N	2	1.22	0.03	5.78	24.65
Error	10	33.91	31.90	218.91	233.08

ANOVA Pooled			
Source of variance	**df**	**Pod weight (g) plant^{-1}**	**Test weight (g)**
Years	1	4.60	0.24
Replication	4	14.38	367.92
Factor C	1	50.25	89.27
Year X Factor C	1	0.08	0.20
Factor N	2	62.60	125.03
Year X Factor N	2	0.94	6.09
Factor C X Factor N	2	161.48	128.02
Year X C X N	2	0.27	2.14
Error	20	65.80	452.03

ANOVA-55: Analysis of variance on yield (t ha^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares of yield (t ha^{-1})					
		Seed yield (t ha^{-1})		Stover yield (t ha^{-1})		Harvest index (%)	
		2019	2020	2019	2020	2019	2020
Replication	2	0.00	0.03	0.22	0.14	7.77	11.65
Factor C	1	3.91	4.01	15.25	15.40	5.87	4.57
Factor N	2	0.64	0.53	1.81	1.60	13.02	7.91
C X N	2	0.07	0.05	0.24	0.19	0.87	0.41
Error	10	0.13	0.09	1.16	0.87	62.52	30.39

ANOVA Pooled				
Source of variance	df	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Years	1	0.02	0.03	0.65
Replication	4	0.03	0.37	19.42
Factor C	1	1.98	6.45	9.74
Year X Factor C	1	0.00	0.00	0.05
Factor N	2	0.43	1.19	9.44
Year X Factor N	2	0.00	0.00	0.52
Factor C X Factor N	2	6.80	26.84	12.83
Year X C X N	2	0.00	0.00	0.07
Error	20	0.22	2.03	92.91

ANOVA-56: Analysis of variance on N content in seed and stover (%) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		N content in seed (%)		N content in stover (%)	
		2019	2020	2019	2020
Replication	2	0.02	0.03	0.02	0.02
Factor C	1	0.01	0.01	0.00	0.00
Factor N	2	0.07	0.07	0.14	0.15
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.09	0.06	0.12	0.13

ANOVA Pooled			
Source of variance	**df**	**N content in seed (%)**	**N content in stover (%)**
Years	1	0.00	0.00
Replication	4	0.05	0.04
Factor C	1	0.02	0.07
Year X Factor C	1	0.00	0.00
Factor N	2	0.04	0.06
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.10	0.17
Year X C X N	2	0.00	0.00
Error	20	0.15	0.25

ANOVA-57: Analysis of variance on P content in seed and stover (%) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		P content in seed (%)		P content in stover (%)	
		2019	2020	2019	2020
Replication	2	0.00	0.00	0.00	0.00
Factor C	1	0.00	0.00	0.00	0.00
Factor N	2	0.00	0.00	0.00	0.00
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.00	0.00	0.00	0.00

ANOVA Pooled			
Source of variance	**df**	**P content in seed (%)**	**P content in stover (%)**
Years	1	0.00	0.00
Replication	4	0.00	0.00
Factor C	1	0.00	0.00
Year X Factor C	1	0.00	0.00
Factor N	2	0.00	0.00
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.00	0.00
Year X C X N	2	0.00	0.00
Error	20	0.00	0.00

ANOVA-58: Analysis of variance on K content in seed and stover (%) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		K content in seed (%)		K content in stover (%)	
		2019	2020	2019	2020
Replication	2	0.01	0.01	0.01	0.01
Factor C	1	0.00	0.00	0.00	0.00
Factor N	2	0.26	0.26	0.54	0.54
C X N	2	0.00	0.00	0.00	0.00
Error	10	0.04	0.03	0.09	0.08

ANOVA Pooled			
Source of variance	df	K content in seed (%)	K content in stover (%)
Years	1	0.00	0.00
Replication	4	0.02	0.02
Factor C	1	0.08	72.98
Year X Factor C	1	0.00	0.00
Factor N	2	0.13	0.18
Year X Factor N	2	0.00	0.00
Factor C X Factor N	2	0.31	0.58
Year X C X N	2	0.00	0.00
Error	20	0.07	0.18

ANOVA-59: Analysis of variance on N uptake in seed and stover (kg ha^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		N uptake in seed (kg ha^{-1})		N uptake in stover (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	8.51	169.24	49.02	31.76
Factor C	1	14706.45	15137.02	5726.91	5815.54
Factor N	2	2724.28	2321.88	1276.90	1194.18
C X N	2	310.67	225.01	173.85	153.41
Error	10	350.29	280.00	607.60	493.51

ANOVA Pooled			
Source of variance	**df**	**N uptake in seed (kg ha^{-1})**	**N uptake in stover (kg ha^{-1})**
Years	1	62.42	13.50
Replication	4	177.73	80.79
Factor C	1	7763.70	3187.14
Year X Factor C	1	0.19	0.72
Factor N	2	1852.00	848.36
Year X Factor N	2	14.58	1.76
Factor C X Factor N	2	25791.60	10301.87
Year X C X N	2	4.24	0.95
Error	20	630.31	1101.9

ANOVA-60: Analysis of variance on P uptake in seed and stover (kg ha^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		P uptake in seed (kg ha^{-1})		**P uptake in stover (kg ha^{-1})**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.04	0.65	1.62	1.09
Factor C	1	58.37	61.26	122.75	128.60
Factor N	2	14.39	12.79	28.50	26.95
C X N	2	1.76	1.28	4.49	4.00
Error	10	1.67	1.63	11.65	8.97

ANOVA Pooled			
Source of variance	**df**	**P uptake in seed (kg ha^{-1})**	**P uptake in stover (kg ha^{-1})**
Years	1	0.40	0.63
Replication	4	0.69	2.71
Factor C	1	36.75	74.76
Year X Factor C	1	0.00	0.03
Factor N	2	9.87	20.36
Year X Factor N	2	0.06	0.04
Factor C X Factor N	2	103.16	220.06
Year X C X N	2	0.02	0.04
Error	20	3.30	20.62

ANOVA-61: Analysis of variance on K uptake in seed and stover (kg ha^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		K uptake in seed (kg ha^{-1})		K uptake in stover (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	2.68	13.57	140.04	88.36
Factor C	1	1026.55	1060.30	9535.10	9634.38
Factor N	2	372.77	344.11	2697.36	2554.86
C X N	2	43.23	36.65	354.01	311.76
Error	10	21.90	14.78	1242.72	970.69

ANOVA Pooled			
Source of variance	**df**	**K uptake in seed (kg ha^{-1})**	**K uptake in stover (kg ha^{-1})**
Years	1	4.75	20.51
Replication	4	16.28	228.42
Factor C	1	741.58	6513.78
Year X Factor C	1	0.06	1.14
Factor N	2	257.77	1820.00
Year X Factor N	2	0.73	3.50
Factor C X Factor N	2	1883.32	16747.34
Year X C X N	2	0.18	1709.00
Error	20	36.68	2213.39

ANOVA-62: Analysis of variance on protein content (%) and protein yield (kg ha^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		Protein content (%)		Protein yield (kg ha^{-1})	
		2019	2020	2019	2020
Replication	2	0.75	1.32	332.60	6610.84
Factor C	1	0.23	0.24	574470.74	591289.84
Factor N	2	2.87	2.91	106417.32	90698.52
C X N	2	0.04	0.03	12135.65	8789.31
Error	10	3.50	2.23	13683.05	10937.38

ANOVA Pooled			
Source of variance	**df**	**Protein content (%)**	**Protein yield (kg ha^{-1})**
Years	1	0.01	2439.97
Replication	4	2.05	6942.24
Factor C	1	0.65	303271.82
Year X Factor C	1	0.00	5.20
Factor N	2	1.61	72345.12
Year X Factor N	2	-0.00	528.70
Factor C X Factor N	2	4.06	1007482.41
Year X C X N	2	0.00	167.31
Error	20	5.74	24621.87

ANOVA-63: Analysis of variance on oil content (%) and oil yield (kg ha^{-1}) of soybean in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	**df**	**Sum of squares**			
		Oil content (%)		**Oil yield (kg ha^{-1})**	
		2019	**2020**	**2019**	**2020**
Replication	2	0.81	0.48	400.06	1950.31
Factor C	1	0.69	1.38	166027.04	175618.00
Factor N	2	22.97	20.80	49962.18	43026.50
C X N	2	0.09	0.20	6050.22	4246.24
Error	10	7.25	8.87	4918.51	3849.72

ANOVA Pooled			
Source of variance	**df**	**Oil content (%)**	**Oil yield (kg ha^{-1})**
Years	1	0.16	938.16
Replication	4	1.29	2350.76
Factor C	1	7.91	107176.43
Year X Factor C	1	0.00	0.54
Factor N	2	8.32	32080.14
Year X Factor N	2	0.05	225.42
Factor C X Factor N	2	29.76	305335.62
Year X C X N	2	0.08	111.86
Error	20	16.12	8767.87

ANOVA-64: Analysis of variance on soil pH in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares			
		pH		Organic carbon (%)	
		2019	2020	2019	2020
Replication	2	0.01	0.02	0.01	0.02
Factor C	1	0.03	0.13	0.02	0.02
Factor N	2	0.00	0.03	0.02	0.01
C X N	2	0.09	0.17	0.02	0.01
Error	10	0.29	0.78	0.12	0.07

ANOVA Pooled			
Source of variance	**df**	**pH**	**Organic carbon (%)**
Years	1	0.06	0.01
Replication	4	0.03	0.02
Factor C	2	0.01	0.03
Year X Factor C	2	0.02	0.00
Factor N	4	0.12	0.03
Year X Factor N	4	0.04	0.00
Factor C X Factor N	8	0.21	0.02
Year X C X N	8	0.05	0.01
Error	56	1.08	0.19

ANOVA-65: Analysis of variance on available N, P and K in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares					
		N		P		K	
		2019	2020	2019	2020	2019	2020
Replication	2	108.45	359.71	1.01	8.92	41.51	54.67
Factor C	1	3403.62	3596.30	10.94	23.38	79.57	68.34
Factor N	2	943.68	1054.05	84.15	93.86	673.57	793.31
C X N	2	82.09	123.28	2.56	10.64	17.10	28.40
Error	10	1703.46	1881.07	58.83	77.11	583.28	614.54

ANOVA Pooled				
Source of variance	**df**	**N**	**P**	**K**
Years	1	202.11	12.91	88.35
Replication	4	467.08	9.94	96.04
Factor C	2	1995.65	177.09	1464.33
Year X Factor C	2	2.49	0.93	2.69
Factor N	4	6998.93	32.99	146.78
Year X Factor N	4	1.82	1.33	1.31
Factor C X Factor N	8	194.28	11.14	41.24
Year X C X N	8	10.44	2.06	4.14
Error	56	3585.70	135.93	1197.97

ANOVA-66: Analysis of variance on bacteria (10^6 x Cfu g^{-1}), fungi (10^3 x Cfu g^{-1}) and actinomycetes (10^5 x Cfu g^{-1}) in rice based intercropping system as influenced by cropping system (C) and nutrient management (N)

Source of variance	df	Sum of squares					
		Bacteria		Fungi		Actinomycetes	
		2019	2020	2019	2020	2019	2020
Replication	2	8.68	8.69	9.07	9.29	0.00	0.00
Factor C	1	1502.12	1566.51	1502.29	1529.26	0.72	0.72
Factor N	2	311.75	312.65	174.43	192.20	0.52	0.55
C X N	2	21.74	32.65	14.60	12.56	0.03	0.03
Error	10	82.67	66.68	101.80	93.21	0.52	0.49

ANOVA Pooled				
Source of variance	**df**	**Bacteria**	**Fungi**	**Actinomycetes**
Years	1	4.41	1.36	0.00
Replication	4	17.36	18.36	0.00
Factor C	2	624.38	366.41	1.07
Year X Factor C	2	0.02	0.23	0.00
Factor N	4	3067.51	3031.16	1.45
Year X Factor N	4	1.14	0.40	0.00
Factor C X Factor N	8	53.16	25.77	0.05
Year X C X N	8	1.22	1.39	0.01
Error	56	149.36	195.01	1.00