RESPONSE OF RICE (*Oryza sativa* L.) TO INTEGRATED NUTRIENT MANAGEMENT AND LIMING AND THEIR RESIDUAL EFFECT ON SUCCEEDING PEA (*Pisum sativum* L.)

Thesis

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DOCTOR OF PHILOSOPHY

in

AGRONOMY

by

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2020

Affectionately Dedicated

to my loving Parents,

and my brothers,

Imya

&

Akum

STUDENT'S DECLARATION

I, Miss Arenjungla Ao, 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 **"Response of rice (*Oryza sativa* L.) to integrated nutrient management and liming and their residual effect on succeeding pea (*Pisum sativum* L.)"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of DOCTOR OF PHILOSOPHY in the discipline of Agronomy, is a record of Research work carried out by **Miss. Arenjungla Ao**, Registration No. 774/2017, under my personal supervision and guidance.

All help received by him/her have been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY AGRONOMY

This is to certify that the thesis entitled **"Response of rice (*Oryza sativa* L.) to integrated nutrient management and liming and their residual effect on succeeding pea (*Pisum sativum* L.)"** submitted by Miss. Arenjungla Ao, Admission No. 190/15, Registration No. 774/2017, 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 20.04.2021.

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

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LIST OF ABBREVIATIONS

%	-	Percentage
$^{-1}$	-	Per
@	-	at the rate of
ºC	-	Degree Centigrade
BCR	-	Benefit cost ratio
cm	-	Centimetre
CD	-	Critical Difference
DAS	-	Days after Sowing
df	-	Degree of freedom
E	-	East
et al.	-	And others
Fig.	-	Figure
FYM	-	Farmyard Manure
g	-	Gram
ha	-	Hectare
i.e.	-	That is
INM	-	Integrated Nutrient Management
K	-	Potassium
kg	-	Kilogram
kg^{-1}	-	Kilogram per hectare
Max.	-	Maximum
Min.	-	Minimum
m	-	Metre
m^2	-	Metre square
mm	-	Millimetre
MOP	-	Muriate of Potash
MT	-	Metric tonnes
mt	-	Million tonnes
N	-	Nitrogen
No.	-	Number
NPK	-	Nitrogen, phosphorus and potassium

NS	-	Non-significant
NU	-	Nagaland University
P	-	Phosphorus
pH	-	negative logarithm of hydrogen ion activity of a soil.
q	-	Quintal
₹	-	Rupees
RBD	-	Randomized Block Design
RDF	-	Recommended Dose of Fertilizer
SASRD	-	School of Agricultural Sciences and Rural Development
SEm±	-	Standard error of mean
Sl. No.	-	Serial number
SOC	-	Soil Organic carbon
SSP	-	Single Superphosphate
t	-	tonnes
viz.	-	Namely

CHAPTER I

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.) is an important staple food crop for more than 50 % of the world's population (Verma *et al*., 2015). By 2050 the world's population is expected to reach 9.1 billion therefore global food production has to be increased at least by 70% over the current level by 2050 to meet the increase demand for food as a result of rapidly growing population (FAO, 2009). In Asia, rice is the most important cereal food crop to feed the ever-growing population, however the average yields in Asia are low compared to global average yields (Haider, 2018). There is limited scope for further expansion in cultivated area under cropping in Asia, however, sustainable intensification of land for crop production and increase in crop productivity could help to meet the current and future food demand. In the global context, India stands first in area with 43.7 m ha, second in production with 106.29 mt and an average productivity of 2.43 t ha^{-1} (Anonymous, 2018). In Nagaland, rice is grown throughout the entire state and covers an area of 214450 hectares with a production of 5,35040 t out of which upland rainfed occupies an area of 91,040 hectares with a production of 1,81080 t (Anonymous, 2019).

Nutrient management is of vital importance to achieve sustainability in crop production. Organic manures improve soil physicochemical properties, enhance soil fertility and promote the crop growth and yield (Mi *et al*., 2018). Organic manure not only provides nutrients to the existing crop but also leaves a considerable residual effect on the succeeding crops in the cropping systems (Gezahegn and Martini, 2020). However, the supply of nutrient requirements of crops is fully not possible with the use of organic manures alone. The efficiency of applied chemical fertilizers is increased when applied along with organic manures (Mahmood *et al*., 2017). Therefore, the combined use of organic manure and inorganic fertilizer help in maintaining yield stability through correction of nutrient deficiencies, enhancing efficiency of applied nutrients, create favorable soil physico-chemical conditions and healthy environment and conserve the soil nutrient balance in the long run to an optimum level for sustaining the desired crop productivity (Singh and Singh, 2014; Selim, 2020). So, by taking into consideration the above facts, integrated nutrient management proved to be the best approach for ensuring sustainable crop production and at the same time, maintain the soil fertility status in rice based cropping systems (Meena *et al*., 2020).

Biofertilizers are economical, eco-friendly, efficient, more productive and accessible to marginal and small farmers over chemical fertilizers (Dey and Mukherjee, 2020). Biofertilizers such as *Azospirillum* have been reported to substitute a part of the recommended dose of chemical fertilizers without affecting the crop yield, especially in favourable rice ecosystem. The mechanism of *Azospirillum* is mobilization of nutrients, production of phytohormones and non-symbiotic nitrogen fixation in the roots of various plants including rice. Use of PSB increases p uptake by the plant and crop yield, increase P availability in soil, minimizes P fertilizer application, reduces environmental pollution and promotes sustainable agriculture (Rodriguez and Fraga, 1999). Thus, judicious use of Biofertilizers along with chemical and organic sources of plant nutrients will help to sustain productivity and soil health apart from meeting a part of fertilizer requirement for different crops.

The majority of the acid soils in Northeast regions of India are acidic (pH 5.0–6.0), rich in organic carbon, deficient in available phosphorus, medium to low in available potassium, and presence of toxic concentration such as iron and aluminum (Thakuria *et al*., 2016; Dambrine, 2018). Amelioration of acid soils with liming materials along with suitable cropping system is necessary to enhance the productivity and water use efficiency of crops in acid soil. Liming is an important practice for ameliorating soil acidity and to achieve optimum yields of all crops grown in acidic soils (Nduwumuremyi, 2013). Liming increases the soil pH, improves availability of plant nutrients, thereby stimulating soil microbial activity, increases nutrient uptake, reduces extractable Al^{3+} and toxicity of some elements (Reddy and Subramanian, 2016). Besides, the importance of managing rice cultivation to facilitate *rabi* cropping and to increase total system productivity has also been well recognized (Sorokhaibam *et al*., 2016).

Nagaland is an agriculturally important state in northeast India, with an average soil pH ranging from 4.1 to 5.9 in cultivated and forest soils. Almost 84% soils of Nagaland are considered strongly acidic soils (Panda, 1998). Acidity–induced soil fertility problems coupled with traditional method of cultivation are often held responsible for low crop productivity in the state. Lime application along with integrated nutrient management is often recommended to increase the phytoavailability of essential nutrients and ameliorate the acidity-induced soil fertility constraints (Kumar *et al*., 2012) and sustains a soil physical environment that is better for achieving higher crop productivity in hilly ecosystem of North-Eastern India (Saha *et al*., 2010).

Generally, the monocropping system of rice (*Oryza sativa* L.) cultivation is practiced in the northeast hill region of India (Das *et al*., 2018). This system has led to depletion in soil fertility and productivity of the soil, increase infestation of pests, diseases and weeds. Diversification of rice based cropping systems with inclusion of pulse crops can increase soil water conservation, improves soil N availability, mobilization of insoluble soil nutrients, especially phosphorus, soil physico-chemical properties such as aggregate stability, soil structure, bulk density, hydraulic conductivity, soil biological activities and system productivity (Kaur *et al*., 2018). The inherent nitrogen fixing capacity of pulse crops enables them to meet a large proportion of their nitrogen requirement, substantially reduces the N requirement from external sources, and also helps in economizing nitrogen in succeeding non-legume crops due to the residual effect. It has been reported that the pulse crop may contribute 18-70 kg N ha^{-1} to the soil and thereby provide substantial amount of nitrogen to the succeeding crop (Ali and Mishra, 2000).

About 11.7 mha of land in India is left fallow after rice (*Oryza sativa* L.) harvest (Gumma *et al*., 2016). The rice fallow areas is mostly concentrated in eastern India (around 80%) covering the states of Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Chhattisgarh, Odisha, West Bengal and North Eastern Hill states (Singh *et al*., 2016). Pulses on account of their inherent properties like, low input requirements, short duration, ability to establish even with surface broadcast, soil fertility restoration through BNF, narrow C:N ratio enriched crop residues and leaf fall etc are ideal for rice fallows. These are in fact soil building crops capable of transforming our dominant cereal based systems to an ideal and sustainable system in time to come (Praharaj *et al*., 2017). North Eastern Region (NER) of India is characterized by low crop intensity (134%) mainly due to non-utilization of fallow lands after harvesting of rainy season rice (*Oryza sativa* L.). Pea (*Pisum sativum* L.) is one of the most potential legume crops of India for crop diversification and enhancing productivity of rice based cropping systems in NER. Thus, introduction of pea in rice fallows with appropriate production technologies may enhance cropping intensity, improve soil health, and productivity of rice based systems in fragile NER of the country. Pea is an acid-sensitive crop and liming is the only option for increasing yield in such soil conditions (Gupta et al., 2000). Nagaland has an area of 7200 ha under pea production with productivity of 1.1 t ha^{-1} (Anonymous, 2017).

Developing effective and efficient acid soil management and enhancing crop productivity are important for enhancing food security globally and regionally (Kumar *et al*., 2012). The best practice is one that combines lime, organic manure and inorganic fertilizers (Mukuralinda, 2007; Wanjiru, 2018). Lime reacts very slowly with the soil to release nutrients from fixation. Hence, plants are unable to access required amount of nutrients in the critical yield forming period. Therefore, combined use of lime, fertilizer and manure application is a good strategy for enhancing crop development, growth under acidic soils (Kumar *et al*., 2012).

In Nagaland, agricultural production system always create jeopardy owing to problems like soil acidity, high loss of nutrients through soil erosion, lower availability and greater fixation of nutrients coupled with little use of external inputs. In the context of sustainable agriculture and the issues related to it, a technological breakthrough in agro-techniques especially in cropping system, nutrient and lime management is essential, so as to improve productivity under rice based cropping system. Considering all these, it was felt pertinent to undertake this investigation entitled **"Response of rice (*Oryza sativa* L.) to integrated nutrient management and liming and their residual effect on succeeding pea (*Pisum sativum* L.)" with the following objectives.**

1) To study the effect of integrated nutrient management and liming on growth and yield of rice.
2) To study the residual effect of integrated nutrient management and liming on the growth and yield of succeeding pea.
3) To evaluate the economics of different treatments under study.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Sustaining rice production has become a great challenge, particularly in areas where rice productivity declines in spite of following recommended nutrient management practices. Nutrient management by integrating organic sources of nutrients along with inorganic fertilizers play an important role in improving and sustaining rice productivity (Mondal *et al.*, 2016) as inorganic fertilizer is one of the key factors to increase the rice productivity.

In North-Eastern region of India, soil acidity is a major constraint that limits the full productivity of crops. Therefore, on such soils liming along with integrated nutrient management is often recommended to increase the phytoavailability of essential nutrients and ameliorate the other acidity-induced fertility constraints (Kumar *et al*., 2012).

Soil acidity management and crop productivity improvement on acid soils is therefore important for enhancing food security globally and regionally. An attempt has been made to review the works carried out on liming and integrated nutrient management in upland rice and also of pea. The literature relevant to the present investigation **"Response of rice (*Oryza sativa* L.) to Integrated nutrient management and liming and their residual effect on succeeding pea (*Pisum sativum* L.)"** is presented in this chapter under the following sub-heads.

2.1 Effect of lime on growth and yield attributes of rice

Badrinath *et al.* (1995) conducted field experiment with liming to acid soils having pH 5.2. It was recorded that the lime application has significant effect in increasing paddy yield and also increasing the availability of potassium during crop growth. The maximum increase in yield was 23 % over the control.

Kumar *et al*. (2012) conducted a field experiment on an acid alfisol (pH 4.6) of Meghalaya to ascertain the individual and synergistic effects of lime, NPK and farmyard manure (FYM) application on maize productivity. Application of recommended NPK dose (80, 60 and 40 kg ha^{-1} of N, P_2O_5 and K_2O) resulted in 53 % yield improvement, while liming @ 300 kg ha^{-1} (furrow application) caused 32 % yield increase over control. Combined application of NPK + Lime resulted in 147 % yield increase while application of FYM @ 5 t ha^{-1} along with NPK + Lime further boosted the yield improvement upto 291 % over control.

Mitu *et al*. (2017) evaluated the effect of fertilizer, manure and lime on growth and yield of Boro rice in acidic red soil. The results revealed that 50% inorganic along with organic and lime application obtained the tallest plant (70.42 cm), longest panicle (22.31cm), more filled grains $panicle^{-1}$ (74.83 cm) and greater production of Boro rice (41.67 g pot^{-1}) compared to 100% recommended dose of NPKSZn.

Ferdous *et al*. (2018) studied the effect of lime and fertilizer application on the growth and yield of rice cv. BRRI dhan50. The highest grain yield (2.90 t ha^{-1}) was recorded from the application of 1.50 t ha^{-1} lime and the lowest (2.06 t ha^{-1}) was from control. On the other hand, the best effect of fertilizers on grain yield (3.08 t ha^{-1}) was found with the application of FYM @ 10 t ha^{-1} and the lowest yield (1.59 t ha^{-1}) was in control. The treatment combination of 1.50 t ha^{-1} lime and FYM @ 10 t ha^{-1} produced the highest grain yield (3.60 t ha^{-1}), followed by treatment combination of 1.50 t ha^{-1} lime and chemical fertilizer @ 100-30-42-4-3-0.4 kg ha^{-1} of N-P-K-Ca-S-Zn (3.28 t ha^{-1}). The study indicated that both FYM and lime could affect to enhance the grain yield of rice in acidic soil.

Sahu *et al.* (2018) carried out a field experiment and results indicated that the grain (46 q ha^{-1}) and straw (51.3 q ha^{-1}) yield of rice was registered higher in treatment (100 % NPK + 5 t FYM + $ZnSO_4$ @ 25 kg ha^{-1} + Lime 3 q ha^{-1}), treatment followed by (100% NPK + 5 t FYM + $ZnSO_4$ @ 25 kg ha^{-1}) recording grain and straw yield (44.8 and 50.2 q ha^{-1}) and lowest in control (24.5 and 37.5 q ha^{-1}) respectively.

Ganapathi *et al*. (2019) conducted a field experiment during *kharif* (2017-18) to study the effect of granulated liming material on yield of paddy. The results revealed that the treatment receiving RDF (60:30:60 Kg N, P_2O_5, K_2O ha^{-1}) + FYM (10 t ha^{-1}) + 50 % lime requirement through granulated lime based on 45 % Ca saturation (1.14 t ha^{-1}) recorded significantly higher growth parameters and yield.

2.2 Effect of INM on growth and yield attributes of rice

Arif *et al*. (2014) revealed that organic and inorganic manures in combination increased the plant height, fertile tillers hill^{-1}, number of grains panicle^{-1}, panicle length, number of panicles hill^{-1}, 1000-grain weight, biological yield, grain yield and harvest index. Maximum number of fertile tillers plant^{-1} (16.79), number of panicles hill^{-1} (8.41), 1000- grain weight (21.12 g), biological yield (10.19 t ha^{-1}), grain yield (4.47 t ha^{-1}) and harvest index (43.76 %) were recorded from the plots receiving poultry manure @ 10 t ha^{-1} in combination with 50% of RDF. This was followed by 100% RDF. It is evident that yield of rice increased significantly with the combined use of organic manure with chemical fertilizers.

Baishya *et al*. (2015) reported that among the organic sources, the crop receiving 2.5 t poultry manure ha^{-1} along with 75 kg N +16.5 kg P + 31.3 kg K ha^{-1} improved yield attributes and yield (6.03 t ha^{-1}) over other treatments.

Chesti *et al.* (2015) carried out field experiment for three consecutive *kharif* seasons (2009 to 2011). Significantly higher grain yield of 5.36 t ha^{-1} with the application of 100% NPK + 10 t FYM ha^{-1} as compared to the grain yield of 4.96 t ha^{-1} with the 100% NPK alone. Thus, integrated application of

100% NPK + 10 t FYM ha^{-1} maximized yields of rice crop and improved the soil fertility in the intermediate zone of Jammu and Kashmir.

Parihar *et al*. (2015) observed that the number of tillers m^{-2}, plant height and 1000 grain weight increased with increase graded levels of inorganic fertilizers with FYM than without FYM on similar dose.

Saidu and Abayomi (2015) conducted field experiment where results showed that the application of different combinations of organic manure and inorganic fertilizer resulted in significantly better growth and grain yield (2.51 t ha^{-1} for 1 t ha^{-1} + 20 kg N ha^{-1} urea and 2.26 t ha^{-1} for 0.5 t ha^{-1} + 40 kg N ha^{-1} urea), compared to control (1.38 ha^{-1}).

Sharma *et al*. (2015) conducted a field experiment during 2010 and 2011 to assess the effect of combined application of fertilizer, organic manures and biofertilizers on yield, nutrient utilization along with soil fertility in rice. The results revealed that the substitution on 25% NPK through FYM and recommended dose of NPK along with 5 kg Zn ha^{-1} and PSB + BGA recorded significantly higher grain yield (3.96 t ha^{-1}) over the 100 % NPK (N,P,K,S and Zn) by rice.

Alagappan and Venkitaswamy (2016) evaluated the impact of different sources of organic manures in comparison with TRRI practice, RDF and INM on growth, yield and soil enzymatic activities of rice – green gram cropping system under site-specific organic farming situation. The results indicated that the performance of INM imposed treatment followed by RDF recorded better growth and yield parameters than the organic treatments during both the years of investigation.

Kandeshwari and Thavaprakaash (2016) revealed that application of 75% inorganic N + 12.5% N through FYM + 12.5% N through well decomposed PM produced higher grain yield (5802 kg ha^{-1}) and straw yield

(8409 kg ha^{-1}) with higher harvest index (0.41) compared to all other treatments.

Kichu *et al.* (2016) carried out a field experiment on twelve treatments involving N, P and K fertilizers, FYM, poultry litter, forest litter, *Azospirillum* and Zn either alone or in combinations and found that maximum plant height, number of productive tillers plant^{-1}, highest grain yield and straw yield was recorded in NPK + FYM + Zn treatment followed by NPK + Poultry litter treatment. Compared with NPK, grain yield in NPK + FYM + Zn, NPK + Poultry litter and NPK + FYM treatments increased significantly and were 38.1, 34.43 and 32.6 % higher, respectively.

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.

Wolie and Admassu (2016) observed that the rice yield and yield contributing traits significantly increased with the use of compost, vermicompost, sesbania, green manure and FYM in combination with chemical fertilizer than individual sources in most of the findings.

Gangmei and George (2017) revealed that the application of treatment (FYM @ 10 t + 100 % RDF through inorganic sources) performed significantly higher than the other treatments with higher number of effective tillers hill^{-1} (11.70), panicle length (25.56 cm), number of spikelets panicle^{-1} (230.40), number of filled spikelets / panicle % (87.67), test weight (24.66 g), grain protein content (13.20 %) and consequently grain yield (5016 kg ha^{-1}) and straw yield (13550 kg ha^{-1}).

Imade *et al.* (2017) studied the effect of organic manures in combination with inorganic fertilizers on transplanted rice under rice–green gram cropping sequence during *kharif* season. The results revealed that the application of general RDF (RDF:100-30-00 kg N-P-K ha^{-1} + FYM @ 10 t ha^{-1}) recorded significantly higher growth attributes *viz*., plant height, total number of tillers $hill^{-1}$, leaf area index, dry matter accumulation $hill^{-1}$ over control. Significantly higher yield attributes *viz.* number of panicles m^{-2}, number of filled grains $panicle^{-1}$, panicle length, test weight, seed and straw yields $hill^{-1}$ and seed and straw yields ha^{-1} recorded under general RDF (RDF:100-30-00 kg N-P-K ha^{-1} + FYM @ 10 t ha^{-1}) over control.

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

Shinde *et al*. (2017) studied the response of rice hybrids *viz.* Sahyadri-3 and Sahyadri-4 to INM comprising different combinations of chemical fertilizers with FYM, poultry manure, glyricidia and Biofertilizers (*Azospirillum* and PSB). It was revealed from the study that the performance of Sahyadri-3 and Sahyadri-4 hybrid rice in terms of their yield attributes, grain yield productivity, quality traits were highest under the application of 50 % recommended dose of N through chemical fertilizers, 25 % through application of FYM and remaining 25 % through poultry manure application over alone application of 100% N applied through inorganic fertilizers to both the rice hybrids.

Apon *et al*. (2018) carried out a field experiment and the results revealed that the application of 100 % RDF + 5 t ha^{-1} FYM enhanced the growth and yield of both the local rice cultivars. The application of 100 % RDF + 5 t ha^{-1} FYM recorded highest number of panicles m^{-2} (120), length of panicle (28.93 cm), test weight (30.55 g), grain yield (3140.28 kg ha^{-1}) and straw yield (8888.89 kg ha^{-1}).

Hoque *et al*. (2018) conducted an experiment consisting seven treatments *viz.* T_0: Control, T_1: 75% RFD; T_2: 100% RFD, T_3: 75% RFD + Kazi Jaibo Shar (5 t ha^{-1}), T_4: 75% RFD + Kazi Jaibo Shar (3 t ha^{-1}), T_5: 75% RFD + Poultry manure (3 t ha^{-1}) and T_6: 75% RFD + Cow dung (5 t ha^{-1}). The performance of 75% RFD with poultry manure @ 3 t ha^{-1} was the best in producing yield components, grain and straw yields of rice.

Sahu *et al*. (2018) conducted a field experiment and the 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 increases quantitative but also increases qualitative parameters which resulted in higher grain and straw yield of rice cultivars.

Singh *et al*. (2018) evaluated the impact of continuous use of inorganic fertilizers and organic nutrients on productivity, economics and soil fertility status of rice. Growth attributes such as plant height (96.8 cm), number of tillers m^{-2} (332), LAI (4.22) and dry matter accumulation (1285.7 gm^{-2}) were found highest with the treatment (50 % RDF + 50 % N through FYM) but remained at par with all the treatment where either 25 or 50 % N was substituted through organic sources.

Iqbal *et al*. (2019) studied the combined effects of cattle manure (CM), poultry manure (PM), and chemical fertilizer (CF) on soil properties, rice growth, physiology, and grain yield and quality. Conclusively, the integration of 30% N from PM or CM with 70% N from CF (urea) is a promising option not only for higher grain yield and quality of rice but also for improved soil health.

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 rice recovery respectively over 100% recommended dose applied as inorganic sources.

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 (5.75 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.

2.3 Effect of lime and INM on soil properties

Venkatesh *et al*. (2002) reported that with the application of P, FYM and lime, there was a significant increase in the organic carbon content of the soil which might be due to addition of organic matter through FYM, incorporation of biomass through root and leaf fall from the plants in varying degrees and creation of favorable conditions for the growth of soil microorganisms.

Senthivelu and Prabha (2007) studied on post harvest nutrient availability and nutrient balance sheet under integrated nutrient management and reported that maximum post harvest nutrient availability (196.79: 14.26: 170.80 kg NPK ha^{-1}) and positive nutrient balance recorded maximum in FYM

@ 12.5 t ha^{-1} + 150: 50: 50 kg NPK ha^{-1}. Net negative nutrient balance was observed in the control treatment.

Sarangi (2008) from his experiment in an acid upland soil reported the improvement of soil pH (5.35), organic carbon (0.77%) and total N (0.81%) with application of 50 % RDF + 5 t FYM ha^{-1} which were significantly higher than pH (4.85), organic carbon (0.52 %) and total N (0.76%) obtained with application of RDF only over initial values of 5.03, 0.62 and 0.65, respectively to preceding rice crop.

Ramesh *et al*. (2014) reported that application of lime and FYM along with 75% recommended NPK increased the soil pH (5.02) whereas, control plot receiving 100% recommended NPK showed the lowest pH (4.19). Combined application of FYM and biofertilizers along with 75% recommended NPK increased the organic carbon content (2.28 g $100g^{-1}$) whereas organic carbon content was decreased (1.78 g 100 g^{-1}) in the treatment receiving lime and biofertilizers along with 75% recommended NPK. Application of lime and FYM along with 100% recommended NPK increased P content (59.95 kg P_2O_5 ha^{-1}) whereas, it decreased P content (18.27 kg P_2O_5 ha^{-1}) with zero NPK. Similarly, K content was increased (293.9 kg K_2O ha^{-1}) in the treatment receiving FYM and biofertilizer along with 75% recommended NPK while it decreased (186.4 kg K_2O ha^{-1}) in control.

Brar *et al*. (2015) reported that integrated use of inorganic fertilizer along with organic fertilizer (100% NPK + FYM) had resulted in increase SOC compared to non treated control. Improvement in SOC and consequently, SOM also improved nutrient uptake of N, P and K significantly in all treatments compared to non-treated control.

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

Kichu *et al.* (2016) evaluated the effect of integrated nutrient management practices on available N, P and K content and found out that NPK + FYM + Zn followed by NPK + Poultry litter can suitably be recommended to build up available N, P and K levels.

Gowda *et al.* (2017) reported that application of inorganics alone resulted in decreased nutrients status over balanced fertilizer application. Soil acidification was accelerated with application of nitrogenous fertilizers alone (-1.87 unit reduction in soil pH over initial) and the soil pH was maintained in balanced fertilization (6.46). Available nutrients in soil were higher in 100 % NPK + FYM + lime and 100 % NPK + FYM application where the combined application of fertilizers, manure and amendments were undertaken.

Mitu *et al*. (2017) conducted a field experiment to study the effect of fertilizer manure and lime on growth and yield of Boro rice in acidic red soil. The results revealed that the level of P and S in rice grain increased more with the application of inorganic fertilizer + lime due to cow dung and poultry manure, respectively.

Ferdous *et al*. (2018) studied the effect of lime and fertilizer application on the growth and yield of rice cv. BRRI dhan 50 and found that application of lime and FYM improved the soil fertility and properties of acidic soil for crop production by increasing the pH, organic matter and availability of some essential nutrients.

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.

Mamatha *et al.* (2018) clearly indicated that in acidic soils, application of basic slag or lime @ 2 t ha^{-1} along with RDF is more beneficial in enhancing the crop yield as well as available nutrient status of soil.

Sahu *et al.* (2018) 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 the soil.

Ganapathi *et al.* (2019) revealed that the treatment receiving RDF (60-30-60 kg N, P_2O_5, K_2O ha^{-1}) + FYM (10 t ha^{-1}) + 50 % lime requirement through granulated lime based on 45 % Ca saturation (1.14 t ha^{-1}) recorded significantly higher soil pH, available N, P_2O_5, K_2O and S.

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.

Yadav *et al.* (2019) reported that soil organic carbon, available N, available P and total K were significantly increased with the conjoint application of organic manure and inorganic fertilizer whereas the concentration of non-exchangeable K was significantly decreased with combined application of organic manure and inorganic fertilizer in comparison to application of fertilizer alone.

2.4 Effect of lime and INM on nutrient uptake (plant)

Senthivelu and Prabha (2007) reported that the treatment receiving FYM @ 12.5 t ha^{-1} + 150- 50- 50 kg N-P-K ha^{-1} registered significantly the highest NPK uptake at all the stages and maximum uptake was recorded at harvest stage (154.24: 24.84: 171.60 kg ha^{-1}). Application of inorganic NPK alone @ 150-50-50 kg ha^{-1} recorded the lower amount of NPK uptake at harvest stage (140.45:22.11:151.58 kg ha^{-1}).

Rani and Sukumari (2013) 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.

Dutta and Sangtam (2014) reported that the uptake of N, P and K was significantly higher in treatments where NPK was added with FYM and poultry litter.

Ghosh *et al*. (2014) showed that the uptake of N, P, K, S, Ca and Mg by both grain and straw of rice were statistically significant due to use of integrated nutrient management. The highest nutrient uptake was recorded from the treatment application of RDF for HYG + cowdung @ 5 t ha^{-1} based on IPNS and the lowest value was obtained from control.

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.

Baishya *et al*. (2015) reported that among the organic sources, the crop receiving 2.5 t poultry manure ha^{-1} along with 75 kg N +16.5 kg P + 31.3 kg K ha^{-1} improved nutrient uptake and crop profitability (₹ 366.28 ha^{-1} day^{-1}) over other treatments.

Chesti *et al.* (2015) carried out field experiment for three consecutive *kharif* seasons (2009 to 2011). Significantly total NPK uptake by rice (96.3, 20.4 and 109.5 kg ha^{-1}, respectively) with the application of 100% NPK + 10 t FYM ha^{-1} as compared to the total NPK uptake (86.5,18.1 and 96.8 kg ha^{-1}, respectively) with the 100% NPK alone.

Kandeshwari and Thavaprakaash (2016) revealed that the higher nutrient uptake was obtained with the application of 75% inorganic N + 12.5% N through FYM + 12.5% N through well decomposed PM; however, the values are on par with 100% N through inorganic fertilizers.

Kichu *et al.* (2016) recorded that the highest accumulation of available N, P and K was found in NPK + Poultry litter, NPK + FYM and ½ N + PK+ ½ N Forest litter treatments, respectively.

Kumar *et al*. (2017) conducted a field experiment and revealed that INM increased nutrient uptake as well as the efficiency of nutrient use. Thus, integrated management of organics and chemical fertilizers in rice found to be more viable for sustaining productivity and improving the efficiency of inorganic fertilizers.

Mitu *et al*. (2017) reported that application of inorganic fertilizer plus manure and lime for rice cultivation significantly increased the grain nutrient level. The level of P and S in rice grain increased more with the application of inorganic fertilizer + lime due to cow dung and poultry manure, respectively.

Naher and Paul (2017) evaluated the effect of integrated nutrient management on T. Aman rice (cv. BRRI dhan 40) and reported that the combined application of chemical fertilizers and organic manure increased organic carbon, total N, available P, K and S contents in post-harvest soil.

Sahu (2017) reported that the use of organic manure like FYM with chemical fertilizers increased the availability of nutrients (N, P, K, S, Ca, Mg) in soil over chemical fertilizer alone.

Srivastava and Singh (2017) evaluated on the nutrient uptake of hybrid rice and the results indicated that uptake of NPKS and Zn was significantly improved under treatments having organic manure along with inorganic levels

(100%, 75% and 50% NPK) of fertilizer over alone levels of inorganic fertilizer.

Bekele *et al*. (2018) investigated an experiment and the results showed that the highest increment of pH from 4.83 at the control to 6.05, reduction of exchangeable Al from 1.70 to 0.09 cmolc·kg^{-1}, highest contents of OM (4.1%) and total nitrogen (0.29%) were obtained from combined application of lime at 4 tons $CaCO_3$ ha^{-1} and VC at 7.5 tons·ha^{-1}. Integrated application of chemical P (60 kg·P·ha^{-1}) with lime (2 tons·ha^{-1}) plus VC (7.5 tons·ha^{-1}) resulted in Bray-II P increased by 45% relative to control.

Sahu *et al*. (2018) conducted a field experiment and the results indicated higher total nutrient uptake by rice crop was recorded under integrated application of inorganic and organic fertilizers.

2.5 Effect of lime and INM on microbial activities of soil

Acharya *et al*. (2012) reported that the highest microbial population was observed due to integrated application of inorganic fertilizer with organic manure. This is due to supply of more amount of carbon through organic manure.

Bahadur *et al*. (2012) reported that improvement in soil microbial population and fertility status was recorded when chemical fertilizers were integrated with organic manures and biofertilizers.

Mairan and Dhawan (2016) reported that the population of bacteria, fungi and actinomycetes decreased in higher proportion in control, however, highest population of microbes was observed in the treatment receiving FYM. Fertilizer application alone showed relatively less increase in population of microbes. However, application of organics in the form of FYM, glyricidia, vermi-compost, plant and weed residues, biofertilizers, neem seed cake, press mud etc. helped to increase bacteria, actinomycetes, fungi and total microbes after two cycles of cropping systems.

Kaur *et al*. (2017) reported that significantly higher total bacterial population (150 × 10^7 CFU g^{-1} of soil) and PGPR (218 × 10^5 CFU g^{-1} of soil) population was observed in treatments when there was combination of organic, inorganic and consortium biofertilizer. Actinomycetes remained unaffected with different fertilizers. Biofertilizer used in combination with FYM resulted in significantly higher population of fungi (20 ×10^3 CFU g^{-1} of soil), diazotrophs (140 ×10^5 CFU g^{-1} of soil) and PSB (80 ×10^4 CFU g^{-1} of soil). Combined application of organic and inorganic fertilizers resulted in improved soil microflora leading to significantly higher enzyme activities which were further enhanced by inoculation of biofertilizers.

Kotha and Nkongolo (2017) reported that significant increase of total microbial biomass in limed sites (342 ng g^{-1}) compared to unlimed areas (149 ng g^{-1}) were observed. For fungi, operational taxonomic units were 96 and 81 for limed and unlimed soil samples, respectively.

Patra *et al*. (2017) conducted long term field experiment and the results indicated that INM treatments with enriched compost as well as biofertilizers had pronounced influence on improving microbial enzymatic activity as compared to inorganic treatment under acid soil.

Sahu *et al*. (2017) conducted a field experiment on rice during *kharif* season of 2015 to study the effect of combined application of fertilizer, micronutrients and biofertilizers on microbial population in rice. Highest population of *Azotobacter* and *Azospirillium* was in combined application of biofertilizers inoculated treatments.

Sepehya *et al*. (2017) reported that application of 50% N through organics + 50% NPK through chemical fertilizers was better than other treatments in improving chemical and microbiological properties of soil and in sustaining the crop yields.

Mallikarjun and Maity (2018) revealed that biological properties of soil were significantly enhanced by the application of combined use of organic and inorganic fertilizers after harvest of crop during both the years of experimentation. The population of bacteria, fungi and actinomycetes decreased in higher proportion in control. Application of 100% RDN through chemical fertilizers alone showed a relatively less increase in population of microbes. However, application of organics in the form of farmyard manure (FYM), mustard oil cake (MOC), Green manuring (GM), Brown manuring (BM) and Azolla helped to increase bacteria, actinomycetes, fungi and enzymatic activity in soil over 100% RDN through chemical fertilizers during both the years of experimentation. The results revealed that treatment (50% N as chemical fertilizer with 25% FYM along with Azolla dual cropping), recorded the maximum load of total bacteria, actinomycetes and fungi. Hence replacement of either 25% RDN or 50% RDN of chemical fertilizers through organics is desirable to improve soil health by increasing microbial load in the lateritic belt of west Bengal.

2.6 Residual effect in succeeding crops

Organic sources of nutrients applied to the preceding crops benefit the succeeding crops to a great extent (Hegde, 1998) and the system productivity may become sustainable through integrated use of organic and inorganic sources of nutrients. Application of organic material along with inorganic fertilizers in soil leads to increase in system productivity and also sustained soil health for longer period and system productivity becomes more sustainable in nature.

Jeyabal and Kuppuswamy (2001) conducted a field investigation on rice–legume cropping system and found that organic carbon content in the residual soil after rice was not depleted due to integrated application. After the legume, organic carbon content increased by 4.55 to 6.82% due to integrated nutrition compared to fertilizer alone. Available N in the residual soil was stable after the rice–legume system. Available P and K contents of the residual soil were depleted considerably in the rice–legume sequence. However, the amount of depletion of available N, P and K in the fertilizer alone treatment was greater than to the integrated nutrition. The microbial population of the residual soil was increased by integrated application.

Puste *et al*. (2001) in an experiment conducted, concluded that 25% of the recommended dose of N from chemical fertilizers instead of 100 % can effectively be substituted for any of the organic sources (green manure, crop residues, FYM, oil cake), which not only produced the highest yields of rice but also the grain yield of pulses were significantly influenced by the residual INM effect, which was adopted in the preceeding rice crop during the wet season. The integrated nutrient management system along with a microbiological approach improved the soil physical and chemical properties considerably and thereby increased the total productivity of the rice-pulse cropping system on a sustained basis.

Singh *et al.* (2001) reported that, application of 100% recommended dose of nitrogen (120 kg N ha^{-1}) when applied 50% N through FYM and 50% N through prilled urea in preceding rice produced pronounced residual effect on plant height, number of branches and dry matter accumulation, highest number of pods $plant^{-1}$, test weight, grain and straw yields of lentil over control.

Mosa *et al*. (2003) registered that the nutrient uptakes and available NPK status after harvest of each cropping sequence were higher following the INM treatments than that of non –INM treatments in maize-groundnut crop sequence.

Subramani *et al*. (2005) conducted a field experiment where nutrient treatments were imposed only to rice crops and no manure/fertilizer applied to rice fallow blackgram. The residual effect of integrated nutrient treatments adopted to advance kar season rice increased the grain yield and yield attributes of rice fallow blackgram.

Gawai and Pawar (2006) carried out an investigation on sorghum-chickpea cropping sequence and observed that plant height, dry matter and yield of succeeding chickpea during both the years were maximum with application of 75% RDF (90-45-45 kg N-P-K ha^{-1}) + FYM @ 5 t ha^{-1} + biofertilizer to *kharif* sorghum and significantly superior to control.

Roul and Mahapatra (2006) reported that residual effect of organic and inorganic sources boosted the productivity of succeeding crop.

Goulding *et al*. (2008) reported that organic manures supply nutrients to the current crop and also leave a substantial residual effect on the succeeding crops in different sequential cropping systems. The efficiency of applied chemical fertilizers is also increased when applied along with organic manures.

Gudadhe (2008) assess the effect of integrated nutrient management treatments applied to summer cotton and levels of recommended dose of fertilizer to *rabi* chickpea at Rahuri (Maharashtra) under cotton-chickpea cropping system and opined that residual effect of 10 t FYM ha^{-1} + RDF-100-50-50 kg N-P-K ha^{-1} applied to summer cotton recorded significantly higher values of chickpea in respect to plant height, number of branches $plant^{-1}$, plant spread, dry matter accumulation $plant^{-1}$, number of pods $plant^{-1}$, 100 grain weight, grain weight $plant^{-1}$ and grain and straw yields of chickpea and was found at par with 100% RDN application through vermicompost and 25% RDF + 75% RDN through vermicompost.

Patil *et al*. (2008) reported that the residual effect of application of 5 t FYM ha^{-1} to preceding sorghum resulted in significantly higher growth, yield attributes and yield of chickpea owing to 100 % RDF to chickpea and at par with that of 50 % RDF showing 50 % saving of nutrients.

Nawle *et al.* (2009) conducted a field experiment to study the effect of integrated nutrient management on *kharif* forage sorghum- chickpea cropping sequence. The residual effect of 25% N through FYM + 25% N through vermicompost + 50% N through RDF applied to *kharif* forage sorghum recorded significantly higher values of number of pods plant^{-1}, 1000 grain weight, grain and straw yields of *rabi* chickpea over control followed by 100% RDF(100-50-50 kg N-P-K ha^{-1}). They further reported that residual effect of 25 % N through FYM + 25 % N through vermicompost + 50 % N through RDF applied to forage sorghum also recorded significantly higher value for nutrient uptake.

Shanwad *et al.* (2010) conducted an experiment at Raichur to study the effect of integrated nutrient management on maize-bengal gram cropping system. The results revealed that application of FYM @ 7.5 t ha^{-1} + 100% RDF (100-50-25 kg N-P-K ha^{-1}) to maize recorded significantly higher Bengal gram yield and was at par with vermicompost @ 2.5 t ha^{-1} + 100% RDF (100-50-25 kg N-P-K ha^{-1}).

Porpavai *et al.* (2011) conducted a field experiment with ten rice based cropping systems during 2002-2006 at Thanjavur (Tamil Nadu) and found that inclusion of pulses (blackgram and greengram) in the cropping system improved the organic carbon and available nitrogen status of the soil.

Kar *et al.* (2012) conducted an on-farm study at Dhenkanal (Odisha), to study the effect of organic manure supplementation on rice–pulse cropping system productivity. Study revealed that all the three crops (pea, greengram and blackgram) achieved the highest seed yield (490, 463, 438 kg ha^{-1}) when the preceding rice crop was cultivated with 75% N (60 kg ha^{-1}) through inorganic fertilizer along with 25% N (20 kg ha^{-1}) through *Sesbania* sp. The results of this treatment were almost statistically at par with 75% N through inorganic fertilizer + 25% N through FYM and 75% N through inorganic fertilizer + 25% N through press mud.

Sohu *et al*. (2015) found that application of organic sources of farmyard manure and poultry manure in combination with inorganic NPK fertilizers had shown positive effect on growth, yield and yield attributes of succeeding chickpea crop in rice-chickpea cropping system.

Sindhi *et al*. (2016) investigated an experiment in maize-greengram cropping sequence and found that grain and straw yields as well as nutrient content (N, P and K) and their uptake by *rabi* maize were maximum with the application of general RDF (RDF + FYM @ 10 t ha^{-1}). Similarly, during summer season the residual effect of general RDF (RDF + FYM @ 10 t ha^{-1}) applied to *rabi* maize showed higher seed and stover yields, nutrient content (N, P and K) and their uptake by greengram (seed and straw) after harvest of greengram, followed by 75% RDN through chemical fertilizer + 25% RDN through vermicompost.

Latha *et al*. (2019) conducted a field experiment and the results of the work indicated that the application of 50% RDN + 25% N through FYM + 25% N through neem cake + recommended dose of microbial consortium (*Azospirillum* + PSB @ 2.5 kg ha^{-1}) recorded significantly higher grain yield and straw yield of rice over 100% RDN. Further they reported that plant height, dry matter yield, yield attributes, grain yield, stover yield, test weight and harvest index of *rabi* crops (blackgram, maize, sorghum, sunflower and mustard) recorded highest in all those plots, which received organics along with 50% RDN+ *Azospirillum* and PSB @ 2.5kg ha^{-1} applied to preceding rice. Application of INM to preceding rice crop increased all the *rabi* crop yields by 25-30% when compared to 100% RDN alone.

Senthilvalavan and Ravichandran (2019) investigated the residual effect of different nutrient management practices imposed to preceding rice crop on the yield, NPK uptake and economics of blackgram grown in rice-fallow-blackgram cropping sequence consecutively for two years. Among nutrient management practices imposed to rice, STCR based IPNS (144:64:60 kg NPK ha^{-1} along with 12.5 t ha^{-1} FYM and bio-fertilizers *viz*. *Azospirillum* and PSB as soil treatment) registered more residual effect by recording the highest yield (seed- 675.8, 689.6 kg ha^{-1} and haulm - 2224.8,2291.6 kg ha^{-1}), NPK uptake in seed and haulm (17.4, 3.82, 9.25 and 18.0, 3.95, 9.57 kg ha^{-1}; 38.1, 5.46, 28.9 and 39.3, 5.63, 29.7 kg ha^{-1}) and net profitability (Net return of ₹ 15,480,16,015 and benefit-cost ratio of 3.74 , 3.88), respectively.

2.7 Effect of lime and INM on productivity, economics / benefit-cost analysis

Mosa *et al*. (2003) concluded that gross and net returns, and B:C ratio worked out at the end of maize-groundnut sequence during both the crop cycles clearly indicated an improvement in profitability of INM treatments, particularly, of those wherever organic manures were applied in addition to the recommended NPK to the preceding crop in sequence.

Acharya and Mondal (2010) from a study on rice-cabbage-greengram cropping system reported higher rice equivalent yield (REY) of 32.33 t ha^{-1} under 75% RDF + 25% N through FYM to all the crops than RDF alone which produced REY of 26.80 t ha^{-1}. Again the study revealed that higher net returns (₹1,43463 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 (₹1,15589 ha^{-1}, B:C ratio 2.46).

Singh *et al.* (2011) while studying rice-pea cropping system on an acid upland soil of Jharkhand, revealed that system productivity was increased by 2 to 4 times under INM treatments over the existing farmers' practices. Higher system productivity (9412 kg ha^{-1}) was obtained with combined application of 5 t FYM + 250 kg lime + 20 kg S+ 1 kg B ha^{-1} along with 50% RDF than obtained with 100% RDF only (6832 kg ha^{-1}). It was also found that cost of cultivation was marginally increased in case of INM, but due to higher grain and straw yields, the net income (₹ 32,823 ha^{-1}) and B:C ratio (2.73) were also higher under the integrated use of organic and inorganic source of nutrients than that received with 100% RDF (₹ 28,823 ha^{-1}) and B:C ratio (2.34).

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.

Sorokhaibam *et al*. (2016) conducted field experiments on rice-rapeseed and reported that application of lime @ 500 kg $CaCO_3$ ha^{-1} before planting rice continuously for two cropping seasons had residual effect on seed and stover yields of succeeding rapeseed resulting in improvement of system productivity in terms of rice equivalent yield (REY) by 7.2 % respectively over no liming.

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.

Shinde *et al*. (2017) studied the response of rice hybrids *viz.,* Sahyadri-3 and Sahyadri-4 to integrated nutrient management comprising different combinations of chemical fertilizers with FYM, poultry manure, glyricidia (green manure) and Biofertilizers (*Azospirillum* and PSB). It was revealed from the study that the economics (gross returns, net returns, B:C ratio) were highest under the application of 50 % RDN through chemical fertilizers, 25% through application of FYM and remaining 25 % through poultry manure application.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter describes the details of the experiment, the procedures, materials and methods followed to study the **"Response of rice (*Oryza sativa* L.) to integrated nutrient management and liming and their residual effect on succeeding pea (*Pisum sativum* L.)".**

3.1 General information

3.1.1 Site of experiment

The present investigation was carried out in the Experimental Research Farm of the School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema Campus during *kharif* and *rabi* seasons of 2016-2017 and 2017-2018. The experimental site is located in the foot hill of Nagaland at an altitude of 310 m above mean sea level with the geographical location at 25°45'43"N latitude and 95°53'04" E longtitude.

3.1.2 Climatic and weather conditions during the experiment period

The climate of the region is sub-tropical having hot and humid summers and cold winters. Monsoon starts from the first week of June and extends to September and the rains gradually decrease from October. The experimental farm lies in the humid sub-tropical zone with an average rainfall ranging from 2000 to 2500 mm per annum. The mean temperature ranges from 21°-32°C during summer and rarely goes below 8°C in winter season. More precise information on meteorological data during the investigation is presented in Table 3.1(a), 3.1(b), 3.2(a) and 3.2(b) and illustrated in Fig. 3.1(a), 3.1(b), 3.2(a) and 3.2(b).

Table 3.1(a) Meteorological data during the *kharif* crop growth period (2016)

Week No.	Temperature		Relative Humidity		Total Rainfall (mm)	Number of Rainy Days	Bright Sunshine Hours
	Max. (ºC)	Min .(ºC)	Max. (%)	Min. (%)			
24	32.9	25.8	90	72	71.3	4	3.3
25	32.9	24.5	90	71	85.5	3	3.0
26	33.6	25.3	89	68	30.2	3	3.8
27	33.3	24.8	92	70	133.2	6	3.4
28	33.4	25.3	91	79	28.1	5	4.0
29	32.0	24.8	91	67	57.1	2	0.5
30	30.6	23.9	93	73	36.6	2	1.2
31	34.2	24.8	92	65	9.6	1	5.3
32	32.6	24.1	94	72	110.9	6	3.5
33	34.6	24.6	91	69	126.4	3	3.9
34	33.7	24.4	91	68	15.2	2	4.5
35	33.9	23.9	94	71	149.9	6	3.9
36	32.9	24.6	93	70	53.6	3	4.4
37	32.4	23.7	94	74	94.1	5	3.4
38	32.7	23.6	94	74	69.9	5	5.1
39	32.2	23.9	95	74	60.0	5	5.3
40	33.9	23.4	94	66	2.8	0	8.2
41	31.9	22.9	93	79	18.3	2	3.8
42	31.7	21.7	94	66	1.8	0	7.8

Table 3.1(b) Meteorological data during the *rabi* crop growth period (2016-17)

Week No.	Temperature		Relative Humidity		Total Rainfall (mm)	Number of Rainy Days	Bright Sunshine Hours
	Max. (ºC)	Min .(ºC)	Max. (%)	Min. (%)			
42	31.7	21.7	94	66	1.8	0	7.8
43	31.1	20.3	94	67	1.5	0	6.2
44	29.2	20.4	94	68	11.4	2	6.9
45	26.6	18.5	94	80	130.1	3	2.7
46	29.1	16.9	95	62	0.0	0	7.9
47	28.0	11.8	95	54	0.0	0	8.2
48	26.5	13.7	95	58	0.6	0	5.4
49	27.8	11.7	95	52	0.0	0	7.6
50	27.2	9.6	94	53	0.0	0	7.8
51	25.7	11.2	95	55	0.0	0	5.2
52	25.5	11.6	94	54	5.8	1	6.4
1	25.5	9.8	95	51	0.7	0	7.3
2	23.9	8.6	93	53	0.0	0	6.3
3	23.8	7.8	95	47	0.0	0	7.3

Source: ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani

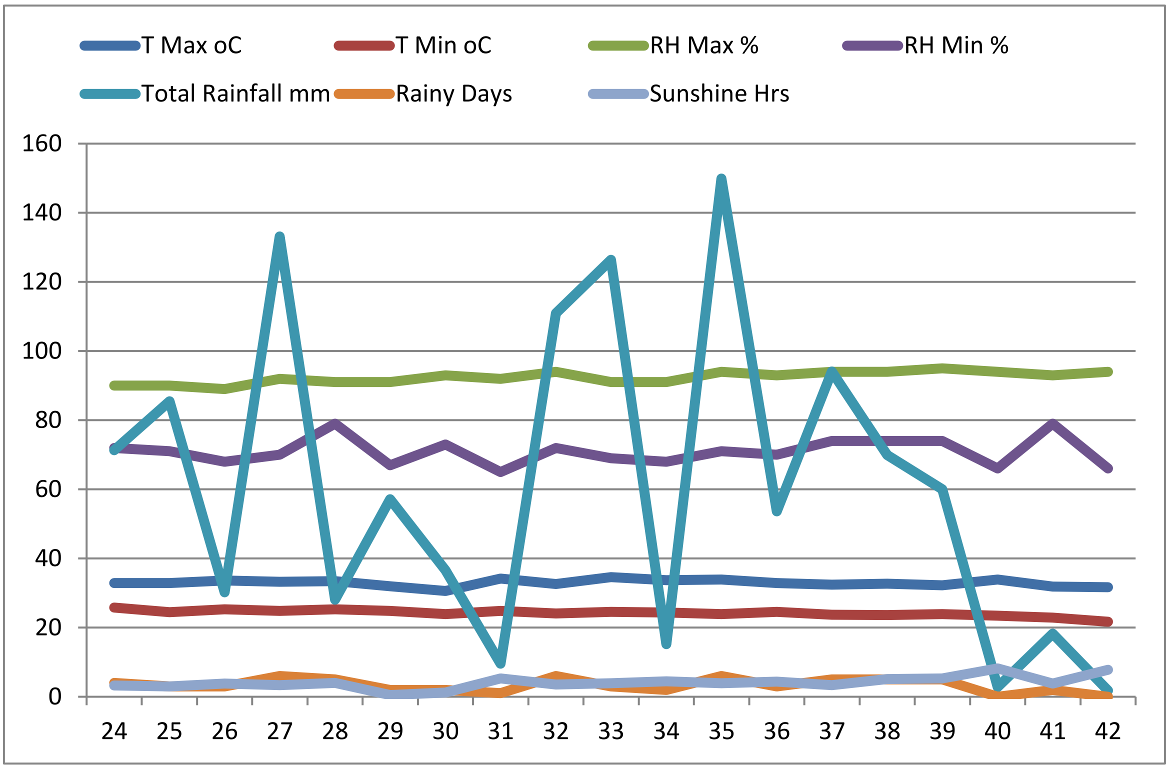


Fig 3.1(a) Meteorological data during the *kharif* crop growth period (2016)

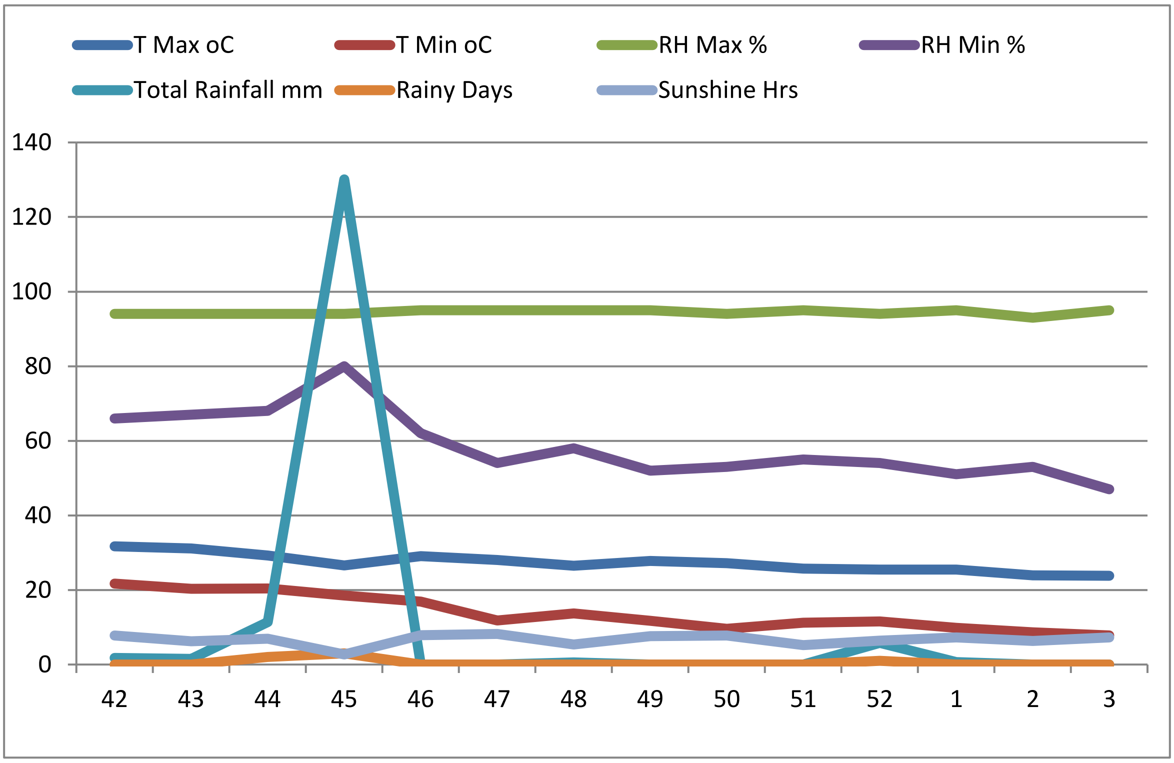


Fig 3.1(b) Meteorological data during the *rabi* crop growth period (2016-17)

Table 3.2(a) Meteorological data during the *kharif* crop growth period (2017)

Week No.	Temperature		Relative Humidity		Total Rainfall (mm)	Number of Rainy Days	Bright Sunshine Hours
	Max. (ºC)	Min .(ºC)	Max. (%)	Min. (%)			
23	33.5	23.1	92	61	4.8	1	7.9
24	31.1	24.1	95	83	127.9	5	2.4
25	30.8	24.0	92	72	22.5	3	3.1
26	31.8	24.4	93	75	134.4	4	1.7
27	31.8	24.7	94	80	153.0	7	1.9
28	29.9	23.6	95	74	104.5	5	3.8
29	31.6	24.7	93	77	131.8	5	3.6
30	31.9	24.7	93	73	61.5	4	3.3
31	33.3	25.0	92	66	33.5	4	6.4
32	31.8	25.1	93	74	81.2	2	0.5
33	31.0	24.5	95	73	50.3	3	3.1
34	32.3	24.1	93	74	271.9	4	6.1
35	30.7	24.6	95	75	92.8	4	2.7
36	33.0	24.8	94	65	4.5	1	5.1
37	31.4	24.2	95	74	38.3	3	4.4
38	31.2	24.8	96	76	8.8	1	4.4
39	31.6	24.3	96	80	155.9	4	4.5
40	31.8	23.7	96	78	33.9	2	6.9
41	32.9	23.6	94	71	3.1	0	6.4

Table 3.2(b) Meteorological data during the *rabi* crop growth period (2017-18)

Week No.	**Temperature**		**Relative Humidity**		**Total Rainfall (mm)**	**Number of Rainy Days**	**Bright Sunshine Hours**
	Max. (ºC)	Min .(ºC)	Max. (%)	Min. (%)			
42	30.9	23.7	95	76	17.9	2	2.8
43	27.8	18.4	95	72	44.7	2	6.0
44	26.7	17.7	95	74	30.4	2	5.7
45	29.6	16.5	94	60	0.0	0	8.4
46	27.4	16.9	97	65	6.4	1	4.5
47	28.5	17.0	98	63	10.0	1	7.5
48	28.9	13.2	97	61	0.0	0	6.3
49	26.0	10.9	95	56	0.0	0	4.5
50	24.9	15.3	98	73	31.8	2	3.3
51	25.6	11.5	95	67	0.0	0	6.5
52	25.7	11.5	97	69	0.0	0	7.2
1	23.7	10.8	97	69	23.0	1	5.2
2	22.5	7.5	97	60	0.0	0	7.5
3	24.2	11.5	97	69	0.0	0	5.4

Source: ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani

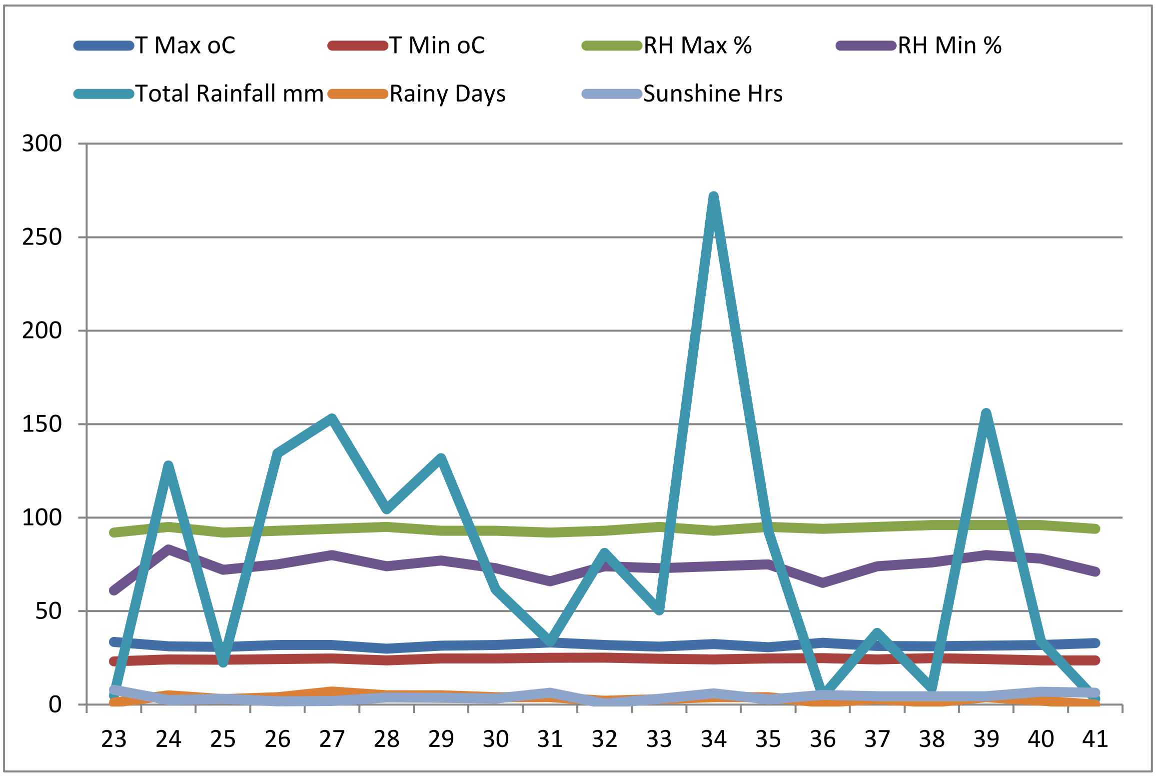


Fig 3.2 (a) Meteorological data during the *kharif* crop growth period (2017)

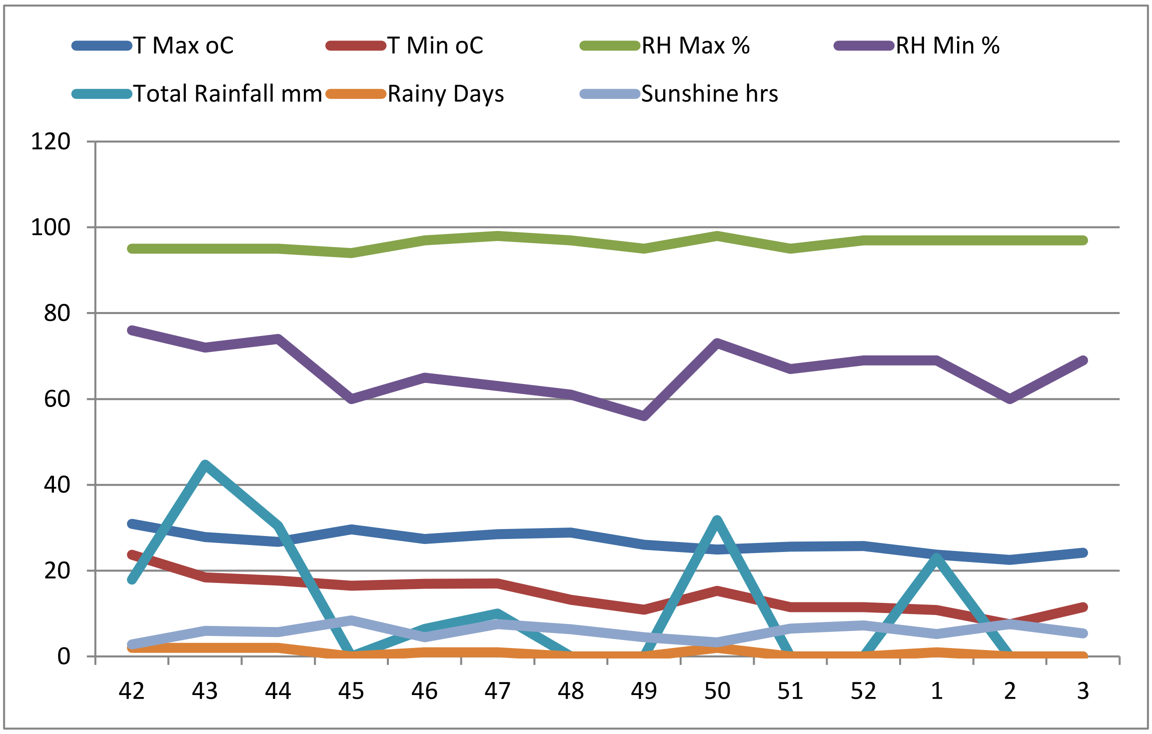


Fig 3.2(b) Meteorological data during the *rabi* crop growth period (2017-18)

3.1.3 Soil condition

In general, the soil type of the experimental site was categorized sandy loam in texture and well drained. The texture and fertility of the soil was ascertained by taking representative soil samples randomly from each experimental plot taken at a depth of 0-15 cm depth with the help of a screw auger, which was processed and analyzed by methods of mechanical and chemical analysis. The results thus obtained are presented in Table 3.3

Table 3.3 Initial soil fertility status of the experimental field

Characteristics	Method followed	2016		2017	
		Content	**Inference**	**Content**	**Inference**
pH	Digital pH meter (Single electrode meter)	4.73	Acidic	4.8	Acidic
Organic carbon (%)	Walkley and Black Method (Piper, 1966)	1.26	High	1.42	High
Available N (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	263.79	Low	282.18	Medium
Available P_2O_5 (kg ha^{-1})	Bray's No.1 method (Bray and Kurtz, 1945)	18.26	Medium	22.42	Medium
Available K_2O (kg ha^{-1})	Flame Photometer (Hanway and Heidal, 1952)	185.17	Medium	220.42	Medium

3.1.4 Cropping history of the Experimental site

Previous crop grown in the experimental site before the cultivation of rice are presented in Table 3.4.

Table 3.4 Cropping history of experimental field

Sl. No.	Year	*Kharif*	*Rabi*
1.	2014	Baby corn (*Zea mays*)	Fallow
2.	2015	Soybean (*Glycine max* L.*merrill*)	Linseed (*Linum usitatissimum* L.)

3.2 Experimental details

3.2.1 Seed material

Rice variety: Longkumtsuk is a local cultivar and grown during *kharif* season. Seeds are sown directly either by broadcasting or dibbling. It matures in 155-160 days and yields 40 q ha^{-1}. The colour of the grain is pale yellow. Seeds were obtained from Yisemyong (Mokokchung district).

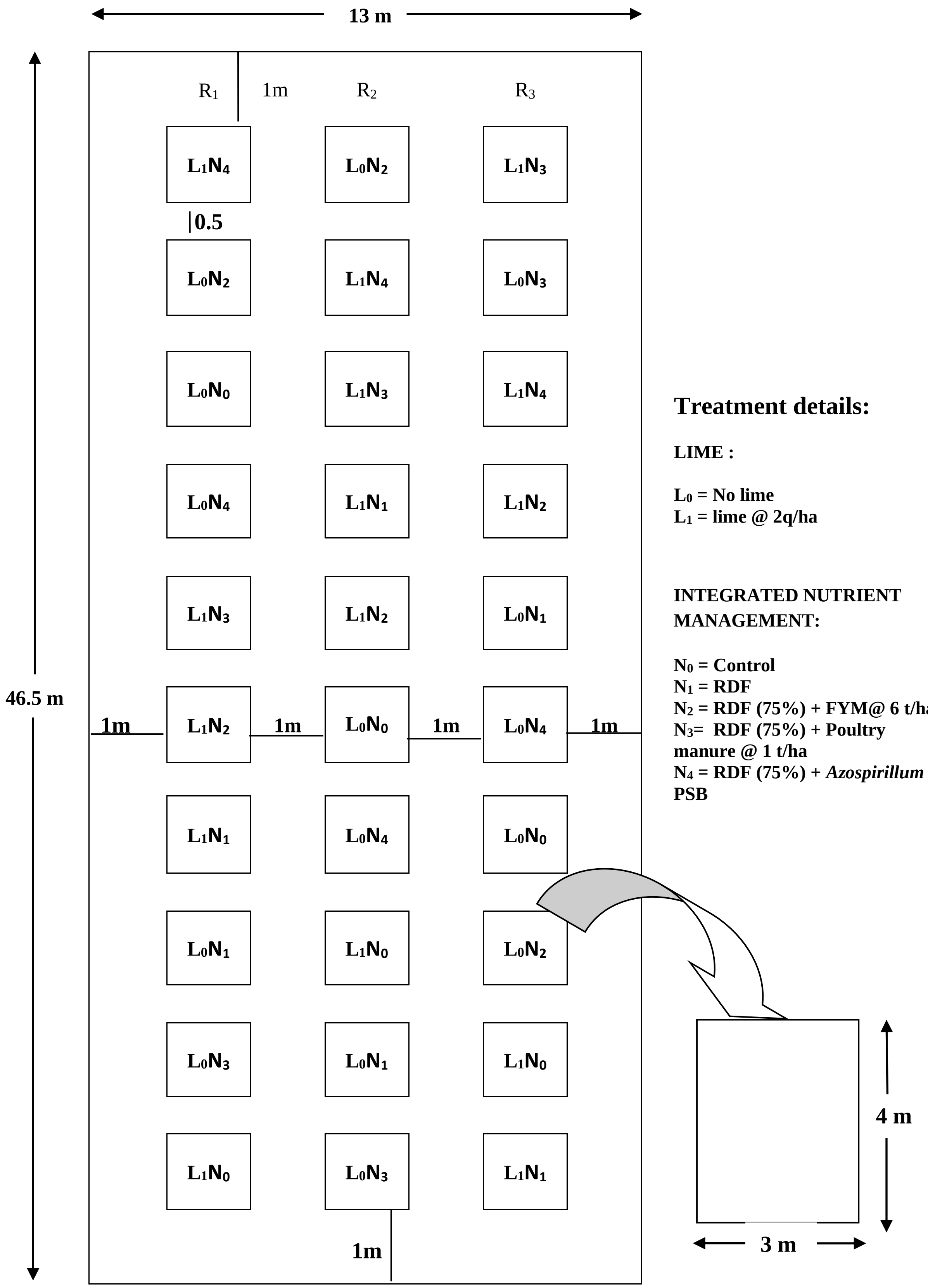
Pea variety: Arkel was introduced from England in 1970. It is an early maturing and dwarf variety. It is highly susceptible to powdery mildew and rust. It is recommended for cultivation all over India. Seeds were obtained from M/S. Hills Enterprises (Dimapur).

3.2.2 Experimental design

The experimental design that was conducted in the experiment field was 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 10 equal sized plots, in total consisting of 30 plots. Placement of each treatment was done in randomized manner. The details of the plan and layout of the experimental field are given in Fig 3.3.

3.2.3 Details of the experiment

1. Experimental design	: Randomized Block Design (RBD)
2. Crop	: Rice (*Oryza sativa* L.)
3. Variety	: Longkumtsuk
4. Spacing	: 20 x 10 cm^2
5. Sequential crop	: Pea (*Pisum sativum* L.)
6. Variety	: Arkel
7. Spacing	: 30 x 10 cm^2
8. Treatments:	
i) Lime	L_0- No lime
	L_1- Lime @ 2 q ha^{-1}
ii) Integrated nutrient management	N_0- Control
	N_1- RDF
	N_2- RDF (75%) + FYM @ 6 t ha^{-1}
	N_3- RDF (75%) + Poultry manure @ 1 t ha^{-1}
	N_4- RDF (75%) + *Azospirillum* + PSB
9. Number of treatment	: 10
10. Number of replication	: 3
11. Total number of experimental plots	: 30
12. Plot size	: 4 x 3 m^2
13. Block border	: 1m
14. Plot border	: 0.5 m
15. Length of experimental field	: 46.5 m



Treatment details:

LIME :

L_0 = No lime
L_1 = lime @ 2q/ha

INTEGRATED NUTRIENT MANAGEMENT:

N_0 = Control
N_1 = RDF
N_2 = RDF (75%) + FYM@ 6 t/ha
N_3= RDF (75%) + Poultry manure @ 1 t/ha
N_4 = RDF (75%) + *Azospirillum* + PSB

<u>Fig 3.3 Field layout of the experiment in Randomized Block Design (RBD)</u>

16. Width of the experimental field : 13 m

17. Total area of the experimental field : 604.5 m^2

3.2.4 Treatment details

The experiment was carried out with the following treatments

Treatment combinations	**Symbol**
Control	T_1 (L_0N_0)
No lime + RDF (120-60-60 N-P-K kg ha^{-1})	T_2 (L_0N_1)
No lime + RDF (75%) + FYM @ 6 t ha^{-1}	T_3 (L_0N_2)
No lime + RDF (75%) + poultry manure @ 1 t ha^{-1}	T_4 (L_0N_3)
No lime + RDF (75%) + *Azospirillum* + PSB	T_5 (L_0N_4)
Lime @ 2 q ha^{-1}	T_6 (L_1N_0)
Lime @ 2 q ha^{-1} + RDF (120- 60- 60 N-P-K kg ha^{-1})	T_7 (L_1N_1)
Lime@ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}	T_8 (L_1N_2)
Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}	T_9 (L_1N_3)
Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB	T_{10} (L_1N_4)

3.3 Cultural/Agronomic practices adopted during the experiment

Table 3.5 Calendar of agronomic management practices

Sl.no.	Operations	Date	
		2016-17	2017-18
Rice			
1.	First ploughing	16/5/16	9/5/17
2.	Second ploughing	23/5/16	16/5/17
3.	Layout	26/5/16	17/5/17
4.	Soil sample collection	27/5/16	18/5/17
5.	FYM @ 6 t ha^{-1}, Poultry manure @ 1 t ha^{-1}, Lime @ 2 q ha^{-1} application	28/5/16	19/5/17
6.	Fertilizers and sowing of seed	13/6/16	6/6/17
7.	Thinning	9/7/16	1/7/17
8.	First weeding	11/7/16	3/7/17
9.	Tagging	12/7/16	4/7/17
10.	Observations of 30 DAS	13/7/16	6/7/17
11.	Second dose of urea applied	18/7/16	12/7/17
12.	Second Weeding	12/8/16	5/7/17
13.	Observations of 60 DAS	13/8/16	7/8/17
14.	Observations of 90 DAS	13/9/16	6/9/17
15.	Observations at Harvest stage	17/10/16	7/10/17
16.	Complete harvesting	19/10/16	12/10/17
17.	Threshing and drying	27/10/16	20/10/17
Pea			
1.	Land preparation (plotwise)	21/10/16	16/10/17
3.	Soil sample collection and application of chloropyriphos @ 2 ml^{-1}	25/10/16	19/10/17
4.	Sowing of seed	26/10/16	21/10/17
5.	1^{st} weeding	21/11/16	16/11/17
6.	Earthing up	24/11/16	17/11/17
7.	Observations of 30DAS	26/11/16	21/11/17
8.	2^{nd} weeding	11/12/16	6/12/17
9.	Observations of 60 DAS	26/12/16	21/12/17
10.	Observations at harvest stage	19/1/17	17/1/18
11.	Complete harvesting	20/1/17	18/1/18

3.3.1 Selection and preparation of field

A three tier terrace having uniform fertility status was selected for conducting field trial in the experimental farm of Agronomy Department. The experimental field was ploughed with a tractor drawn disc plough in 2^{nd} and 3^{rd} week of May during 2016-2017 and 2017-2018. Final ploughing and breaking of clods were done with the help of a rotavator. Then the weeds and the stubbles were removed. Finally, the field was levelled and laid out according to the plan and design of the experimental field.

3.3.2 Lime application

Application of liming material @ 2 q ha^{-1} was done in furrows two weeks ahead before sowing and properly mixed with the soil as soil amendment to reduce the high acidic condition of the field. It was applied to the plots having treatments T_6 : Lime @ 2 q ha^{-1}, T_7 : Lime @ 2 q ha^{-1} + RDF (120 -60 - 60 N-P-K kg ha^{-1}), T_8 : Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}, T_9 : Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1t ha^{-1}, T_{10} : Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB.

3.3.3 Manure application

During the land preparation, well decomposed FYM @ 6 t ha^{-1} was uniformly broadcasted into the plots of FYM treatments *i.e.* T_3 - RDF (75%) + FYM @ 6 t ha^{-1} and T_8 - Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} while poultry manure was uniformly applied into the plots of PM treatments *i.e.* T_4 - RDF (75%) + poultry manure @ 1 t ha^{-1} and T_9 - Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}. The FYM and PM were thoroughly incorporated into the soil of the experimental site 15 days before sowing.

3.3.4 Fertilizer application

The recommended doses of fertilizers were applied as per *viz.* RDF @ N_{120} : P_{60}: K_{60} kg ha^{-1} (T_1 - Control, T_2 - RDF, T_3 - RDF (75%) + FYM @ 6 t ha^{-1}, T_4 - RDF (75%) + poultry manure @ 1 t ha^{-1}, T_5 - RDF (75%) + *Azospirillum* + PSB, T_7 - Lime @ 2 q ha^{-1} + RDF (120- 60- 60 N-P-K kg ha^{-1}), T_8 - Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}, T_9 - Lime @ 2 q ha^{-1} +

RDF (75%) + Poultry manure @ 1 t ha^{-1} and T_{10} - Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB).

The nitrogen dose in the form of urea was applied in 3 equal split doses *i.e.* 1/3rd each as basal application, active tillering stage and at panicle initiation stage of rice. The full doses of both phosphorus and potassium were applied as basal dose at the time of final field preparation as per recommendation through SSP and MOP respectively.

For pea, the crop was raised exclusively on residual resources of rice crop.

3.3.5 Seed and Sowing

For sowing rice seeds, furrows were made in lines with spacing of 20 cm apart which was followed by spreading of Malathion dust over the furrows and then slightly covering with soil to control ants and termites. After which line sowing of the seeds were done maintaining a depth of about 3-5 cm. The sowing was done on 13th June. While during the second year sowing was done a week ahead *i.e.* 6th June with a seed rate of 80 kg ha^{-1}.

In succeeding pea crop no fertilizer was applied and pea was raised on residual fertility left over by different sources of organic and inorganic nutrients. The land was prepared to necessary tilth by spade digging without disturbing the plot boundaries. Seed was sown in line maintaining a spacing of 30 cm x 10 cm and covered with soil. Seeds were sown at a depth of 3-4 cm in soil.

3.3.6 Thinning and gap filling

The thinning operation was carried out after about one month of sowing to maintain an optimum plant to plant spacing at 10 cm by removing excess germinated seedlings and at the same time gap filling was done in required plots for rice crop.

3.3.7 Weed control

Hand weeding was done twice with the help of khurpi and local hoe at around 20 days interval from the date of sowing. This cultural practice was carried out because during the seedling stage the crop-weed competition was very high especially for direct seeded rice.

For pea, weeding was done twice manually at 25 and 45 days after sowing.

3.3.8 Insect-pest and disease management

Chloropyriphos was applied through knapsack sprayer @ 2.5 ml litre^{-1} of water in order to control the attack of soil termites and stem borer infestation. Gundhi bugs were found to be prevalent during flowering and milking stage of the crop. Dusting of malathion 5% dust @ 25 kg ha^{-1} was done to control the same.

Disease infestation like blast was observed during vegetative stage and examined and sprayed hexaconazole 0.5% @ 1ml litre^{-1} of water through knapsack sprayer.

Besides the insect-pest infestation, several bird attacks during the maturity stage were a serious matter of concern causing much loss of crop yield. Though several methods were applied to manage the problem, desired result couldn’t be achieved.

3.3.9 Harvesting and threshing

The rice was harvested at ground level with the help of sickles. The plot wise bundle of harvested crop was dried, threshed and cleaned manually.

The pea were harvested when the pods turn from dark green to light green in colour and are well filled with grains. Harvesting was done by picking of the pods.

3.4 Experimental observations to be recorded

3.4.1 Meteorological observations

Meteorological observations on relative humidity (%), temperature (maximum and minimum in ^{0}C), bright sunshine hours, rainfall (mm) and number of rainy days were recorded for the research period during both the years.

3.4.2 Growth attributes of rice

Five plants were randomly selected in each plot and tagged. Their growth attributes were recorded.

3.4.2.1 Plant height (cm)

Five plants in each plot were tagged for recording the plant height. The plant height was measured in centimetres from the ground level to the tip of the upper most leaf of the plant at 30, 60, 90 DAS and at harvest. The average plant height was calculated for each treatment respectively.

3.4.2.2 Number of tillers running metre^{-1}

The number of tillers running metre^{-1} was counted in a randomly selected row consisting of ten hills from each plot or treatment at 30, 60, 90 DAS and at harvest.

3.4.2.3 Green leaf area (cm^2)

Five hills plot^{-1} were selected at random. From each selected hill, the number of tillers was counted, measured the length and maximum width of each leaves on the middle tiller and computed the leaf area using the length-width method (Yoshida *et al.*, 1976).

Leaf area (cm^2) = K x Length (cm) x Width (cm)

Where, K is the "adjustment factor" varies with the shape of the leaf which in turn is affected by the variety, nutritional status, and growth stage of the leaf. The value of 0.75 can be used for all stages of growth except for the seedling stage and harvest is 0.67.

Leaf area hill^{-1} = Total leaf area of middle tiller x Total number of tillers

3.4.2.4 Leaf Area Index

Leaf area index at 30, 60, 90 DAS and at harvest was calculated by the formula:

$$\text{LAI} = \frac{\text{Sum of leaf area hill}^{-1}\text{ of five hills (cm}^2\text{)}}{\text{Area of land covered by five hills (cm}^2\text{)}}$$

3.4.2.5 Shoot dry weight (g plant^{-1})

The shoot dry weight was taken at 30, 60, 90 DAS and at harvest by uprooting the five randomly selected plants from each treatment plot leaving the border rows. After removal of root portion, first plants were sun dried and then samples were oven dried at 75 ^{o}C for 48 hours. When plant samples attained constant weight, the shoot dry weight was recorded in g plant^{-1}.

3.4.2.6 Crop Growth Rate (g m^{-2} day^{-1})

The crop growth rate (CGR) at 30, 60, 90 DAS and at harvest was calculated by using the dry matter accumulation (g) of plant for each plot at successive growth with the following formula.

$$\text{CGR} = \frac{w_2 - w_1}{(t_2 - t_1)S}$$

Where, W_1 and W_2 are the dry weight of the plants at time t_1 and t_2 respectively. S is land area (m^2) over which dry matter was recorded.

3.4.2.7 Relative Growth Rate (g g^{-1} day^{-1})

The relative growth rate (RGR) at 30, 60, 90 DAS and at harvest was also calculated using the same recorded data of the dry accumulation of plant with the help of the following formula.

$$RGR = \frac{\ln W_2 - \ln W_1}{(t_2 - t_1)}$$

Where, W_1 and W_2 are dry matter produced by a gram (g) of existing dry matter in a day at time t_1 and t_2 respectively.

3.4.2.8 Dry matter

The dry matter was taken at 30, 60, 90 DAS and at harvest by uprooting the five plants as samples from each treatment plot leaving the border rows. Shoot portion as well as the root portion of the plants were sun dried and then samples were oven dried at 75 ^oC for 48 hours. When plant samples attained constant weight, the dry matter weight was recorded in g $plant^{-1}$.

3.4.3 Yield and yield attributes of rice

3.4.3.1 Number of panicles m^{-2}

Total number of panicles was counted from randomly selected in one $metre^2$ from each plot.

3.4.3.2 Length of panicle (cm)

Five panicles were selected from sampled plants from each plot and the length of each panicle was recorded from the base (neck joint) to the tip of the last grain and the average length (cm) was recorded.

3.4.3.3 Number of filled grains $panicle^{-1}$

Number of filled grains $panicle^{-1}$ from five panicles of sampled plants of each plot was counted and the average number of filled grains $panicle^{-1}$ was recorded thereafter.

3.43.4 Filled grains percentage (%)

Five panicles were randomly selected and the number of fertile and unfertile grains $panicle^{-1}$ was counted and thereafter calculated using the given formula. The average was then recorded.

$$\text{Filled grains percentage (\%)} = \frac{\text{Number of filled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.4.3.5 Test weight (g)

The dried filled grain was counted to determine the weights of thousand grains or test weight for each treatment.

3.4.3.6 Grain yield (q ha^{-1})

The obtained grains from each plot after threshing were thoroughly sun dried and then weighed to determine the grain yield. The grain yield obtained from each plot area was recorded in kg which was converted into q ha^{-1} using the formula:

$$\text{Grain yield (q ha}^{-1}) = \frac{\text{Weight of the grain per plot (kg)}}{\text{Size of the plot (m}^2\text{) x 100}} \text{ x } 10000$$

3.4.3.7 Straw yield (q ha^{-1})

The straw bundles collected from each plot after threshing were allowed to dry in the sun for some days and then weight was taken separately to determine the straw yield. The straw yield obtained from each plot was recorded in kg which was converted into q ha^{-1} using the formula:

$$\text{Straw yield (q ha}^{-1}) = \frac{\text{Weight of the straw per plot (kg)}}{\text{Size of the plot (m}^2\text{) x 100}} \text{ x } 10000$$

3.4.3.8 Harvest index (%)

Harvest index is the ratio of economic yield to biological yield and were calculated by using the formula

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \text{ x } 100$$

3.4.4 Growth attributes of Pea

3.4.4.1 Plant height (cm)

Five plants in each experimental plot was selected and tagged for recording of plant height. The plant heights was measured from base to the terminal apex for each tagged plants at 30, 60 DAS and at harvest. The average plant height was calculated for each treatment and recorded in cm.

3.4.4.2 Number of branches plant^{-1}

The total number of branches plant^{-1} was counted from the five tagged plants at 30, 60 DAS and at harvest and average number of branches plant^{-1} was recorded.

3.4.4.3 Dry weight plant^{-1}

The dry weight plant^{-1} was taken at 30, 60 and at harvest by uprooting the five randomly selected plants from each treatment plot leaving the border rows. After removal of root portion, first plants were sun dried and then oven dried to get constant weight. Thereafter, the average dry weight plant^{-1} was recorded.

3.4.5 Yield attributes of Pea

3.4.5.1 Number of pods plant^{-1}

Number of pods plant^{-1} was counted from the tagged plants at harvesting time and its average was recorded.

3.4.5.2 Number of seeds pod^{-1}

The number of seeds pod^{-1} was calculated by counting the number of seeds from the tagged plants and its average was recorded.

3.4.5.3 Test weight (g)

The dried pods were counted to determine the weights of hundred pods or test weight for each treatment.

3.4.5.4 Pod yield (q ha^{-1})

The pod yield obtained from each plot area was recorded in kg which was converted into q ha^{-1} using the formula:

$$\text{Pod yield (q ha}^{-1}\text{)} = \frac{\text{Weight of the pod per plot (kg)}}{\text{Size of the plot (m}^2\text{) x 100}} \text{ x } 10000$$

3.4.5.5 Stover yield (q ha^{-1})

The stover yield obtained from each plot area was recorded in kg which was converted into qha^{-1} using the formula:

$$\text{Stover yield (q ha}^{-1}\text{)} = \frac{\text{Weight of the stover per plot (kg)}}{\text{Size of the plot (m}^2\text{) x 100}} \text{ x } 10000$$

3.4.5.6 Harvest index (%)

Harvest index is the ratio of economic yield to biological yield and were calculated by using the formula.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \text{ x } 100$$

3.4.6 Nutrient status of the soil and plant after harvest

To determine the nutrient status of the soil, soil sample of experimental field was analyzed for pH, organic carbon, available nitrogen, available phosphorus, available potassium and nutrient uptake at harvest of both the crops.

3.4.6.1 Soil pH

Soil pH was determined in soil: water (1:2) ratio by Digital pH meter (Jackson, 1967).

3.4.6.2 Soil Organic Carbon (%)

Organic carbon was determined by Walkey and Black rapid titration method as outlined by piper (1966). The results were expressed in terms of percentage.

3.4.6.3 Available Nitrogen (kg ha^{-1})

The available soil nitrogen (N) was determined by alkaline potassium permanganate solution determining the ammonia liberated**.** This serves as an index of the available (mineralization) N status of the soil and was proposed as soil test for N by Subbiah and Asija (1956). The data was calculated in terms of kg ha^{-1}.

3.4.6.4 Available Phosphorus (kg ha^{-1})

The available soil phosphorus (P_2O_5) was extracted with 0.03 n NH_4F in 0.02 NHCL. The procedure is mainly for soils which are moderate to strongly acidic with pH around 5.5 or less (Bray and Kurtz, 1945). The results were expressed in kg ha^{-1}.

3.4.6.5 Available Potassium (kg ha^{-1})

The available soil potassium (K_2O) was determined from 5 g of soil by shaking with 25 ml of Neutral Normal Ammonium Acetate (pH 7) solution for half an hour and the extract was filtered immediately through a dry filter paper (Whatman No.1) and then potassium concentration in the extract was determined by flame photometer (Hanway and Heidal, 1952) and the result obtained were expressed in kg ha^{-1}.

3.4.6.6 Nutrient balance sheet of soil

After the harvest of rice and pea crop, the nutrient balance sheet of the research plot was worked out and accordingly, nutrient status was evaluated.

3.4.6.7 Plant sample for NPK uptake

Nutrient uptake is the amount of nutrient taken up by the crop. The plant after threshing was dried in the oven and grinded and then sieved for determination of NPK uptake. The uptake of nutrient was computed as follows.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Percent nutrient content x yield (kg ha}^{-1})}{100}$$

3.5 Soil Microbial Analysis

3.5.1 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 tubes containing 9ml of sterile distilled water were taken. One test tube containing 10 ml of sterile distilled water was taken and added 1 g of soil to the test tube. Thereafter, the soil was mixed thoroughly with the sterile distilled water. Then, 1 ml of microbial suspension was added to another test tube containing 9ml of sterile distilled water and thoroughly mixed. Further, 1ml of microbial suspensions was added to another test tube containing 9 ml sterile distilled water. The same step was repeated serially for other test tubes. In this way the microbial suspension was diluted 10 fold. Finally, 100 µl of diluted suspension was poured into the 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.

3.5.1.1 Bacteria (x 10^6 cfu g^{-1} soil)

Nutrient agar medium was used for the enumeration of bacteria.

3.5.1.2 Fungi (x 10^3 cfu g^{-1} soil)

Potato Dextrose Agar medium was used for enumeration of fungi.

3.5.1.3 Actinomycetes (x 10^5 cfu g^{-1} soil)

Kenknight medium was used for the enumeration of actinomycetes.

3.6 Economic analysis

Gross and net returns, and benefit-cost ratio were worked out for various treatments at the end of the first crop and also at the end of the crop sequence on the basis of input costs and output prices. Economics of different treatment was worked out as per existing market prices.

3.6.1 Cost of cultivation (₹ ha^{-1})

The cost of cultivation was calculated as per item wise cost incurred in each treatment.

3.6.2 Gross return (₹ ha^{-1})

Gross return for each treatment was calculated by multiplying the values of economic produce with the prevailing support prices of output.

3.6.3 Net return (₹ ha^{-1})

Net return for each treatment was estimated by subtracting the total cost of cultivation from the gross return.

3.6.4 Benefit: Cost ratio

Benefit Cost Ratio (B: C ratio) was calculated by the formula

$$\text{(B: C ratio)} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

3.6.5 Rice equivalent yield (REY) of pea

The pod yield of pea was converted into rice equivalent yield taking into consideration the prevailing price of rice and pea as follows:

REY of pea = (Rice yield) + (Pea yield x Price of Pea) / Price of Rice)

3.6.6 System productivity

Productivity of rice-pea cropping system was calculated in terms of rice equivalent yield (REY) by using following expression

System productivity = Rice yield + REY of Pea

3.7 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 (1976). ‘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:

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

Where, SEm± = Standard error mean

t0.05= Table value of students obtained at 5 % probability test.

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

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

The ANOVA are annexed under the appendices.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Effect of lime and INM and their interaction effects on growth attributes of rice

4.1.1 Plant height (cm)

The results presented in table 4.1(a) showed the effects of lime and INM on plant height (cm) and table 4.1(b) showed its interaction effects on plant height (cm) recorded at 30, 60, 90 DAS and at harvest for both the years of experimentation.

Lime

Between lime levels, plant height was influenced significantly at all stages of observations during both the years of experiment. It is indicated from the data that during 2016, higher value of plant height of (77.04 cm), (116.29 cm), (150.72 cm) and (161.69 cm) was recorded with the application of treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60, 90 DAS and at harvest respectively. Similarly during 2017, higher value of plant height of (77.86 cm), (116.33 cm), (152.27 cm) and (163.63 cm) was also recorded with the application of treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60, 90 DAS and at harvest, respectively. The pooled data also revealed a significant difference with the highest plant height recorded in treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest in treatment L_0 (without lime) at all stages of observations during both the years of experiment.

The increase in plant height in lime treated plots might be due to improvement of soil pH that accelerated the rate of decomposition and mineralization of nitrogen and increased nitrogen availability to the plants. Similarly, the positive influence of liming on crops to increase plant height in acidic soil is in conformity with the findings of Ferdous *et al*. (2018). However, the lowest plant height was recorded with treatment L_0 (without lime) at all stages of observation. Reduced plant height might be due to the toxic effect of Al and Mn which leads to stunting growth of plants in lime-untreated plots.

INM

The results pertaining to plant height due to different INM levels showed significant variation during both the years of experiment. During 2016, treatment N_2 (RDF @ 75% + FYM @ 6 t ha^{-1}) recorded the highest plant height of (79.59 cm), (119.05 cm), (153.26 cm) and (164.26 cm) at 30, 60, 90 DAS and at harvest, respectively. Similar trend of findings was also recorded during 2017, with the highest plant height of (79.79 cm), (119.31 cm), (154.50 cm) and (166.94 cm) at 30, 60, 90 DAS and at harvest respectively. The pooled data of both the years also revealed a significant difference with the highest plant height recorded in treatment N_2 (RDF @ 75% + FYM @ 6 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and the lowest in treatment N_0 (Control) at all stages of observations.

The increase in plant height might be due to reduced loss of nutrients by fixation of NH^{4+} ion with humus present in FYM and increased availability to crop which ultimately increased the plant height. Singh *et al.* (2018) reported that integration of 25 or 50 % FYM with 50 or 75% inorganic, release slow and continuous nutrients to the plant, and better soil physical environment which enhance the root growth leading to better uptake of water and nutrients from the soil and hence results in increased plant height. These findings are also in close agreement with those of Revathi *et al.* (2014) and Gangmei and George (2017).

Table 4.1(a) Effect of lime and integrated nutrient management on plant height (cm) at different growth stages of rice

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime												
L_0	71.37	72.70	72.04	110.14	110.98	110.56	137.52	139.44	138.48	146.68	148.34	147.51
L_1	77.04	77.86	77.45	116.29	116.33	116.31	150.72	152.27	151.50	161.69	163.63	162.66
SEm±	0.39	0.30	0.25	0.34	0.36	0.25	0.18	0.25	0.16	0.58	0.69	0.45
CD (P= 0.05)	1.16	0.90	0.71	1.02	1.08	0.71	0.55	0.75	0.45	1.74	2.06	1.30
INM												
N_0	64.28	65.41	64.84	102.45	101.34	101.89	121.38	123.08	122.23	130.68	131.04	130.86
N_1	75.15	76.91	76.03	114.81	115.69	115.25	147.89	149.99	148.94	156.74	158.73	157.74
N_2	79.59	79.79	79.69	119.05	119.31	119.18	153.26	154.50	153.88	164.26	166.94	165.60
N_3	75.08	76.27	75.67	113.07	114.73	113.90	147.00	148.83	147.92	159.03	158.84	158.93
N_4	76.95	78.03	77.49	116.71	117.23	116.97	151.10	152.89	151.99	160.23	164.38	162.31
SEm±	0.62	0.48	0.39	0.54	0.57	0.39	0.29	0.40	0.25	0.92	1.09	0.72
CD (P= 0.05)	1.84	1.43	1.12	1.61	1.70	1.13	0.87	1.19	0.71	2.74	3.25	2.05

Table 4.1(b) Interaction effects of lime and integrated nutrient management on plant height (cm) at different growth stages of rice

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM												
L_0N_0	61.38	61.85	61.62	100.00	100.02	100.01	114.25	115.75	115.00	120.28	119.32	119.80
L_0N_1	71.52	74.57	73.05	112.28	112.82	112.55	142.45	144.26	143.36	149.80	151.58	150.69
L_0N_2	78.40	78.42	78.41	116.72	117.12	116.92	146.92	149.00	147.96	157.46	161.86	159.66
L_0N_3	71.10	73.00	72.05	108.02	110.30	109.16	139.00	140.86	139.93	152.20	149.80	151.00
L_0N_4	74.45	75.68	75.07	113.70	114.65	114.18	145.00	147.35	146.18	153.68	159.15	156.41
L_1N_0	67.18	68.97	68.07	104.90	102.65	103.77	128.50	130.42	129.46	141.07	142.77	141.92
L_1N_1	78.78	79.25	79.01	117.35	118.56	117.96	153.32	155.72	154.52	163.68	165.88	164.78
L_1N_2	80.77	81.16	80.97	121.38	121.50	121.44	159.60	160.00	159.80	171.07	172.03	171.55
L_1N_3	79.05	79.54	79.30	118.12	119.16	118.64	155.00	156.80	155.90	165.86	167.87	166.86
L_1N_4	79.44	80.39	79.92	119.72	119.80	119.76	157.20	158.42	157.81	166.78	169.62	168.20
SEm±	0.88	0.68	0.55	0.76	0.81	0.56	0.41	0.56	0.35	1.31	1.55	1.01
CD (P= 0.05)	2.60	2.02	1.59	2.27	2.41	1.60	1.23	1.68	1.00	3.88	4.60	2.90

Interaction effects

The interaction effects between lime and INM on plant height was found to be significant at all stages of observation. The highest plant height of (80.77 cm), (81.16 cm) at 30 DAS, (121.38 cm), (121.50 cm) at 60 DAS, (159.60 cm) and (160.00 cm) at 90 DAS and (171.07 cm) and (172.03 cm) at harvest during first year and second year respectively was associated with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}, while the lowest plant height was recorded in L_0N_0 (Control). However, the interactions L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime@ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par. The pooled result of both the years also showed significantly higher plant height of (80.97), (121.44), (159.80) and (171.55 cm) at 30, 60, 90 DAS and at harvest respectively with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest plant height was recorded in L_0N_0 (control). Sahu *et al*. (2018) also found out that the half doses of RDF combined with FYM alone or with combination of lime and zinc sulphate resulted in significant increase in plant height as compared to control and remained at par with full doses of RDF.

4.1.2 Number of tillers running meter^{-1}

A perusal of the results pertaining to number of tillers running meter^{-1} as influenced by levels of lime and INM are presented in Table 4.2(a) and Table 4.2 (b) showed its interaction effects on number of tillers running meter^{-1} at 30, 60, 90 DAS and at harvest for both the years of experiment.

Lime

The results pertaining to number of tillers running meter^{-1} due to lime levels showed significant variation at all stages of observations during both the years of experiment. The maximum number of tillers running meter^{-1} (23.27), (31.20), (36.80) and (36.07) at 30, 60, 90 DAS and at harvest, respectively was recorded in treatment L_1 (Lime @ 2q ha^{-1}) and the minimum in L_0 (without lime) during the year 2016. Similar trend of findings was also recorded during 2017, with the maximum number of tillers running meter^{-1} (24.13), (32.20), (39.00) and (38.20) at 30, 60, 90 DAS and at harvest respectively and the minimum in L_0 (without lime). Pooled data of both the years also showed the significant difference with the maximum number of tillers running meter^{-1} in treatment L_1 as compared to treatment L_0 (without lime). The increase in number of tillers might be owing to increase in soil pH. These results supported the previous findings of Cifu *et al*. (2004) and Caires *et al.* (2006) that lime is effective in alleviating soil acidity.

INM

The results pertaining to number of tillers running meter^{-1} due to INM levels showed significant variation during both the years of experiment. The maximum number of tillers running meter^{-1} (24.17), (31.83), (36.50) and (36.17) at 30, 60, 90 DAS and at harvest respectively, was recorded during the first year with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). During the second year also recorded similar result with the maximum number of tillers running meter^{-1} (24.83), (32.83), (39.50) and (38.33) at 30, 60, 90 DAS and at harvest respectively with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years followed the similar findings with the highest number of tillers running meter^{-1} in treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). An application of balanced inorganic fertilizer with FYM in rice supply plant nutrients in adequate amount which resulted in increased photosynthetic activity of the plants and reflected in a significant increase in the number of tillers running meter^{-1}. This is in agreement with the findings of Guleria *et al*. (2018) which reported that FYM application gave maximum number of tillers over rest of the sources. Similar findings were reported by Puli *et al.* (2016). The treatments N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) were found to be statistically at par. The minimum was observed in N_0 (Control) for both the years.

Table 4.2(a) Effect of lime and integrated nutrient management on number of tillers running meter^{-1} at different growth stages of rice

Treatments	Number of tillers running meter^{-1}											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime												
L_0	21.13	21.73	21.43	27.87	28.33	28.10	31.93	33.20	32.57	31.47	32.00	31.73
L_1	23.27	24.13	23.70	31.20	32.20	31.70	36.80	39.00	37.90	36.07	38.20	37.13
SEm±	0.26	0.17	0.15	0.18	0.27	0.16	0.22	0.30	0.19	0.23	0.23	0.16
CD (P= 0.05)	0.76	0.50	0.44	0.53	0.79	0.46	0.65	0.89	0.53	0.69	0.68	0.47
INM												
N_0	17.00	18.17	17.58	23.67	24.17	23.92	27.67	29.17	28.42	27.17	27.33	27.25
N_1	23.17	23.50	23.33	30.50	31.00	30.75	36.00	36.33	36.17	35.17	35.67	35.42
N_2	24.17	24.83	24.50	31.83	32.83	32.33	36.50	39.50	38.00	36.17	38.33	37.25
N_3	23.00	23.67	23.33	30.17	31.00	30.58	35.83	37.50	36.67	35.00	36.67	35.83
N_4	23.67	24.50	24.08	31.50	32.33	31.92	35.83	38.00	36.92	35.33	37.50	36.42
SEm±	0.41	0.26	0.24	0.28	0.42	0.25	0.34	0.47	0.29	0.37	0.36	0.26
CD (P= 0.05)	1.21	0.78	0.69	0.84	1.25	0.73	1.02	1.41	0.84	1.09	1.08	0.74

Table 4.2(b) Interaction effects of lime and integrated nutrient management on number of tillers running meter^{-1} at different growth stages of rice

Treatments	Number of tillers running meter^{-1}											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM												
L_0N_0	14.67	15.33	15.00	20.00	20.33	20.17	23.00	22.67	22.83	22.33	20.00	21.17
L_0N_1	22.67	23.00	22.83	29.67	30.00	29.83	34.33	36.00	35.17	34.00	34.67	34.33
L_0N_2	23.33	24.00	23.67	30.67	31.67	31.17	34.67	37.67	36.17	34.33	36.33	35.33
L_0N_3	22.00	22.67	22.33	28.33	28.67	28.50	34.00	34.67	34.33	33.33	34.00	33.67
L_0N_4	23.00	23.67	23.33	30.67	31.00	30.83	33.67	35.00	34.33	33.33	35.00	34.17
L_1N_0	19.33	21.00	20.17	27.33	28.00	27.67	32.33	35.67	34.00	32.00	34.67	33.33
L_1N_1	23.67	24.00	23.83	31.33	32.00	31.67	37.67	36.67	37.17	36.33	36.67	36.50
L_1N_2	25.00	25.67	25.33	33.00	34.00	33.50	38.33	41.33	39.83	38.00	40.33	39.17
L_1N_3	24.00	24.67	24.33	32.00	33.33	32.67	37.67	40.33	39.00	36.67	39.33	38.00
L_1N_4	24.33	25.33	24.83	32.33	33.67	33.00	38.00	41.00	39.50	37.33	40.00	38.67
SEm±	0.57	0.37	0.34	0.40	0.60	0.36	0.49	0.67	0.41	0.52	0.51	0.37
CD (P= 0.05)	1.71	1.11	0.98	1.19	1.77	1.03	1.45	1.99	1.19	1.54	1.52	1.05

Interaction effects

The number of tillers running meter^{-1} varied significantly due to application of lime and INM at all stages of observations in both the years of experiment. The maximum number of tillers running meter^{-1} was associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} while the lowest value was recorded in L_0N_0 (Control). The pooled result of 2 years also showed significantly maximum number of tillers running meter^{-1} of (25.33), (33.50), (39.83) and (39.17) at 30, 60, 90 DAS and at harvest respectively with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) while the lowest was recorded in L_0N_0 (Control). It could be observed from the data that reclamation and management of soil acidity through lime and nutrient management in rice had significant effect on the number of tillers running meter^{-1}. This is in accordance with the findings of Ferdous *et al*. (2018). Sahu *et al*. (2018) also found out that the half doses of RDF combined with FYM alone or with combination of lime and zinc sulphate resulted in significant increase in number of tillers and effective tillers hill^{-1} as compare to control and remained at par with full dose of RDF.

4.1.3 Green leaf area (cm^2)

The data on green leaf area (cm^2) due to various treatments on lime and INM are presented in Table 4.3 and Table 4.3 also showed its interaction effects on green leaf area (cm^2) at 30, 60 and at 90 DAS for both the years of experimentation.

Lime

The variation in green leaf area (cm^2) due to liming showed significant results during both the years of experiment. During 2016, the maximum green leaf area (227.51 cm^2), (277.37cm^2) and (414.31 cm^2) was obtained from the treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60 and at 90 DAS respectively. Similar result was also during 2017 with the maximum green leaf area (230.20 cm^2), (280.07 cm^2) and (419.02 cm^2) recorded from the treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60 and at 90 DAS respectively. Pooled result thus obtained complied with the findings of both the years of experiment, with treatment L_1 (Lime @ 2 q ha^{-1}) showing the maximum green leaf area (cm^2) at all stages of observation as compared to treatment L_0 (without lime).

INM

The variation in green leaf area (cm^2) due to INM levels also showed significant results during both the years. During 2016, the maximum green leaf area (231.92 cm^2), (282.77 cm^2) and (414.83 cm^2) was recorded from the treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 and at 90 DAS respectively, which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and the lowest was recorded in control. During 2017 also, the maximum green leaf area (235.55 cm^2), (283.84 cm^2) and (417.58 cm^2) was recorded from the treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 and at 90 DAS respectively, which was at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and the lowest was recorded from control. Pooled data of both the years showed significant variation with similar trend of findings with the maximum green leaf area recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The available nutrients due to balance application of organic and chemical fertilizers resulted in higher uptake of nutrients by the plants which might have helped in enhancing more green leaf area. These results are supported by the findings of Swarup and Yaduvanshi (2000) and Krishnaprabu and Grace (2017).

Interaction effects

The interaction effects between lime and INM levels on green leaf area (cm^2) failed to show any significant variation during both the years of experiment at all stages of observation.

Table 4.3 Effect of lime and integrated nutrient management on green leaf area (cm^2) of rice at different growth stages

Treatments	Green leaf area (cm^2)								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime									
L_0	210.58	212.18	211.38	255.89	258.48	257.19	377.26	384.29	380.78
L_1	227.51	230.20	228.85	277.37	280.07	278.72	414.31	419.02	416.66
SEm±	2.54	3.52	2.17	2.27	2.82	1.81	2.82	3.33	2.18
CD (P= 0.05)	7.55	10.45	6.22	6.75	8.37	5.19	8.37	9.91	6.26
INM									
N_0	196.47	198.86	197.67	246.05	246.16	246.11	360.89	366.03	363.46
N_1	222.16	224.39	223.28	266.50	272.60	269.55	402.82	410.74	406.78
N_2	231.92	235.55	233.73	282.77	283.84	283.31	414.83	417.58	416.20
N_3	221.15	220.61	220.88	266.29	269.97	268.13	397.51	404.40	400.96
N_4	223.54	226.55	225.04	271.54	273.82	272.68	402.86	409.54	406.20
SEm±	4.02	5.56	3.43	3.59	4.46	2.86	4.45	5.27	3.45
CD (P= 0.05)	11.94	16.52	9.84	10.67	13.24	8.21	13.23	15.67	9.90
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.4 Leaf Area Index (LAI)

Table 4.4 showed the effects of lime and INM levels on leaf area index at 30, 60 and at 90 DAS for both the years of experimentation.

Lime

The variation in leaf area index due to lime levels was found to be significant during both the years of experiment at all stages of observation. Significantly lower leaf area index was recorded at 30, 60 and at 90 DAS with treatment L_0 (without lime) in both the years. During 2016, the highest leaf area index (1.13), (1.38) and (2.07) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60 and at 90 DAS respectively. Similar trend of result was also recorded during 2017 with treatment L_1 (Lime @ 2 q ha^{-1}) showing higher leaf area index (1.14), (1.40) and (2.10) at 30, 60 and at 90 DAS respectively. Pooled data of both the years also showed a significant variation with treatment L_1 (Lime @ 2 q ha^{-1}) showing higher leaf area index over L_0 (without lime). Singh *et al*. (2016) also reported that liming registered significantly higher leaf area index than those of control at all growth stages.

INM

The effects of INM levels on leaf area index were found to be significant during both the years of experiment. The highest leaf area index (1.15), (1.41) and (2.07) during the year 2016 was recorded with treatment N_2 RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 and at 90 DAS respectively, which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and the lowest was recorded in N_0 (Control). The results obtained during 2017 complied with the findings of the year 2016 with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) showing the highest value (1.17), (1.42) and (2.09) at 30, 60 and 90 DAS respectively and the lowest was recorded in N_0 (Control). Pooled result also showed variation with the highest leaf area index recorded with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at all stages and the lowest was recorded in N_0 (Control). Adequate supply of nitrogen through application of 75% RDF along

Table 4.4 Effect of lime and integrated nutrient management on Leaf Area Index (LAI) at different stages of crop growth

Treatments	Leaf Area Index								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime									
L_0	1.05	1.05	1.05	1.28	1.29	1.29	1.89	1.92	1.90
L_1	1.13	1.14	1.14	1.38	1.40	1.39	2.07	2.10	2.08
SEm±	0.013	0.018	0.011	0.011	0.014	0.009	0.01	0.02	0.01
CD (P= 0.05)	0.038	0.052	0.031	0.034	0.042	0.026	0.04	0.05	0.03
INM									
N_0	0.98	0.99	0.98	1.23	1.23	1.23	1.80	1.83	1.82
N_1	1.10	1.11	1.11	1.33	1.36	1.35	2.01	2.06	2.03
N_2	1.15	1.17	1.16	1.41	1.42	1.42	2.07	2.09	2.08
N_3	1.10	1.10	1.10	1.33	1.35	1.34	1.99	2.02	2.00
N_4	1.11	1.13	1.12	1.36	1.37	1.36	2.02	2.05	2.03
SEm±	0.020	0.028	0.017	0.018	0.022	0.014	0.02	0.03	0.02
CD (P= 0.05)	0.060	0.083	0.049	0.054	0.066	0.041	0.07	0.08	0.05
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

with 25% N through FYM produced larger leaves which in turn, resulted more photosynthetic surface area *i.e.* LAI. Kadarrv *et al*. (2010) also reported similar findings that application of 75% RDF along with 25% N through manure at 30 and 60 days after sowing recorded significantly higher LAI.

Interaction effects

The interaction effects between lime and INM levels on leaf area index were found to be non-significant during both the years of experiment at all stages of observation.

4.1.5 Shoot dry weight (g plant^{-1})

The data on shoot dry weight (g plant^{-1}) due to various treatment on lime and INM levels are presented in Table 4.5(a) and Table 4.5(b) showed its interaction effects on shoot dry weight (g plant^{-1}) at 30, 60, 90 DAS and at harvest.

Lime

The variation on shoot dry weight (g plant^{-1}) due to lime levels was found to be significant during both the years of experiment at all stages of observation. The highest shoot dry weight (1.66 g plant^{-1}), (12.49 g plant^{-1}), (27.16 g plant^{-1}) and (35.62 g plant^{-1}) observed in treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60, 90 DAS and at harvest respectively as compared to treatment L_0 (without lime) during 2016. During 2017, significant result was recorded with treatment L_1 (Lime @ 2 q ha^{-1}) giving the maximum shoot dry weight (1.69 g plant^{-1}), (13.42 g plant^{-1}), (28.91 g plant^{-1}) and (36.77 g plant^{-1}) over treatment L_0 (without lime). Pooled data of both the years also recorded higher shoot dry weight in treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60, 90 DAS and at harvest respectively as compared to treatment L_0 (without lime). These increments related to the increase in soil fertility and reduction of the toxic Al concentration which improves plant growth. Seng *et al*. (2006) reported that shoot dry matter responded strongly to lime application as the increase in shoot

Table 4.5(a) Effect of lime and integrated nutrient management on shoot dry weight (g plant^{-1}) at different growth stages of rice

Treatments	Shoot dry weight (g plant^{-1})											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime												
L_0	1.25	1.28	1.27	10.24	10.69	10.46	21.58	22.67	22.12	29.15	30.16	29.65
L_1	1.66	1.69	1.67	12.49	13.42	12.96	27.16	28.91	28.04	35.62	36.77	36.19
SEm±	0.01	0.01	0.01	0.24	0.29	0.19	0.45	0.32	0.28	0.45	0.54	0.35
CD (P= 0.05)	0.04	0.04	0.03	0.72	0.87	0.55	1.32	0.96	0.79	1.35	1.59	1.01
INM												
N_0	0.98	1.00	0.99	8.48	8.57	8.53	19.00	19.34	19.17	26.36	25.71	26.03
N_1	1.40	1.45	1.43	11.71	12.31	12.01	24.83	26.48	25.66	32.52	33.16	32.84
N_2	1.73	1.74	1.74	12.55	13.44	13.00	26.20	28.19	27.19	35.64	37.04	36.34
N_3	1.55	1.58	1.56	11.87	12.52	12.19	25.55	26.90	26.22	33.90	36.55	35.22
N_4	1.62	1.65	1.64	12.22	13.43	12.83	26.27	28.05	27.16	33.50	34.87	34.18
SEm±	0.02	0.02	0.02	0.38	0.46	0.30	0.70	0.51	0.44	0.72	0.85	0.55
CD (P= 0.05)	0.07	0.07	0.05	1.14	1.37	0.86	2.09	1.52	1.25	2.13	2.51	1.59

dry matter of rice with lime was associated from better availability of nutrients due to moderation of soil reaction and an increase in plant uptake.

INM

The results pertaining to shoot dry weight (g plant^{-1}) due to different INM levels during both the years of experiment were found to be significant. The highest shoot dry weight (1.73 g plant^{-1}), (12.55 g plant^{-1}), (35.64 g plant^{-1}) during the year 2016 was recorded with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 DAS and at harvest, while treatment N_4 (RDF (75%) + *Azospirillim* + PSB) recorded the highest shoot dry weight (26.27 g plant^{-1}) at 90 DAS followed by N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest was recorded in N_0 (Control). The following year also recorded similar findings with the highest shoot dry weight (1.74 g plant^{-1}), (13.44 g plant^{-1}), (28.19 g plant^{-1}) and (37.04 g plant^{-1}) with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years recorded the highest shoot dry weight (1.74 g plant^{-1}), (13.00 g plant^{-1}), (27.19 g plant^{-1}) and (36.34 g plant^{-1}) at 30, 60, 90 DAS and at harvest respectively with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). According to the results obtained, combination of FYM along with inorganic fertilizers achieved significantly highest shoot dry weight which could be owing to better physiological growth of plants as an addition of organic matter from FYM increased the moisture holding capacity, improved nutrient cycling and helps to maintain soil nutrient status, cation exchange capacity (CEC) and soil's biological activity and improved soil physical properties. These findings were supported by Dobermann and Fairhust (2000) and Naing *et al*. (2010).

Interaction effects

The interaction effects between lime and INM levels on shoot dry weight (g plant^{-1}) were found significant in both years of experimentation at various stages of observation. During 2016, the highest shoot dry weight (1.92 g plant^{-1}), (13.40 g plant^{-1}), (38.92 g plant^{-1}) was associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 DAS and at

Table 4.5(b) Interaction effects of lime and integrated nutrient management on shoot dry weight (g plant^{-1}) at different growth stages of rice

Treatments	Shoot dry weight (g plant^{-1})											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM												
L_0N_0	0.73	0.76	0.75	6.17	6.12	6.14	13.29	13.56	13.43	20.95	19.26	20.11
L_0N_1	1.28	1.30	1.29	11.17	11.79	11.48	23.48	24.90	24.19	30.73	30.42	30.58
L_0N_2	1.54	1.55	1.55	11.70	12.20	11.95	24.12	25.64	24.88	32.35	34.43	33.39
L_0N_3	1.33	1.35	1.34	10.94	11.25	11.09	22.97	23.88	23.43	31.33	35.37	33.35
L_0N_4	1.38	1.42	1.40	11.22	12.09	11.66	24.02	25.38	24.70	30.37	31.32	30.84
L_1N_0	1.23	1.24	1.24	10.80	11.02	10.91	24.70	25.12	24.91	31.76	32.15	31.96
L_1N_1	1.52	1.60	1.56	12.25	12.82	12.54	26.18	28.07	27.13	34.32	35.89	35.10
L_1N_2	1.92	1.93	1.93	13.40	14.69	14.04	28.28	30.74	29.51	38.92	39.65	39.28
L_1N_3	1.76	1.80	1.78	12.80	13.79	13.30	28.12	29.92	29.02	36.47	37.72	37.10
L_1N_4	1.85	1.88	1.87	13.22	14.76	13.99	28.52	30.72	29.62	36.62	38.41	37.52
SEm±	0.03	0.03	0.02	0.54	0.65	0.42	1.00	0.72	0.62	1.01	1.20	0.78
CD (P= 0.05)	0.09	NS	0.06	1.61	NS	1.22	2.96	2.15	1.77	3.01	3.55	2.25

harvest, which was statistically at par with interaction L_1N_4 (Lime @ 2 q ha^{-1} RDF (75%) + *Azospirillim* + PSB), while the lowest was recorded from interaction L_0N_0 (control). At 90 DAS, the highest shoot dry weight (28.52 g plant^{-1}) was recorded from L_1N_4 (Lime @ 2 q ha^{-1} RDF (75%) + *Azospirillim* + PSB) which was statistically at par with (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in L_0N_0 (Control). During 2017, the highest shoot dry weight (1.93 g plant^{-1}), (30.74 g plant^{-1}), (39.65 g plant^{-1}) was associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 90 DAS and at harvest while at 60 DAS, treatment L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) recorded the highest (14.76 g plant^{-1}). The pooled data of both the years recorded the highest shoot dry weight with treatment interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) followed by interaction L_1N_4 (Lime @ 2 q ha^{-1} RDF (75%) + *Azospirillim* + PSB). The findings of the present investigation are in agreement with Weng *et al*. (1982) and Tanaka (1983).

4.1.6 Crop Growth Rate (g m^{-2} day^{-1})

The data on crop growth rate (g m^{-2} day^{-1}) due to different levels of lime and INM are presented in Table 4.6(a) and Table 4.6(b) showed its interaction effects on crop growth rate at 30, 60, 90 DAS and at harvest.

Lime

The variations on crop growth rate due to lime levels were found to be significant at 30-60 DAS and 60-90 DAS except at 90 DAS-harvest which showed non-significant effects during both years of experiment. During 2016, treatment L_1 (Lime @ 2 q ha^{-1}) showed the highest crop growth rate (18.06 g m^{-2} day^{-1}) and (22.13 g m^{-2} day^{-1}) at (30-60) DAS and (60-90) DAS respectively. Pooled result of both the years thus obtained showed a significant variation with the highest growth rate (18.44 g m^{-2} day^{-1}) and (24.14 g m^{-2} day^{-1}) at (30-60) DAS and (60-90) DAS respectively from treatment L_1 (Lime @ 2 q ha^{-1}) over L_0 (without lime). The remarkable increase in crop growth

Table 4.6(a) Effect of lime and integrated nutrient management on Crop Growth Rate (g $m^{-2}day^{-1}$)

Treatments	Crop Growth Rate (g m^{-2} day^{-1})								
	30-60 DAS			60-90 DAS			90 DAS- harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime									
L_0	14.98	15.29	15.13	18.15	19.95	19.05	10.88	11.01	10.94
L_1	18.06	18.83	18.44	22.13	26.15	24.14	12.44	11.33	11.88
SEm±	0.41	0.57	0.35	1.10	0.94	0.72	0.90	0.82	0.61
CD (P= 0.05)	1.22	1.71	1.01	3.27	2.80	2.08	NS	NS	NS
INM									
N_0	12.50	12.62	12.56	17.52	17.96	17.74	10.83	8.82	9.82
N_1	17.18	17.10	17.14	20.51	23.78	22.14	11.31	9.81	10.56
N_2	18.03	19.50	18.77	21.03	24.02	22.53	13.87	13.02	13.45
N_3	17.21	18.24	17.72	21.09	23.97	22.53	12.29	14.19	13.24
N_4	17.68	17.84	17.76	20.54	25.54	23.04	9.99	10.02	10.00
SEm±	0.65	0.91	0.56	1.74	1.49	1.14	1.43	1.30	0.97
CD (P= 0.05)	1.93	2.70	1.60	NS	4.42	3.28	NS	3.87	NS

Table 4.6(b) Interaction effects of lime and integrated nutrient management on Crop Growth Rate (g m^{-2} day^{-1})

Treatments	Crop Growth Rate (g m^{-2} day^{-1})								
	30-60 DAS			60-90 DAS			90 DAS-harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM									
L_0N_0	9.06	8.93	9.00	11.87	12.41	12.14	11.27	8.39	9.83
L_0N_1	16.48	15.50	15.99	20.52	21.85	21.19	10.66	8.12	9.39
L_0N_2	16.94	17.74	17.34	20.70	22.30	21.50	12.11	12.93	12.52
L_0N_3	16.01	16.49	16.25	20.06	21.05	20.56	12.30	16.89	14.59
L_0N_4	16.40	17.78	17.09	17.58	22.15	19.87	8.06	8.73	8.39
L_1N_0	15.95	16.30	16.13	23.17	23.51	23.34	10.38	9.24	9.81
L_1N_1	17.88	18.71	18.29	20.49	25.71	23.10	11.96	11.50	11.73
L_1N_2	19.13	21.26	20.19	21.36	25.75	23.55	15.64	13.11	14.37
L_1N_3	18.41	19.98	19.20	22.12	26.88	24.50	12.28	11.48	11.88
L_1N_4	18.95	17.89	18.42	23.50	28.92	26.21	11.91	11.32	11.62
SEm±	0.92	1.28	0.79	2.46	2.11	1.62	2.02	1.84	1.37
CD (P= 0.05)	NS	NS	2.27	NS	NS	NS	NS	NS	NS

rate with liming resulted from better uptake of nutrients due to better availability of nutrients. Similar results also reported by Lynrah and Nongmaithem (2017).

INM

The effects of INM levels on crop growth rate showed varied variations during both the years of experiment. During 2016, the highest crop growth rate (18.03 g m^{-2} day^{-1}) and (13.87 g m^{-2} day^{-1}) was recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30-60 DAS and at 90 DAS–harvest and highest crop growth rate (21.09 g m^{-2} day^{-1}) in treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) at 60-90 DAS. The following year, highest crop growth rate was recorded by treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30-60 DAS, N_4 (RDF (75%) + *Azospirillim* + PSB) at 60-90 DAS and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) at 90 DAS- harvest. Pooled data of both the years also showed significant variations with the highest crop growth rate recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30-60 DAS and 90 DAS-harvest while N_4 (RDF (75%) + *Azospirillim* + PSB) recorded highest at 60-90 DAS and the lowest observed in N_0 (Control). The higher crop growth rate is because of higher values of Leaf area index (LAI). Similar findings were reported by Mia and Shamsuddin (2011).

Interaction effects

The interaction effects between lime and INM levels on crop growth rate was found non-significant during both the years of experimentation at various stages of observation.

4.1.7 Relative Growth Rate (g g^{-1} day^{-1})

The result presented in Table 4.7 showed the effects of lime and INM levels on relative growth rate (g g^{-1} day^{-1}) at (30-60 DAS), (60-90 DAS) and (90 DAS- harvest).

Table 4.7 Effect of lime and integrated nutrient management on Relative Growth Rate (g $g^{-1}day^{-1}$)

Treatments	Relative Growth Rate (g $g^{-1}day^{-1}$)								
	30 to 60 DAS			60 to 90 DAS			90 DAS to harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime									
L_0	0.070	0.071	0.070	0.025	0.025	0.025	0.009	0.008	0.009
L_1	0.068	0.069	0.068	0.026	0.027	0.026	0.008	0.007	0.007
SEm±	0.001	0.001	0.001	0.001	0.002	0.001	0.0007	0.0005	0.0004
CD (P= 0.05)	NS	NS	0.002	NS	NS	NS	NS	NS	NS
INM									
N_0	0.072	0.071	0.071	0.027	0.027	0.027	0.011	0.009	0.010
N_1	0.071	0.071	0.071	0.025	0.029	0.027	0.008	0.007	0.007
N_2	0.066	0.068	0.067	0.025	0.025	0.025	0.009	0.008	0.008
N_3	0.068	0.069	0.069	0.025	0.025	0.025	0.008	0.009	0.009
N_4	0.068	0.068	0.068	0.025	0.024	0.025	0.007	0.007	0.007
SEm±	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.0008	0.0007
CD (P= 0.05)	NS	NS	0.003	NS	NS	NS	NS	NS	NS
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

Lime

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

INM

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

Interaction effects

The interaction effects between lime and INM levels on relative growth rate failed to show any significant variation during both the years at all stages of observation.

4.1.8 Dry matter (g)

The result presented in Table 4.8(a) showed the effects of lime and INM levels on dry matter (g) plant^{-1} and Table 4.8(b) showed its interaction on dry matter (g) plant^{-1} at 30, 60, 90 DAS and at harvest.

Lime

The variation on dry matter due to lime levels was found to be significant during both the years of experiment at all stages of observation. In the first year, the highest dry matter (1.99 g), (13.45 g), (30.74 g) and (41.51 g) at 30, 60, 90 DAS and at harvest respectively was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). Also during 2017, the highest dry matter (1.98 g), (14.36 g), (30.71 g), (42.62 g) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). Pooled data also recorded similar trend of findings with the highest dry matter recorded in treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). The increase in soil fertility and reduction of phytotoxic levels of Al by liming enhanced vegetative growth of rice which resulted in increased dry biomass yield. Similar results reported by Ameyu (2019).

Table 4.8(a) Effect of lime and integrated nutrient management on dry matter (g) plant^{-1} at different stages of crop growth

Treatments	Dry matter (g)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime												
L_0	1.49	1.47	1.48	10.98	11.45	11.21	23.73	23.89	23.81	33.78	34.80	34.29
L_1	1.99	1.98	1.98	13.45	14.36	13.91	30.74	30.71	30.73	41.51	42.62	42.07
SEm±	0.02	0.02	0.01	0.25	0.30	0.19	0.44	0.42	0.30	0.52	0.59	0.39
CD (P= 0.05)	0.07	0.05	0.04	0.74	0.89	0.56	1.29	1.26	0.87	1.56	1.75	1.13
INM												
N_0	1.22	1.15	1.19	9.02	9.10	9.06	20.90	21.02	20.96	30.62	29.82	30.22
N_1	1.70	1.73	1.71	12.63	13.22	12.92	27.76	27.82	27.79	38.26	38.46	38.36
N_2	2.00	2.01	2.00	13.56	14.46	14.01	29.09	29.13	29.11	41.11	42.55	41.83
N_3	1.86	1.86	1.86	12.73	13.40	13.06	28.37	28.22	28.29	39.55	42.57	41.06
N_4	1.91	1.89	1.90	13.12	14.36	13.74	30.05	30.34	30.19	38.69	40.16	39.42
SEm±	0.04	0.03	0.02	0.39	0.47	0.31	0.69	0.67	0.48	0.83	0.93	0.62
CD (P= 0.05)	0.11	0.08	0.07	1.17	1.40	0.88	2.04	1.99	1.38	2.46	2.76	1.79

INM

The variations on dry matter during both the years of experiment were found to be significant. During 2016, the highest dry matter (2.00 g), (13.56 g), (41.11 g) was recorded in treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 and at harvest respectively. However at 90 DAS, the highest dry matter recorded in N_4 (RDF (75%) + *Azospirillim* + PSB) which was statistically at par with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Similar findings recorded during 2017 as well as pooled data of both the years. The greater LAI, plant height, macro and micronutrients availability due to supply of nutrients through application of inorganic fertilizer with FYM in suitable proportions might have resulted in a significant increase in dry matter accumulation at all stages of rice crop. Priyanka *et al.* (2013) reported results in line with the above observation. Tiwari *et al*. (2020) also reported that the progressive increase in dry matter production with NPK levels incorporated with FYM might be due to increased in plant height, leaf area and leaf area index which are indicator of higher chlorophyll content per unit leaf area improving accumulation of nutrients which in turn resulted in higher dry matter accumulation of plants.

Interaction effects

The interaction effects between lime and INM levels were found to be non-significant at 30 DAS during both the years of experiment. During 2016 and 2017, the highest dry matter was associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 and at harvest respectively. However, the highest dry matter (33.83 g), (33.89 g) was associated with the interaction L_1N_4 (Lime @ 2 q ha^{-1} RDF (75%) + *Azospirillim* + PSB) at 90 DAS during 2016 and 2017 respectively which was statistically at par with L_1N_2 (Lime @ 2q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in L_0N_0 (Control). The higher LAI and leaf area resulted in higher dry matter production. The increase in total dry matter depends on the leaf area production as reported by Weng *et al*. (1982) and Tanaka (1983).

Table 4.8(b) Interaction effects of lime and integrated nutrient management on dry matter (g) plant^{-1} at different stages of crop growth

Treatments	Dry matter (g)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM												
L_0N_0	0.980	0.883	0.932	6.57	6.50	6.54	15.00	15.12	15.06	24.91	23.10	24.01
L_0N_1	1.53	1.52	1.53	12.05	12.69	12.37	25.64	25.80	25.72	35.93	34.74	35.33
L_0N_2	1.76	1.74	1.75	12.63	13.11	12.87	26.38	26.40	26.39	37.06	39.17	38.12
L_0N_3	1.58	1.58	1.58	11.69	12.05	11.87	25.35	25.37	25.36	36.35	41.36	38.86
L_0N_4	1.61	1.62	1.62	11.96	12.88	12.42	26.26	26.78	26.52	34.65	35.61	35.13
L_1N_0	1.47	1.42	1.44	11.47	11.69	11.58	26.80	26.91	26.86	36.33	36.53	36.43
L_1N_1	1.87	1.93	1.90	13.20	13.75	13.47	29.88	29.84	29.86	40.59	42.17	41.38
L_1N_2	2.23	2.27	2.25	14.50	15.82	15.16	31.80	31.86	31.83	45.16	45.92	45.54
L_1N_3	2.14	2.13	2.13	13.77	14.74	14.26	31.38	31.07	31.23	42.74	43.79	43.26
L_1N_4	2.21	2.15	2.18	14.29	15.83	15.06	33.83	33.89	33.86	42.72	44.71	43.72
SEm±	0.05	0.04	0.03	0.56	0.67	0.43	0.97	0.95	0.68	1.17	1.31	0.88
CD (P= 0.05)	NS	NS	NS	1.65	NS	1.25	2.89	2.82	1.95	NS	3.91	2.53

4.2 Effect of lime and INM and their interaction effects on yield attributes of rice

The data on yield attributes *viz*. number of panicles m^{-2}, length of panicle (cm), number of filled grains $panicle^{-1}$, filled grain percentage (%) and test weight (g) due to effects of lime and INM recorded during 2016 and 2017 are presented in Table 4.9(a) along with Fig 4.1 and 4.2 while their interaction effects are given in table 4.9(b). Finally grain yield (q ha^{-1}), straw yield (q ha^{-1}) and harvest index (%) due to the effects of lime and INM are given in Table 4.10(a) while their interaction effects are given in Table 4.10(b). Fig 4.3(a) and 4.3(b) shows the effects of lime and INM and their interaction effects on grain yield.

4.2.1 Number of panicles m^{-2}

Lime

The variation on number of panicles m^{-2} due to lime application was found to be significant during both years of experiment. During 2016 and 2017, the highest number of panicles m^{-2} (224.67) and (232.33) was recorded with the treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). Pooled result thus obtained recorded the highest number of panicles (228.50) with treatment L_1 (Lime @ 2 q ha^{-1}). The significant increase in number of panicles m^{-2} was probably owing to improvement of acid soil by liming. Slattery and Conventry (1993) and Moody *et al*. (1995) reported that liming has been suggested as the most efficient and effective practice to maintain a desirable soil pH for the growth of panicles.

INM

The variation on number of panicles m^{-2} due to variation in INM levels showed significant variation. The highest number of panicles m^{-2} (229.00) during 2016 was recorded with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}). During 2017, the highest number of panicles m^{-2} (238.00) during 2017 was recorded with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}), while N_0 (Control) recorded the lowest number of panicles m^{-2}. Pooled result thus obtained complied with the findings of both the years. The highest number of panicles m^{-2} (233.50) was recorded with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}). Increase in panicles m^{-2} through FYM was supported by Mirza *et al*. (2005), Barik *et al*. (2006) and Revathi *et al*. (2014).

Interaction effects

The interaction effects between lime and INM levels on number of panicles m^{-2} recorded non-significant variation during both the years of experimentation.

4.2.2 Length of panicle (cm)

Lime

The results revealed that different liming rates had non-significant effect on panicle length during both the years of experiment.

INM

Variations on length of panicle due to INM levels were found to be significant during both the years of experiment. The longest panicle (26.63 cm) during 2016 was recorded with the treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Treatment N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) were found to be at par, while the shortest panicle (23.67 cm) was recorded with treatment N_0 (Control). During the second year 2017, the longest panicle length (27.18 cm) was recorded by the same treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the shortest recorded with treatment N_0 (Control). Pooled result thus obtained also recorded the longest panicle length with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}), while treatment N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) were found to be statistically at par. Arif *et al*. (2014) reported that balanced supply of nutrients enhanced panicle length which might be due to more availability of macro as well as micronutrients.

Interaction effects

The treatment interaction of lime and INM levels on length of panicle was found to be non-significant during both the years of experiment.

4.2.3 Number of filled grains panicle^{-1}

Lime

The variation on number of filled grains panicle^{-1} due to lime levels showed significant variation during both the years of experiment. The highest number of filled grains panicle^{-1} (127.22) and (128.69) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) during 2016 and 2017 respectively. Pooled result thus obtained shows that the highest number of filled grains panicle^{-1} (127.96) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) while the lowest was recorded with treatment L_0 (without lime). These results clearly indicate that lime application has positive effects on filled grain panicle^{-1} which eventually reflected in higher yield. These observations are in consonance with the findings of Ferdous *et al*. (2018).

INM

The mean data of number of filled grains panicle^{-1} showed a significant variation due to application of different INM levels. The highest number of filled grains panicle^{-1} (128.22) during 2016 was recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was statistically at par with treatment N_4 (RDF (75%) + *Azospirillim* + PSB). During 2017, the highest number of filled grains panicle^{-1} (129.57) recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB), while treatment N_0 (Control) recorded the lowest number of filled grains panicle^{-1} during both the years. Pooled result thus obtained depicts that the highest number of filled grains panicle^{-1} (128.90) was recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was statistically at par with treatment N_4 (RDF (75%) + *Azospirillim* + PSB). The reason for maximum number of filled grains panicle^{-1} may be owing to balanced addition of FYM with inorganic fertilizers which provide K in adequate amounts. K significantly increases the number of filled spikelets panicle^{-1} (Dobermann & Fairhurst 2000; Bahmaniar *et al*. 2007). The findings of the present 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 which in turn increases the number of filled grains panicle^{-1}.

Interaction effects

The interaction effect between lime and INM during 2017 failed to show any significant variation on the number of filled grains panicle^{-1}. During 2016, the highest number of filled grains panicle^{-1} (133.40) with interaction L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) which was statistically at par with L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). Pooled result thus obtained complied with the findings of both the years giving the highest number of filled grains panicle^{-1} (134.65) observed from the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) followed by L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB). Ferdous *et al.* (2018) also reported similar findings that the highest number of spikelets panicle^{-1} (136.1) observed from the combination of lime and fertilizer treatment.

4.2.4 Filled grain percentage (%)

Lime

The variation on filled grain percentage (%) due to lime levels reported significant variation during both the years of experiment. During the year 2016 and 2017, lime significantly recorded the highest filled grain percentage over no lime. Pooled data of both the years followed the same trend of finding with treatment L_1 (Lime @ 2 q ha^{-1}) significantly giving the highest filled grain percentage (87.81 %). The highest filled grain percentage recorded in lime treated plots may be due to lowest partially filled and unfilled grains. The results were further supported by Puteh *et al*. (2014).

INM

The variation on filled grain percentage (%) due to different nutrient doses also recorded significant variation. During the year 2016, treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded significantly highest filled grain percentage (88.78 %) which was statistically at par with N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) while control showed the lowest filled grain percentage. During the year 2017, treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) also recorded significantly higher filled grain percentage (89.42 %) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB). Pooled data thus obtained complied with the finding of the two year experiment where N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) significantly recorded the highest filled grain percentage (89.10 %), which was followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) while control recorded the lowest filled grain percentage. These results indicate that proper partitioning might have occurred from source to sink and as a result the filled grain percentage has improved. This finding is in corroboration with the finding of Ramesh *et al*. (2005).

Table 4.9(a) Effect of lime and integrated nutrient management on yield attributes of rice

Treatments	Number of panicles m^{-2}			Length of panicle (cm)			Number of filled grains $panicle^{-1}$			Filled grain percentage (%)			Test weight (g)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime															
L_0	199.35	202.00	200.67	25.43	25.52	25.47	112.05	114.61	113.33	85.26	85.44	85.35	29.81	30.63	30.22
L_1	224.67	232.33	228.50	25.72	26.36	26.04	127.22	128.69	127.96	87.81	87.81	87.81	31.74	32.26	32.00
SEm±	3.91	4.86	3.12	0.32	0.39	0.25	1.10	1.01	0.75	0.34	0.68	0.38	0.66	0.74	0.50
CD (P= 0.05)	11.61	14.45	8.95	NS	NS	NS	3.26	3.00	2.14	1.00	2.02	1.09	NS	NS	NS
INM															
N_0	162.17	164.17	163.17	23.67	24.04	23.85	92.43	95.17	93.80	80.98	81.33	81.15	28.89	29.21	29.05
N_1	217.03	218.33	217.68	25.42	25.79	25.61	123.00	126.08	124.54	86.97	85.68	86.33	30.70	31.26	30.98
N_2	229.00	238.00	233.50	26.63	27.18	26.91	128.22	129.57	128.90	88.78	89.42	89.10	31.55	32.61	32.08
N_3	223.33	229.17	226.25	25.77	25.99	25.88	126.83	128.92	127.88	88.30	88.22	88.26	31.81	31.85	31.83
N_4	228.50	236.17	232.33	26.41	26.70	26.55	127.70	128.50	128.10	87.65	88.47	88.06	30.93	32.28	31.60
SEm±	6.18	7.69	4.93	0.51	0.61	0.40	1.73	1.60	1.18	0.53	1.07	0.60	1.05	1.17	0.79
CD (P= 0.05)	18.36	22.84	14.15	1.52	1.81	1.14	5.15	4.75	3.38	1.59	3.19	1.72	NS	NS	NS

Table 4.9(b) Interaction effects of lime and integrated nutrient management on yield attributes of rice

Treatments	Number of panicles m^{-2}			Length of panicle (cm)			Number of filled grains $panicle^{-1}$			Filled grains percentage (%)			Test weight (g)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM															
L_0N_0	134.00	129.67	131.83	23.50	23.54	23.52	79.46	83.55	81.51	79.10	78.86	78.98	28.20	28.47	28.33
L_0N_1	206.40	201.67	204.03	24.75	25.03	24.89	114.22	119.67	116.94	85.38	84.88	85.13	30.02	30.29	30.16
L_0N_2	218.00	227.67	222.83	26.70	26.64	26.67	123.11	123.18	123.15	87.74	88.19	87.97	30.62	31.98	31.30
L_0N_3	217.00	221.33	219.17	26.00	26.04	26.02	121.44	124.30	122.87	87.40	87.19	87.29	30.76	30.86	30.81
L_0N_4	221.33	229.67	225.50	26.22	26.33	26.27	122.00	122.34	122.17	86.70	88.10	87.40	29.46	31.53	30.50
L_1N_0	190.33	198.67	194.50	23.84	24.53	24.19	105.39	106.80	106.09	82.85	83.80	83.33	29.58	29.94	29.76
L_1N_1	227.67	235.00	231.33	26.09	26.55	26.32	131.78	132.49	132.13	88.57	86.48	87.52	31.38	32.23	31.80
L_1N_2	240.00	248.33	244.17	26.55	27.73	27.14	133.33	135.97	134.65	89.82	90.66	90.24	32.48	33.24	32.86
L_1N_3	229.67	237.00	233.33	25.55	25.94	25.74	132.22	133.54	132.88	89.20	89.26	89.23	32.86	32.85	32.85
L_1N_4	235.67	242.67	239.17	26.59	27.08	26.84	133.40	134.66	134.03	88.61	88.85	88.73	32.39	33.02	32.71
SEm±	8.74	10.87	6.97	0.72	0.86	0.56	2.45	2.26	1.67	0.76	1.52	0.85	1.48	1.66	1.11
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	7.28	NS	4.78	NS	NS	NS	NS	NS	NS

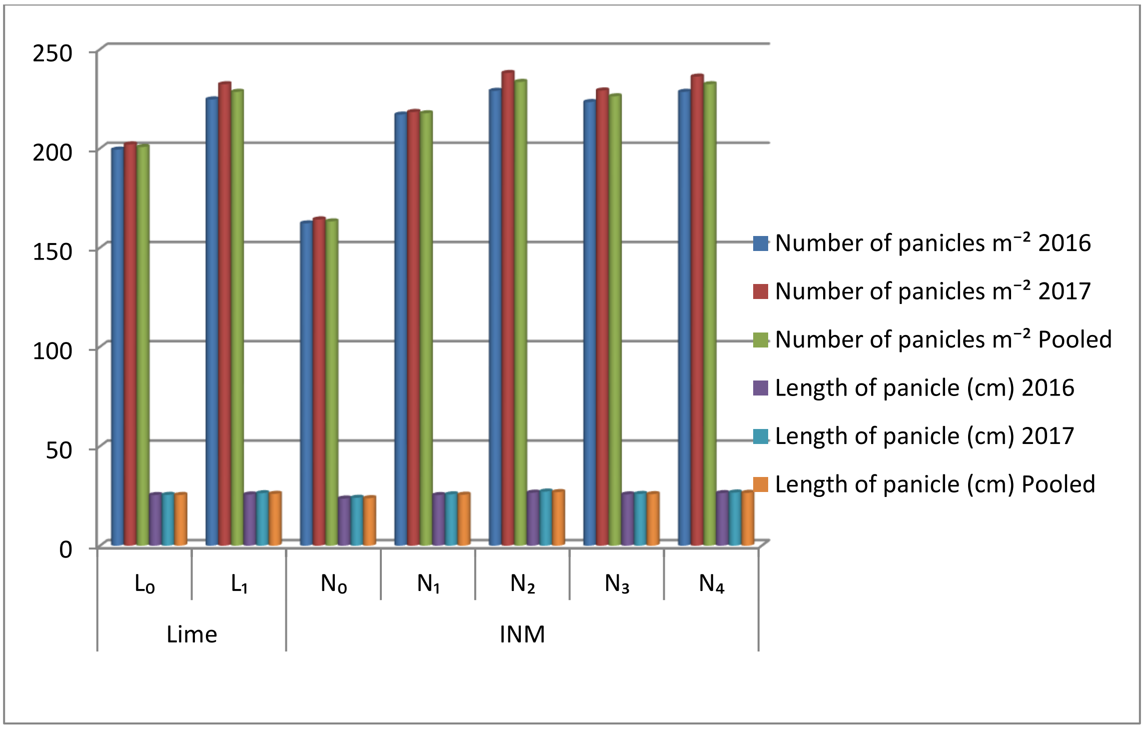


Fig 4.1 Effect of lime and integrated nutrient management on number of panicles m^{-2} and Length of panicle (cm)

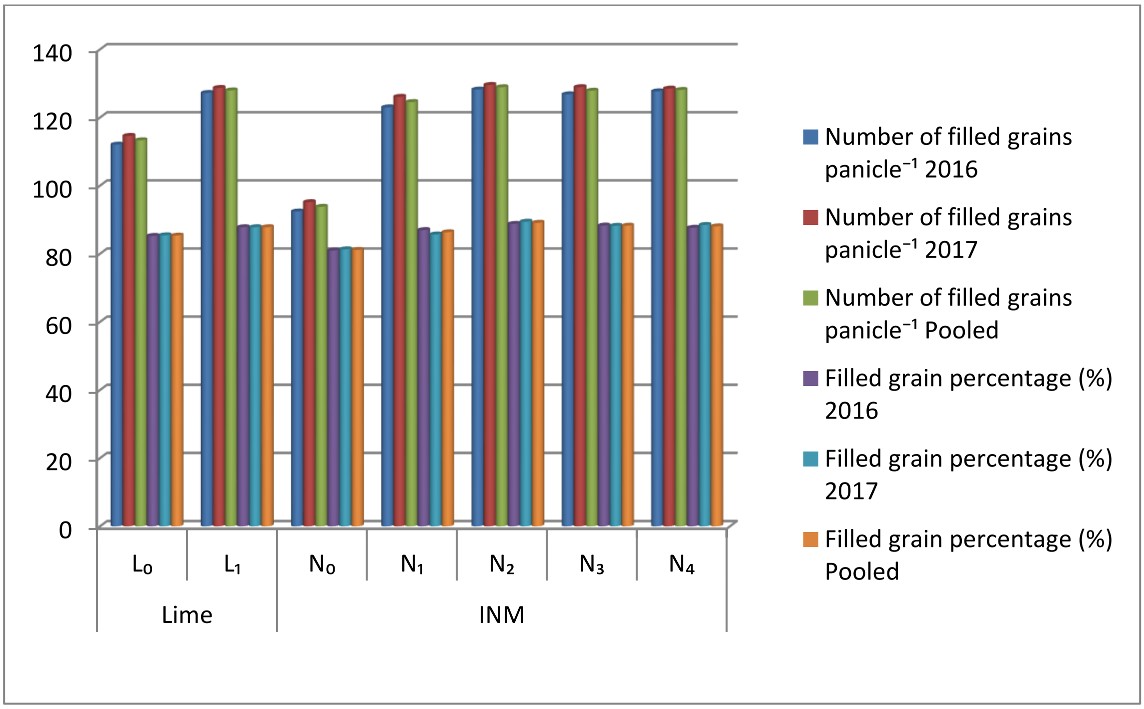


Fig 4.2 Effect of lime and integrated nutrient management on number of filled grains panicle^{-1} and filled grains percentage (%)

Interaction effects

The interaction effect between lime and INM failed to show significant variation on filled grain percentage (%) during both the years of experiment.

4.2.5 Test weight (g)

The variations on test weight (g) among the lime, INM levels as well as their interactions recorded non-significant during both the years of experiment.

4.2.6 Grain yield (q ha^{-1})

Lime

The variation in grain yield due to lime levels reported significant variation during both the years of experiment. During 2016, grain yield due to lime levels (35.01 q ha^{-1}) was recorded with treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). During the year 2017 also, the highest grain yield (35.75 q ha^{-1}) was recorded with treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). Pooled data recorded the same trend of findings. The grain yield benefits can be ascribed due to the increase in soil pH from application of lime along with the associated improvement in nutrients availability, reduced Fe availability and reduction of Al concentration (Venkatesh *et al*., 2002; Cifu *et al*., 2004; Costa & Rosolem, 2007; Kumar *et al*., 2012).

INM

The variations in grain yields due to INM levels were found to be significant. During 2016, the highest grain yield (35.88 q ha^{-1}) was recorded in N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB). The lowest recorded in N_0 (Control). Similar findings were recorded during 2017. Pooled data also recorded the highest grain yield (36.54 q ha^{-1}) with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was at par with N_4 (RDF (75%) + *Azospirillim* + PSB) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1} and the lowest recorded with N_0 (Control). The highest

Table 4.10 (a) Effect of lime and integrated nutrient management on yield of rice

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime									
L_0	30.94	31.33	31.14	64.60	64.94	64.77	32.36	32.43	32.40
L_1	35.01	35.75	35.38	69.05	70.43	69.74	33.66	33.70	33.68
SEm±	0.24	0.34	0.21	1.11	1.32	0.86	0.44	0.52	0.34
CD (P= 0.05)	0.71	1.02	0.60	3.29	3.91	2.46	NS	NS	0.98
INM									
N_0	25.80	26.25	26.03	57.61	58.89	58.25	30.89	30.79	30.84
N_1	33.82	33.90	33.86	67.14	67.69	67.42	33.64	33.39	33.51
N_2	35.88	37.20	36.54	70.62	69.68	70.15	33.74	34.86	34.30
N_3	34.69	35.14	34.92	72.61	71.78	72.19	32.34	32.92	32.63
N_4	34.68	35.22	34.95	66.15	70.38	68.27	34.44	33.37	33.90
SEm±	0.38	0.54	0.33	1.75	2.08	1.36	0.70	0.83	0.54
CD (P= 0.05)	1.13	1.61	0.95	5.20	6.18	3.90	2.07	2.46	1.55

Table 4.10 (b) Interaction effects of lime and integrated nutrient management on yield of rice

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM									
L_0N_0	21.89	21.04	21.47	52.20	51.62	51.91	29.72	29.27	29.50
L_0N_1	32.15	31.28	31.71	60.55	63.10	61.83	34.72	33.20	33.96
L_0N_2	33.67	35.83	34.75	74.34	70.90	72.62	31.20	33.62	32.41
L_0N_3	33.34	33.83	33.59	70.75	67.30	69.03	32.05	33.47	32.76
L_0N_4	33.65	34.67	34.16	65.17	71.80	68.48	34.12	32.58	33.35
L_1N_0	29.71	31.45	30.58	63.01	66.17	64.59	32.06	32.31	32.19
L_1N_1	35.49	36.52	36.01	73.73	72.29	73.01	32.56	33.57	33.06
L_1N_2	38.08	38.57	38.33	66.90	68.46	67.68	36.29	36.09	36.19
L_1N_3	36.04	36.45	36.24	74.46	76.25	75.36	32.63	32.37	32.50
L_1N_4	35.70	35.77	35.74	67.13	68.96	68.05	34.75	34.16	34.45
SEm±	0.54	0.76	0.47	2.47	2.94	1.92	0.98	1.17	0.76
CD (P= 0.05)	1.60	2.27	1.34	7.35	8.74	5.51	2.92	NS	NS

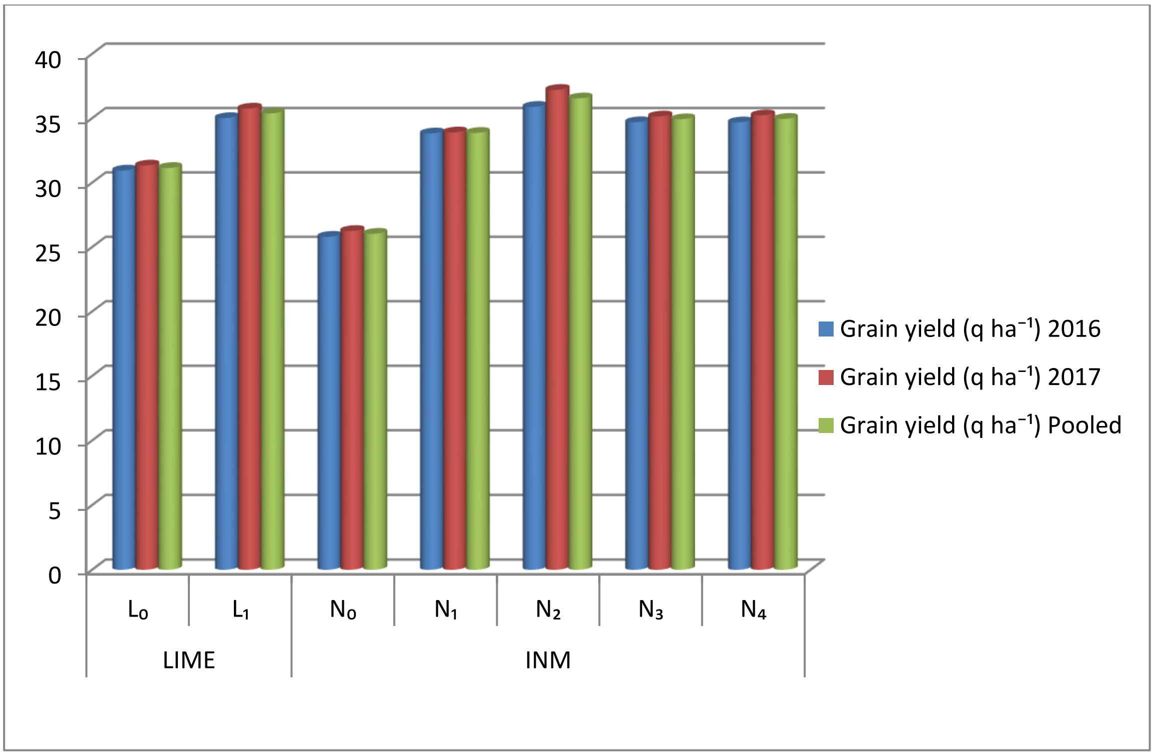


Fig 4.3(a) Effect of lime and integrated nutrient management on grain yield (q ha^{-1})

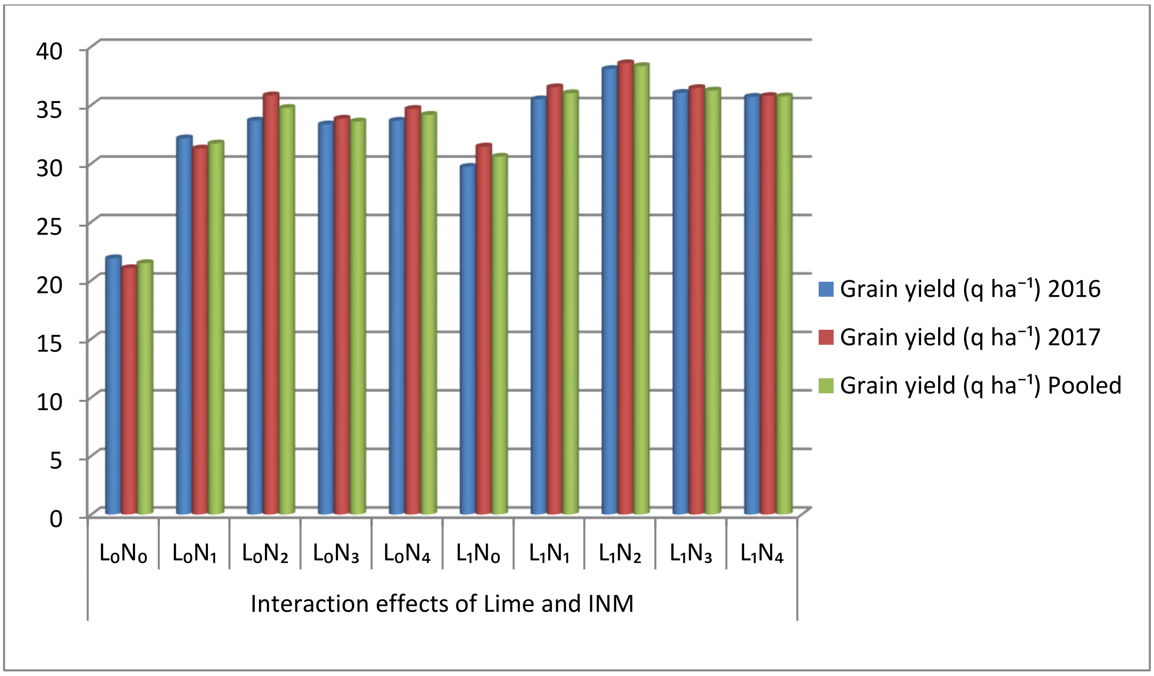


Fig 4.3(b) Interaction effects of lime and integrated nutrient management on grain yield (q ha^{-1})

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 and number of filled grains panicle^{-1}. Improved yields were due to instant supply of nutrients through chemical fertilizers and steady supply through mineralization of FYM to the crop throughout the crop period (Sharma *et al*., 2016; Singh *et al*., 2018; Tang *et al*., 2018). Sravan and singh (2019) also got similar result that integrated approach of (75% RDF + 25% FYM) enhanced higher grain yield.

Interaction effects

The interaction effects of treatments on grain yield also produced significant variation during both years of experiment. The highest grain yield (38.08 q ha^{-1}) during 2016 was associated with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} which was followed by L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) and L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}), while the lowest was recorded with interaction L_0N_0 (Control). Similar findings were recorded during the following year with the highest grain yield (38.57 q ha^{-1}) associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) which was followed by L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) and L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}). The pooled data thus obtained complied with the findings of both the years of experiment with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) giving the highest value (38.33 q ha^{-1}). The interactions L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) and L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) were found to be statistically at par with each other, while the lowest grain yield (21.47 q ha^{-1}) recorded with interaction L_0N_0 (Control). The results clearly indicate that organic and inorganic fertilizer with lime had more profound effect on rice grain due to the higher available nutrients and improvement in soil properties. Similar finding was reported by Mitu *et al*. (2017). Sahu *et al*. (2018) also observed similar results that the half doses of RDF combined with FYM alone or with combination of lime and zinc sulphate resulted in significant increase in grain yield as compare to control and remained at par with full doses of RDF.

4.2.7 Straw yield (q ha^{-1})

Lime

The variations on straw yield due to lime levels were found significant during both years of experiment. During 2016, the highest straw yield (69.05 q ha^{-1}) was recorded with application of treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). During 2017, the same trend of finding followed with treatment L_1 (Lime @ 2 q ha^{-1}) giving the highest straw yield (70.43 q ha^{-1}) as compared to treatment L_0 (without lime). Pooled data of both the years showed significant variation with the highest straw yield (69.74 q ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). Highest straw yield may be due to improvement in soil pH and soil physicochemical properties that increased availability of soil nutrients leading to improvement in plant growth. Lime untreated soils reported the lowest straw yields which may be due to the low soil nutrient status and poor microbial activity as affected by soil acidity. Similar results due to liming on straw yields have been reported by Caires *et al.* (2006) and Ferdous *et al.* (2018). Murphy and Sims (2012) also reported that liming increases soil pH and reduce soil acidity which ultimately increased the straw yields.

INM

The variations on straw yield due to INM levels were found significant during both the years of experiment. The highest straw yield (72.61 q ha^{-1}) during first year of experiment was recorded with N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) followed by N_2 (RDF (75%) + FYM @ 6 t ha^{-1}), while the lowest was recorded in N_0 (Control). During 2017, the highest straw yield (71.78 q ha^{-1}) was also recorded with N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}). The treatments N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and N_4 (RDF (75%) +

Azospirillim + PSB) were found to be statistically at par. Pooled data obtained showed a significant variation with treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) giving the highest value for straw yield (72.19 q ha^{-1}) which was followed by N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) while the lowest was recorded in treatment N_0 (Control). This is in line with the findings of Singh *et al*. (2018), who reported that all the yield attributes were higher with the substitution of organic manures in combination with 50-75% RDF due to regulated balanced supply of nutrients in adequate quantities over prolonged period and enables the rice plants to assimilate sufficient photosynthetic products and ultimately resulted in increased straw yield.

Interaction effects

Significant effect due to interaction of lime and INM levels was observed during both the years of experiment where the highest straw yield (74.46 q ha^{-1}) and (76.25 q ha^{-1}) was associated with interaction L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and the lowest recorded in L_0N_0 (Control). Pooled data revealed similar findings with treatment interaction L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) giving the highest straw yield (75.36 q ha^{-1}) while treatment interaction L_0N_0 (Control) recorded the lowest straw yield. This finding was in conformity with Sahu *et al.* (2018) who reported improved straw yields with the application of fertilizers, manures and lime which might be due to favorable soil condition. Urkurkar *et al.* (2010) and Alim (2012) also reported similar findings.

4.2.8 Harvest index (%)

Lime

Harvest index due to lime levels could not produced significant result during both years of experiment. However, pooled data of both the years recorded significant variation with the highest harvest index (33.68 %) recorded with treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime).

INM

The variations in harvest index due to INM levels were found to be significant during both the years of experiment. During 2016, the highest harvest index (34.44 %) was recorded with treatment N_4 (RDF (75%) + *Azospirillim* + PSB) followed by the treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The lowest recorded in treatment N_0 (Control). During 2017 as well as the pooled data, the highest harvest index was recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was followed by N_4 (RDF (75%) + *Azospirillim* + PSB). Similar findings have been reported by Singh *et al*. (2018).

Interaction effects

The interaction effects of different treatments were found to be non-significant during 2017. During 2016, significant variation was observed with the highest value of harvest index (36.29 %) associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) followed by interaction L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB). The lowest was recorded in RDF and L_0N_0 (Control). High harvest index might be due to high yield and high percentages of grain filling. Acharya *et al*. (2012) also reported similar findings that combine application of NPK, FYM and lime recorded highest harvest index (47.9%) over RDF and control.

4.3 Soil chemical and nutrient status of the soil after harvest of rice

The data collected on soil nutrient status due to various treatments between lime and INM are presented in Table 4.11(a) along with Fig 4.4(a) and Table 4.11(b) along with depicted Fig 4.4(b) showed its interaction effects.

Lime

The variation on soil pH due to lime levels was found to be significant in both the experimental years. During the year 2016, maximum soil pH (4.96) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest (4.75) in treatment L_0 (without lime). During the second year also similar result was found with the highest soil pH (5.03) recorded in treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest (4.76) in treatment L_0 (without lime). Pooled data obtained complied with the findings of both the years of experiment with the highest soil pH (4.99) recorded in treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest (4.76) in treatment in L_0 (without lime). When lime reacts with water, it leads to the production of OH^- ions and Ca^{2+} ions. The Ca^{2+} ions displaces H^+ and Al^{3+} ions from soil adsorption sites where OH^- neutralizes the H^+ in solution resulting in an increase in soil pH. This was supported by the findings of Parvathi *et al*. (2013).

INM

The differences in soil pH due to INM levels were found to be significant during both the years of experiment. During 2016, the highest soil pH (4.98) was recorded for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) which was statistically at par with N_4 (RDF (75%) + *Azospirillim* + PSB). The lowest was recorded in treatment N_0 (Control). During the second year, treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest soil pH (5.04) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB). Pooled data also recorded significant variation with the highest value (5.01) for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_0 (Control). FYM treated plots had a favorable effect on soil pH. Soil pH increased due to the acidifying effect of organic acids produced during the course of decomposition of organic manures. This agrees with the findings of Mishra *et al.*, 2008; Kumari *et al*., 2013; Verma, 2017.

Interaction effects

The interaction effects due to lime and INM levels were found non-significant during both the years of experiment.

4.3.2 Organic carbon (%)

Lime

The variations on soil organic carbon (%) due to lime levels were found to be significant. During the year 2016, the highest organic carbon (1.45 %) was recorded with the treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest (1.35 %) in treatment L_0 (without lime). During the year 2017, similar result of findings with treatment L_1 (Lime @ 2 q ha^{-1}) recorded the highest organic carbon (1.56 %) and the lowest (1.41%) in treatment L_0 (without lime). Pooled data showed the same trend of findings with treatment L_1 (Lime @ 2 q ha^{-1}) recorded the highest organic carbon (1.50 %). The increase in soil organic carbon due to lime application can be attributed to the favorable condition provide to microbes in the soil. The increased in organic carbon with liming was also reported by Costa (2012) and Toppo and Kumar (2018). MassaoInagaki *et al*. (2016) reported that lime application in acid soil significantly improved the stocks of several SOC pools.

INM

The differences in soil organic carbon due to INM levels were found to be significant for both the years of experiment. The highest value (1.48 %) of soil organic carbon recorded during 2016 for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The following year, the highest value (1.63 %) of soil organic carbon was also recorded for the same treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and treatment N_4 (RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par and the lowest in N_0 (Control) during both the years of experiment. Pooled data also recorded similar results with the highest value (1.55 %) of soil organic carbon recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The increase in SOC was due to the addition of carbon source through FYM, higher contribution of root and shoot biomass to the soil (Upadhyay and Vishwakarma, 2014) and the effect was further enhanced by addition of NPK fertilizers resulting in higher root and shoot growth and thus increased in biomass production which raised the organic carbon content in soil. Similar findings were also reported by Majumder *et al*. (2008) and Nayak *et al*. (2012).

Interaction effects

The interaction effects due to lime and INM levels were found to be non-significant during both the years of experiment.

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

Lime

The variations on nitrogen availability in soil due to lime levels were found to be significant during both the years of experiment. Soil under treatment L_1 (Lime @ 2 q ha^{-1}) recorded the highest value (278.98 kg N ha^{-1}) of nitrogen availability during the year 2016 and the lowest (264.62 kg N ha^{-1}) in treatment L_0 (without lime). Similar trend of result was recorded in the following year of experiment. The highest value (285.52 kg N ha^{-1}) was recorded from treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest (266.24 kg N ha^{-1}) in treatment L_0 (without lime). Pooled data thus obtained also revealed similar finding with the highest value (282.25 kg N ha^{-1}) recorded for treatment L_1 (Lime @ 2 q ha^{-1}) while the lowest (265.43 kg N ha^{-1}) was recorded with treatment L_0 (without lime). The increase in soil available nitrogen following liming could be due to enhanced microbial activities in the soils owing to increased soil pH that accelerated the rate of decomposition of organic matter, thus enhancing the process of mineralization of nitrogen (Edmeades and Ridley, 2003).

INM

The variations in nitrogen availability in soil due to INM levels were found to be significant during both the years of experiment. The highest available nitrogen (284.82 kg N ha^{-1}) was recorded in 2016 with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by the treatment N_3 (RDF (75%) +

Poultry manure @ 1 t ha^{-1}) and treatment N_4 (RDF (75%) + *Azospirillim* + PSB). Similar trend of result was reported in the following year with the highest nitrogen availability (292.40 kg N ha^{-1}) recorded for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by the treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and treatment N_4 (RDF (75%) + *Azospirillim* + PSB). The lowest was in N_0 (control) for both the years of experiment. Pooled data also revealed similar findings with the highest nitrogen availability (288.61 kg N ha^{-1}) in soil for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The increase in available N in treatments where the N was supplied through NPK along with FYM could be attributed to the production of carbonic acids produced during decomposition of organics which mineralize the complex organic substances which contributes to the N pool. The increase could also be attributed to enhanced soil microbial activity which helps in conversion of organically bound soil N to inorganic N through the mineralization of organic N from FYM. Yadav *et al*. (2019) reported that the lower of available N in unfertilized control plot was due to the continuous mining of native soil N by crop in the absence of external nutrient inputs.

Interaction effects

The interaction effects between lime and INM levels on soil available nitrogen were found to be significant during both the years of experiment. The highest available nitrogen (286.78 kg N ha^{-1}) was recorded during the year 2016 for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The interaction effects of L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) and L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) were found to be at par. During the year 2017, the highest available nitrogen (299.24 kg N ha^{-1}) recorded for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}), while interaction effects of L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) and L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) were found to be at par. Pooled data also complied with the findings of both the years of experiment with the highest available nitrogen (293.01 kg N ha^{-1}) still recorded with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) which was at par with L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) while the lowest (231.20 kg N ha^{-1}) was recorded in treatment interaction L_0N_0. Saha *et al.* (2010) also found that liming and organic manure application along with chemical fertilizers resulted in the greatest total N content of the soils in maize-mustard. Therefore, it was evident from the results that soil fertility status was improved by use of inorganic chemical fertilizers, organic manure and lime.

4.3.4 Available phosphorus (kg ha^{-1})

Lime

The difference in phosphorus availability in soil was found to be significant under different lime levels during both the years of experiment. The availability of phosphorus (24.78 kg ha^{-1}), (25.96 kg ha^{-1}) was more in limed plots as compared to that of control plot during the year 2016 and 2017. Pooled data also recorded significant variation with the highest phosphorus availability (25.37 kg ha^{-1}) recorded with treatment L_1 (Lime @ 2 q ha^{-1}). The increase in phosphorus availability might be due to dissolution of complex Fe and Al phosphates, and thus reduces P sorption making phosphate available for plant uptake. This result agrees well with other findings, indicating that liming improves soil pH which in turn reduced P fixation and enhanced available P (Halim *et al.*, 2014; Ramesh *et al.*, 2014; Kisinyo, 2016; Mamatha *et al.*, 2018).

INM

The variation in phosphorus availability in soil due to INM levels was found to be significant during both the years of experiment. During 2016 and 2017, the highest available phosphorus recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest was in N_0 (Control). While N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par. Also, the pooled data thus obtained complied with the findings of both the years, with the treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest available phosphorus (25.87 kg ha^{-1}). The significant increase in P availability could be attributed to the organic manure mediated complexation of Al responsible for fixation of P in soil (Sushma *et al.*, 2007), reduce the fixation of applied P and helps in releasing P through solubilizing native P in the soil (Subehia and Sepehya, 2012). Kumar *et al*. (2014) also reported that addition of FYM with inorganic fertilizers had the beneficial effect in increasing the phosphate availability.

Interaction effects

The interaction effects between lime and INM levels on soil available phosphorus were found to be significant during both the years of experiment. The highest available phosphorus (26.59 kg ha^{-1}) and (28.45 kg ha^{-1}) was recorded for the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) during 2016 and 2017 respectively. The interaction effects of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be at par. Pooled data of both the years showed significant variation with the highest available phosphorus (27.52 kg ha^{-1}) for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) while the lowest (14.29 kg ha^{-1}) was recorded with treatment interaction L_0N_0 (Control). It is evident from the result that application of balanced chemical fertilizer and FYM with lime recorded an increase in the available phosphorus content of soil over control. These findings are similar to findings of Singh *et al*. (2017).

4.3.5 Available Potassium (kg ha^{-1})

Lime

The differences on potassium availability in soil due to different lime levels were found to be significant during both the years of experiment. The highest value of available potassium (254.26 kg ha^{-1}) during the first year was recorded from treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime).

Treatment L_1 (Lime @ 2 q ha^{-1}) also recorded the highest potassium availability in soil (258.93 kg ha^{-1}) during the following year of experiment. Pooled data also followed the similar trend of findings with the highest (256.60 kg ha^{-1}) from the treatment L_1 (Lime @ 2 q ha^{-1}). The increase in K content in soil by liming might be due to displacement of exchangeable potassium by calcium. These results confirm the findings of Chimdi *et al*. (2012) and Singh *et al*. (2017).

INM

The variation in potassium availability in soil due to INM levels was found to be significant during both the years of experiment. The highest available potassium (257.33 kg ha^{-1}) was recorded for N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_0 (control). Same trend of findings followed during the second year of experiment with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) giving the highest value for potassium availability (265.14 kg ha^{-1}). Pooled data complied with the findings of both the years and it was found that N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest value for potassium availability (261.24 kg ha^{-1}) which was followed by N_4 (RDF (75%) + *Azospirillim* + PSB) while the lowest was recorded in N_O (control). Significant increase in available K content in soil might be due to additional supply of K from FYM, which helped to maintain the supply of K by releasing from soil K reserve. Similar findings have been reported by Sharma *et al*. (2015) as well as Verma (2017). The present findings was also in agreement with Yadav *et al*. (2019), who reported that application of FYM along with recommended fertilizer recorded significantly higher available potassium in soil as compared to mere application of recommended NPK alone and control.

Interaction effects

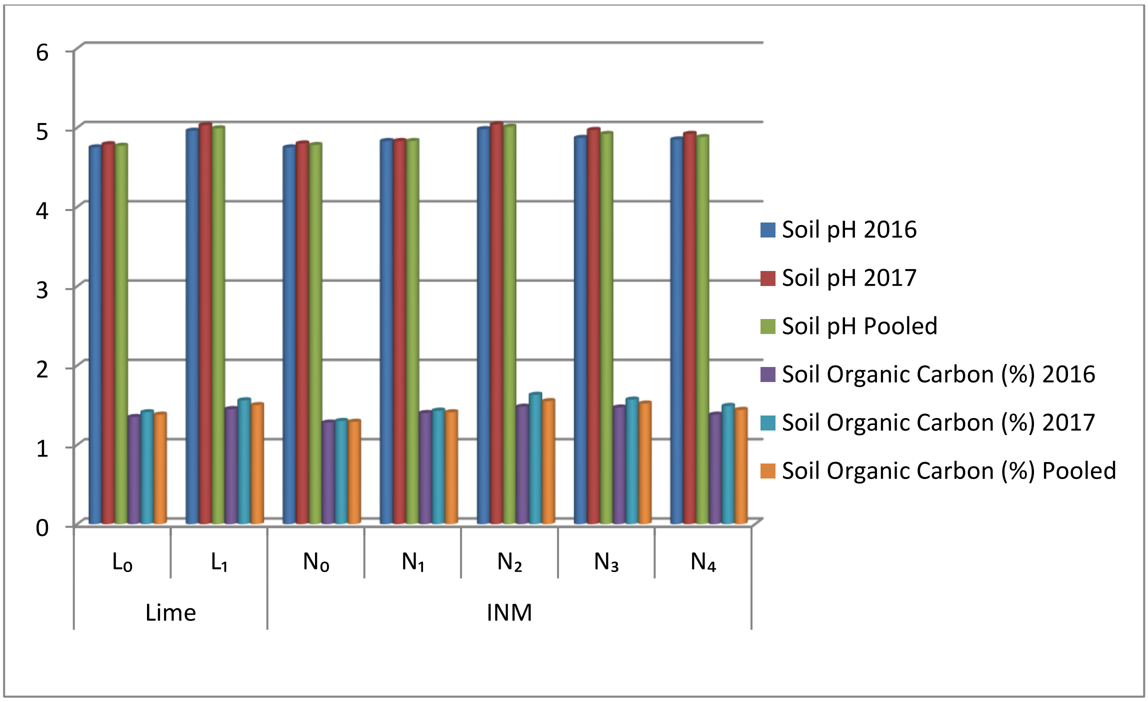
The interaction effects between lime and INM levels on soil available potassium showed significant variation only during the second year of experiment. During the year 2017, the highest available potassium (272.78 kg

Table 4.11 (a) Effect of lime and integrated nutrient management on soil nutrient status after harvest of rice

Treatments	Soil nutrient status after harvest of rice														
	Soil pH			Soil Organic Carbon (%)			Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime															
L_0	4.75	4.79	4.77	1.35	1.41	1.38	264.62	266.24	265.43	20.31	20.69	20.50	229.75	231.74	230.74
L_1	4.96	5.03	4.99	1.45	1.56	1.50	278.98	285.52	282.25	24.78	25.96	25.37	254.26	258.93	256.60
SEm±	0.02	0.02	0.01	0.01	0.02	0.01	1.59	1.71	1.17	0.16	0.27	0.16	2.19	1.66	1.37
CD (P= 0.05)	0.05	0.05	0.04	0.03	0.05	0.03	4.74	5.08	3.35	0.48	0.81	0.45	6.51	4.92	3.94
INM															
N_0	4.75	4.80	4.78	1.28	1.30	1.29	249.06	252.74	250.90	18.33	18.34	18.34	209.69	207.02	208.35
N_1	4.83	4.83	4.83	1.40	1.43	1.41	262.72	261.89	262.30	20.96	21.40	21.18	236.39	236.77	236.58
N_2	4.98	5.04	5.01	1.48	1.63	1.55	284.82	292.40	288.61	24.83	26.90	25.87	257.33	265.14	261.24
N_3	4.87	4.97	4.92	1.47	1.57	1.52	282.32	288.40	285.36	23.79	24.59	24.19	253.54	256.40	254.97
N_4	4.85	4.92	4.88	1.38	1.49	1.44	280.08	283.98	282.03	24.81	25.38	25.10	253.07	261.35	257.21
SEm±	0.03	0.03	0.02	0.02	0.03	0.02	2.52	2.70	1.85	0.26	0.43	0.25	3.47	2.62	2.17
CD (P= 0.05)	0.08	0.09	0.06	0.05	0.08	0.05	7.49	8.03	5.30	0.76	1.28	0.72	10.30	7.78	6.23

Table 4.11(b) Interaction effects of lime and integrated nutrient management on soil nutrient status after harvest of rice

Treatments	Soil nutrient status after harvest of rice														
	Soil pH			Soil Organic Carbon (%)			Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Lime x INM															
L_0N_0	4.67	4.72	4.69	1.21	1.19	1.20	228.68	233.72	231.20	14.52	14.06	14.29	197.77	195.92	196.85
L_0N_1	4.73	4.75	4.74	1.38	1.35	1.37	253.33	247.38	250.36	18.03	17.56	17.80	222.70	210.08	216.39
L_0N_2	4.85	4.89	4.87	1.43	1.60	1.52	282.87	285.56	284.21	23.07	25.35	24.21	246.79	257.50	252.15
L_0N_3	4.77	4.81	4.79	1.39	1.51	1.45	280.46	284.84	282.65	22.52	22.98	22.75	239.64	242.56	241.10
L_0N_4	4.75	4.80	4.78	1.34	1.41	1.37	277.76	279.71	278.74	23.41	23.48	23.45	241.83	252.66	247.24
L_1N_0	4.83	4.88	4.86	1.36	1.40	1.38	269.43	271.75	270.59	22.14	22.63	22.39	221.60	218.11	219.86
L_1N_1	4.93	4.92	4.93	1.41	1.51	1.46	272.10	276.40	274.25	23.89	25.25	24.57	250.08	263.46	256.77
L_1N_2	5.10	5.19	5.14	1.52	1.65	1.59	286.78	299.24	293.01	26.59	28.45	27.52	267.87	272.78	270.33
L_1N_3	4.97	5.14	5.05	1.55	1.64	1.59	284.18	291.95	288.07	25.06	26.20	25.63	267.44	270.24	268.84
L_1N_4	4.95	5.03	4.99	1.42	1.58	1.50	282.39	288.25	285.32	26.20	27.28	26.74	264.32	270.04	267.18
SEm±	0.04	0.04	0.03	0.02	0.04	0.02	3.57	3.82	2.61	0.36	0.61	0.35	4.90	3.70	3.07
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	10.59	11.35	7.50	1.07	1.81	1.01	NS	11.00	8.81



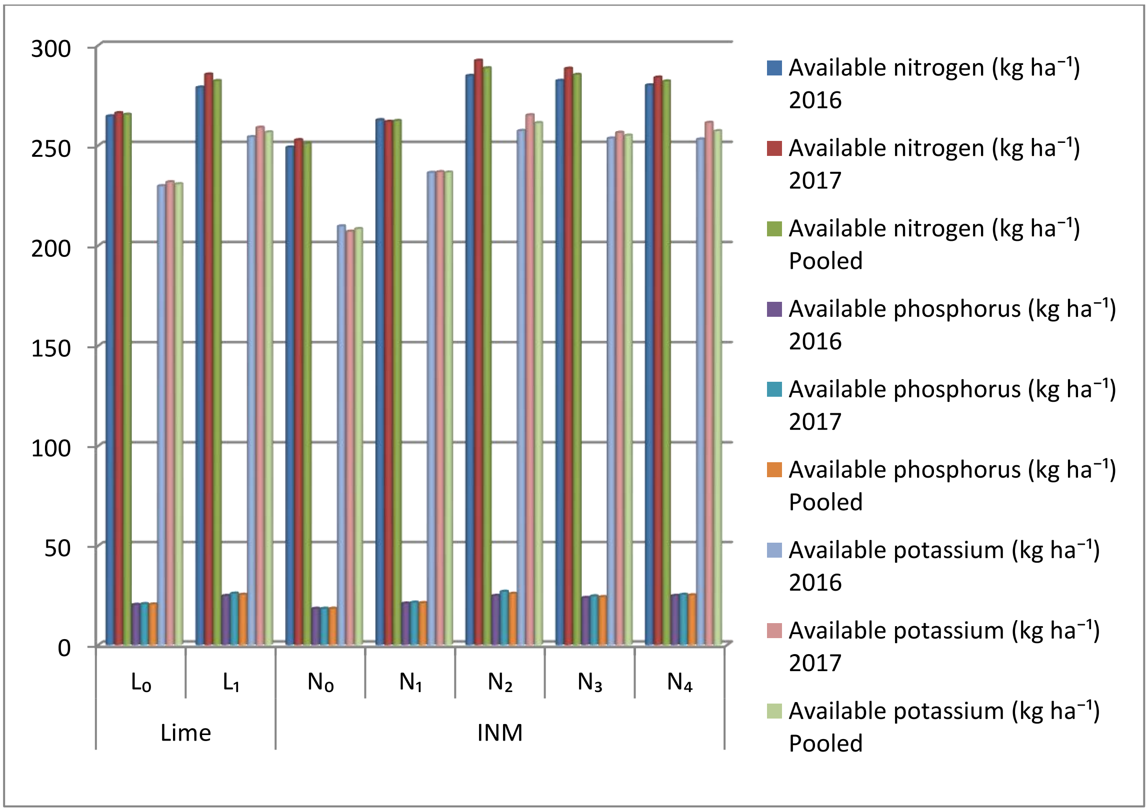


Fig 4.4(a) Effect of lime and integrated nutrient management on soil nutrient status after harvest of rice

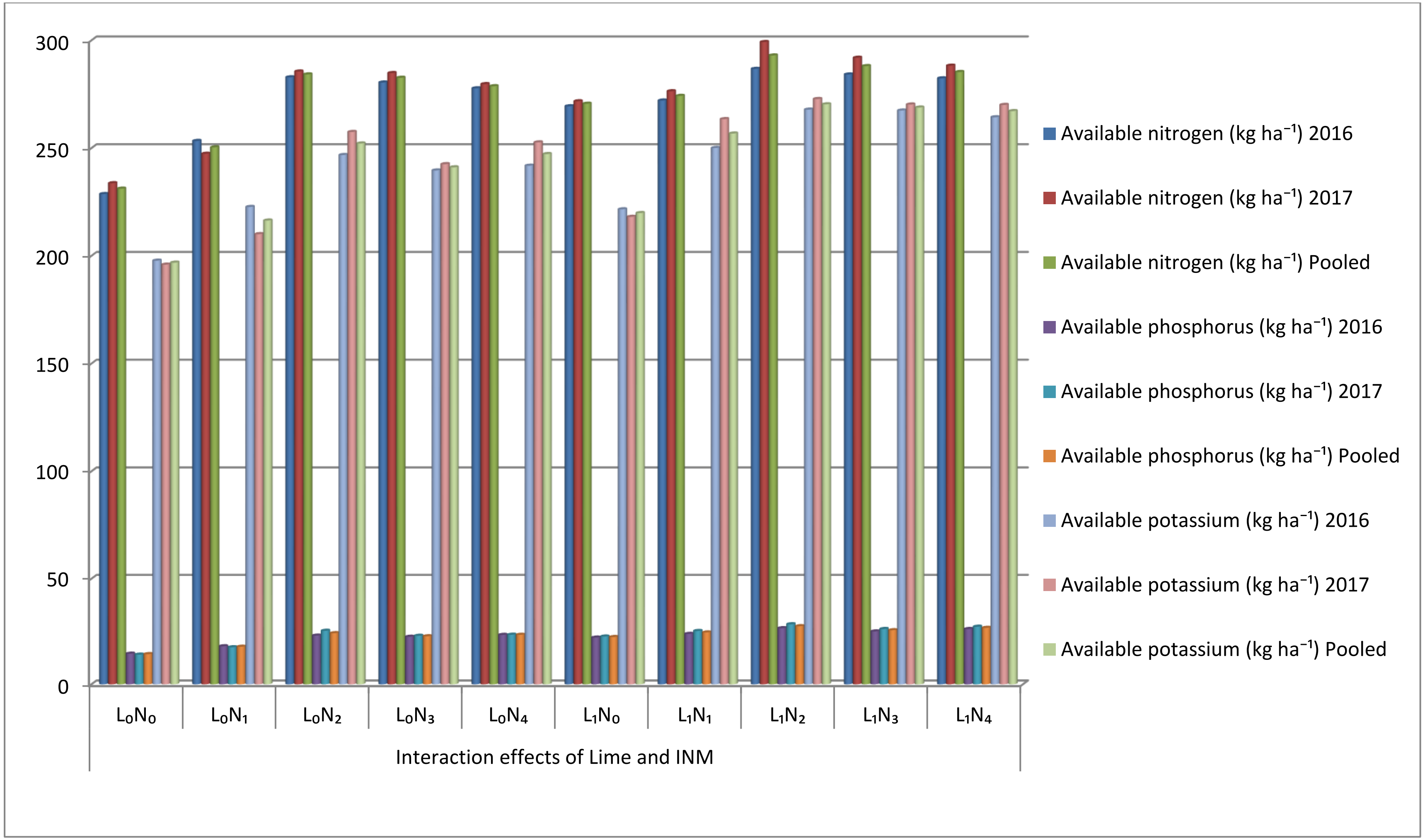


Fig 4.4(b) Interaction effects of lime and integrated nutrient management on soil nutrient status after harvest of rice

ha^{-1}) was recorded for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The interaction effects of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par. Pooled data obtained also revealed similar finding with the highest available potassium (270.33 kg ha^{-1}) recorded for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) while the lowest was recorded in L_0N_0 (Control). Combining FYM with NPK through fertilizers resulted in higher build-up of available K which might be ascribed to the additional supply of K through FYM and fertilizer K over the initial values. The improvement in soil pH through the application of lime is also responsible for increasing the K availability in acid soil (Chimdi *et al*., 2012). Adeniyan *et al.* (2011) also reported that there is increased soil available K when organic manure was applied in combination with fertilizer and lime.

4.4 Plant analysis: Nutrient uptake (kg ha^{-1}) by rice

The data on nitrogen uptake, Phosphorus uptake and Potassium uptake to various treatments on lime and INM are presented in Table 4.12(a), Table 4.13(a) and Table 4.14(a) with Fig 4.5(a) while their interaction effects are given in Table 4.12(b), Table 4.13(b) and Table 4.14(b) with Fig 4.5(b).

4.4.1 Nitrogen uptake (kg ha^{-1})

Lime

The variations on nitrogen uptake due to lime levels were found to be significant during both the years of experiment. The highest nitrogen uptake (51.53 kg ha^{-1}) and (53.47 kg ha^{-1}) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) during 2016 and 2017 respectively. Pooled data thus obtained also showed a significant variation with the highest nitrogen uptake (52.50 kg ha^{-1}) recorded for treatment L_1 (Lime @ 2 q ha^{-1}), while the lowest was recorded with treatment L_0 (without lime). The nutrient absorption depends on their ionic forms in the rhizosphere is influenced by soil acidity and the nutrient concentrations in the soil. The reduction in soil acidity increased the pH and

Table 4.12(a) Effect of lime and integrated nutrient management on plant nitrogen uptake by rice

Treatments	Nitrogen uptake by rice (kg ha^{-1})								
	2016			2017			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Lime									
L_0	30.81	15.89	46.71	31.15	16.33	47.47	30.98	16.11	47.09
L_1	34.66	16.87	51.53	36.10	17.37	53.47	35.38	17.12	52.50
SEm±	0.50	0.28	0.55	0.19	0.19	0.26	0.26	0.15	0.31
CD (P= 0.05)	1.47	0.83	1.63	0.55	0.58	0.79	0.78	0.43	0.88
INM									
N_0	27.45	14.47	41.91	27.03	14.45	41.48	27.24	14.46	41.70
N_1	31.79	16.08	47.87	31.47	15.81	47.27	31.63	15.94	47.57
N_2	36.89	17.00	53.89	38.22	18.72	56.94	37.56	17.86	55.41
N_3	33.72	16.76	50.48	36.38	16.90	53.28	35.05	16.83	51.88
N_4	33.85	17.60	51.45	35.02	18.36	53.38	34.43	17.98	52.41
SEm±	0.78	0.44	0.87	0.29	0.31	0.42	0.41	0.23	0.48
CD (P= 0.05)	2.33	1.31	2.58	0.87	0.91	1.24	1.23	0.68	1.38

availability of N and ultimately its uptake by the crop (Kihanda *et al*., 1999; Mamatha *et al*., 2018; Mansingh *et al*., 2019).

INM

The effect of INM levels on nitrogen uptake by the plant showed significant variation during both the years of experiment. The highest nitrogen uptake (53.89 kg ha^{-1}) and (56.94 kg ha^{-1}) was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) during 2016 and 2017 respectively Pooled data also followed the similar trend of findings with the highest nitrogen uptake (55.41 kg ha^{-1}) recorded for N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The treatment effects of N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) were found to be at par. This observation are in consonance with the findings of Kumar *et al*. (2017), who reported the enhancement of N uptake by rice plants indicating better utilization of applied nutrients with FYM supplemented with any level of inorganic fertilizers as compared to fertilizers application alone. The findings are also in agreement with Argal *et al*. (2018), who reported that FYM incorporated along with inorganic nutrients considerably enhanced the yield and N uptake and hence highest N recovery obtained by application of 5 t of FYM ha^{-1} under INM.

Interaction effects

The interaction effects between lime and INM levels on plant nitrogen uptake was significantly affected during both the years of experiment. Pooled data also showed a significant variation with the highest nitrogen uptake (56.51 kg ha^{-1}) recorded for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The interaction effects of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be at par. The conjunctive use of FYM, along with balanced fertilizers and lime under acid soil condition controls soil acidity, stimulate uptake of nutrients through enhanced microbial population activity and better root growth under congenial soil physical condition created

Table 4.12(b) Interaction effects of lime and integrated nutrient management on plant nitrogen uptake by rice

Treatments	Nitrogen uptake by rice (kg ha^{-1})								
	2016			2017			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Lime x INM									
L_0N_0	23.76	12.82	36.58	22.95	12.29	35.24	23.35	12.56	35.91
L_0N_1	31.99	15.58	47.58	30.60	14.99	45.59	31.30	15.29	46.58
L_0N_2	36.45	16.47	52.92	37.18	18.53	55.71	36.82	17.50	54.32
L_0N_3	31.45	16.84	48.28	33.53	16.44	49.97	32.49	16.64	49.13
L_0N_4	30.42	17.75	48.17	31.48	19.37	50.85	30.95	18.56	49.51
L_1N_0	31.14	16.11	47.25	31.11	16.60	47.71	31.13	16.36	47.48
L_1N_1	31.58	16.57	48.15	32.33	16.62	48.95	31.96	16.60	48.55
L_1N_2	37.33	17.52	54.85	39.26	18.91	58.17	38.30	18.22	56.51
L_1N_3	36.00	16.68	52.67	39.23	17.36	56.59	37.61	17.02	54.63
L_1N_4	37.27	17.46	54.73	38.55	17.35	55.91	37.91	17.41	55.32
SEm±	1.11	0.62	1.23	0.42	0.43	0.59	0.59	0.33	0.68
CD (P= 0.05)	3.29	NS	3.65	1.24	1.29	1.76	1.74	0.97	1.96

by addition of FYM. These results corroborate with the findings of Mishra and Das (2000). Sahu *et al*. (2018) also reported that among the treatments, highest total nitrogen uptake (76.65 kg ha^{-1}) was observed in 100% NPK + 5 t FYM + $ZnSO_4$ @ 25 kg ha^{-1} + lime 3 q ha^{-1} which was at par with 100% NPK +5 t FYM + $ZnSO_4$ @ 25 kg ha^{-1}.

4.4.2 Phosphorus uptake (kg ha^{-1})

Lime

The variations on phosphorus uptake due to INM levels were found to be significant during both the years of experiment. Treatment L_1 (Lime @ 2 q ha^{-1}) recorded the highest phosphorus uptake (20.80 kg ha^{-1}) during the year 2016. Similar trend of result was recorded in the following year of experiment with the highest phosphorus uptake (20.99 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). Pooled data also showed significant variation in phosphorus uptake with the highest uptake (20.89 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). The reason for high P uptake in lime treated plots is because liming material precipitates the Al^{3+} at high pH, increases the availability of P and thereby making P readily available to crops. This is in line with the findings of Meena *et al*. (2017). Liming also increased root proliferation by reducing toxic effects of Al and thus enhanced the uptake of P which attributed in increase in the yield of rice (Mamatha *et al*., 2018).

INM

The variations on phosphorus uptake due to INM levels were found to be significant during both the years of experiment. Treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest phosphorus uptake (21.71 kg ha^{-1}) during the year 2016. Similar trend of result was recorded in the following year of experiment with the highest phosphorus uptake (23.13 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). Pooled data also showed significant variation in phosphorus uptake with the highest uptake (22.42 kg ha^{-1}) recorded

Table 4.13(a) Effect of lime and integrated nutrient management on plant phosphorus uptake by rice

Treatments	Phosphorus uptake by rice (kg ha^{-1})								
	2016			2017			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Lime									
L_0	11.53	7.23	18.76	12.45	7.43	19.89	11.99	7.33	19.33
L_1	12.71	8.08	20.80	12.69	8.29	20.99	12.70	8.19	20.89
SEm±	0.14	0.08	0.17	0.32	0.08	0.31	0.15	0.07	0.18
CD (P= 0.05)	0.42	0.22	0.50	NS	0.24	0.93	0.44	0.20	0.51
INM									
N_0	9.67	6.23	15.89	8.95	6.21	15.16	9.31	6.22	15.52
N_1	12.07	7.58	19.66	11.95	7.69	19.64	12.01	7.64	19.65
N_2	13.47	8.24	21.71	14.45	8.68	23.13	13.96	8.46	22.42
N_3	12.57	7.81	20.37	14.01	8.09	22.10	13.29	7.95	21.24
N_4	12.83	8.45	21.28	13.52	8.64	22.16	13.18	8.54	21.72
SEm±	0.22	0.12	0.27	0.51	0.13	0.49	0.23	0.10	0.28
CD (P= 0.05)	0.66	0.35	0.79	1.52	0.38	1.47	0.69	0.31	0.81

Table 4.13(b) Interaction effects of lime and integrated nutrient management on plant phosphorus uptake by rice

Treatments	Phosphorus uptake by rice (kg ha^{-1})								
	2016			2017			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Lime x INM									
L_0N_0	8.41	5.33	13.74	8.36	5.16	13.52	8.39	5.25	13.63
L_0N_1	12.16	7.33	19.49	12.45	7.25	19.71	12.31	7.29	19.60
L_0N_2	13.30	8.19	21.49	14.12	8.69	22.81	13.71	8.44	22.15
L_0N_3	11.54	7.37	18.91	13.84	7.83	21.67	12.69	7.60	20.29
L_0N_4	12.25	7.94	20.19	13.50	8.23	21.72	12.87	8.09	20.96
L_1N_0	10.92	7.12	18.04	9.54	7.26	16.80	10.23	7.19	17.42
L_1N_1	11.99	7.83	19.82	11.44	8.13	19.56	11.71	7.98	19.69
L_1N_2	13.65	8.28	21.93	14.78	8.66	23.44	14.22	8.47	22.68
L_1N_3	13.60	8.24	21.84	14.17	8.36	22.53	13.89	8.30	22.19
L_1N_4	13.42	8.95	22.37	13.54	9.06	22.60	13.48	9.00	22.48
SEm±	0.31	0.17	0.38	0.73	0.18	0.70	0.33	0.15	0.40
CD (P= 0.05)	0.93	0.50	1.12	NS	0.54	NS	0.98	0.44	1.14

from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The treatment effects of N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) were found to be at par. The higher P uptake in FYM treated plots may be due to the fact that organic materials form chelates with Al^{3+} and Fe^{3+} resulting in reduced P fixing capacity and thus making the phosphate available to plants. A similar finding was reported by Meena *et al*. (2017). The findings are also in agreement with Argal *et al*. (2018) who reported that FYM incorporation along with inorganic nutrients considerably enhanced the yield and P uptake and hence highest P recovery obtained by application of 5 t of FYM ha^{-1} under INM.

Interaction effects

The interaction effects between lime and INM levels on plant phosphorus uptake were found to be significant during the first year of experiment. However, non-significant variation was recorded during the following year. Pooled data showed significant variation with the highest phosphorus uptake (22.68 kg ha^{-1}) recorded from interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) which was at par with interaction L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB). The conjunctive use of FYM, along with balanced fertilizers and lime under acid soil condition controls soil acidity, stimulate uptake of nutrients through enhanced microbial population activity and better root growth under congenial soil physical condition created by addition of FYM. These results corroborate with the findings of Mishra and Das (2000).

4.4.3 Potassium uptake (kg ha^{-1})

Lime

The variations on potassium uptake between lime levels were found to be significant during both the years of experiment with the highest value recorded from treatment L_1 (Lime @ 2 q ha^{-1}), while the lowest was recorded with treatment L_0 (without lime). Pooled data showed significant variation with

Table 4.14(a) Effect of lime and integrated nutrient management on plant potassium uptake by rice

Treatments	Potassium uptake by rice (kg ha^{-1})								
	2016			2017			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Lime									
L_0	21.54	12.28	33.82	22.13	12.73	34.85	21.83	12.50	34.34
L_1	25.03	15.14	40.17	25.42	15.10	40.53	25.23	15.12	40.35
SEm±	0.23	0.22	0.24	0.30	0.37	0.37	0.20	0.15	0.26
CD (P= 0.05)	0.69	0.66	0.72	0.89	0.78	1.40	0.60	0.43	0.76
INM									
N_0	20.20	11.60	31.80	20.32	11.88	32.20	20.26	11.74	32.00
N_1	23.06	13.66	36.71	23.27	13.43	36.70	23.16	13.54	36.71
N_2	25.54	15.11	40.64	25.56	15.21	40.77	25.55	15.16	40.71
N_3	23.60	13.87	37.47	24.62	14.57	39.19	24.11	14.22	38.33
N_4	24.03	14.31	38.34	25.11	14.48	39.59	24.57	14.40	38.96
SEm±	0.37	0.35	0.38	0.47	0.42	0.74	0.32	0.23	0.42
CD (P= 0.05)	1.10	1.04	1.14	1.40	1.24	2.21	0.95	0.69	1.20

the highest value (40.35 kg ha^{-1}) recorded for treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). This finding is in agreement with the findings of Meena *et al*. (2017), who reported that the positive effects of liming on K uptake was due to the improvement in soil pH and increased availability of nutrients resulting in increased K uptake. Liming also increased root proliferation by reducing toxic effects of Al and thus enhanced the uptake of K which attributed in increase in the yield of rice (Mamatha *et al*., 2018).

INM

The effect of INM levels on potassium uptake by the crop was found to be significant during both the years of experiment. Pooled data thus obtained showed a significant variation with the highest potassium uptake (40.71 kg ha^{-1}) recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was followed by N_4 (RDF (75%) + *Azospirillim* + PSB). Higher uptake of K might be due to the priming effect that organic manure on decomposition release organic acids that solubilise native K *i.e*. fixed and non-exchangeable form of K and change the soil solution with potassium ions at later stage of crop growth. The findings are also in agreement with Argal *et al*. (2018), who reported that FYM incorporation along with inorganic fertilizers considerably enhanced K uptake and hence highest K recovery, obtained by application of 5 t of FYM ha^{-1} under INM.

Interaction effects

Pooled data showed significant variation with interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) giving the highest potassium uptake (42.79 kg ha^{-1}). The interaction effects of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be at par. These results corroborate the earlier findings of Mishra and Das (2000).

Table 4.14(b) Interaction effects of lime and integrated nutrient management on plant potassium uptake by rice

Treatments	Potassium uptake by rice (kg ha^{-1})								
	2016			2017			Pooled		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Lime x INM									
L_0N_0	18.08	9.95	28.03	17.87	10.28	28.15	17.98	10.12	28.09
L_0N_1	21.19	12.49	33.68	21.83	12.60	34.42	21.51	12.55	34.05
L_0N_2	24.60	14.37	38.96	23.96	14.32	38.28	24.28	14.35	38.62
L_0N_3	21.63	11.86	33.49	23.77	13.51	37.28	22.70	12.68	35.38
L_0N_4	22.21	12.72	34.93	23.21	12.92	36.13	22.71	12.82	35.53
L_1N_0	22.32	13.25	35.57	22.76	13.48	36.24	22.54	13.37	35.91
L_1N_1	24.92	14.82	39.74	24.71	14.26	38.97	24.82	14.54	39.36
L_1N_2	26.48	15.84	42.32	27.16	16.10	43.25	26.82	15.97	42.79
L_1N_3	25.56	15.89	41.45	25.48	15.63	41.11	25.52	15.76	41.28
L_1N_4	25.85	15.89	41.74	27.01	16.05	43.06	26.43	15.97	42.40
SEm±	0.52	0.50	0.54	0.67	0.84	0.84	0.45	0.33	0.59
CD (P= 0.05)	NS	NS	1.61	NS	NS	NS	NS	NS	1.70

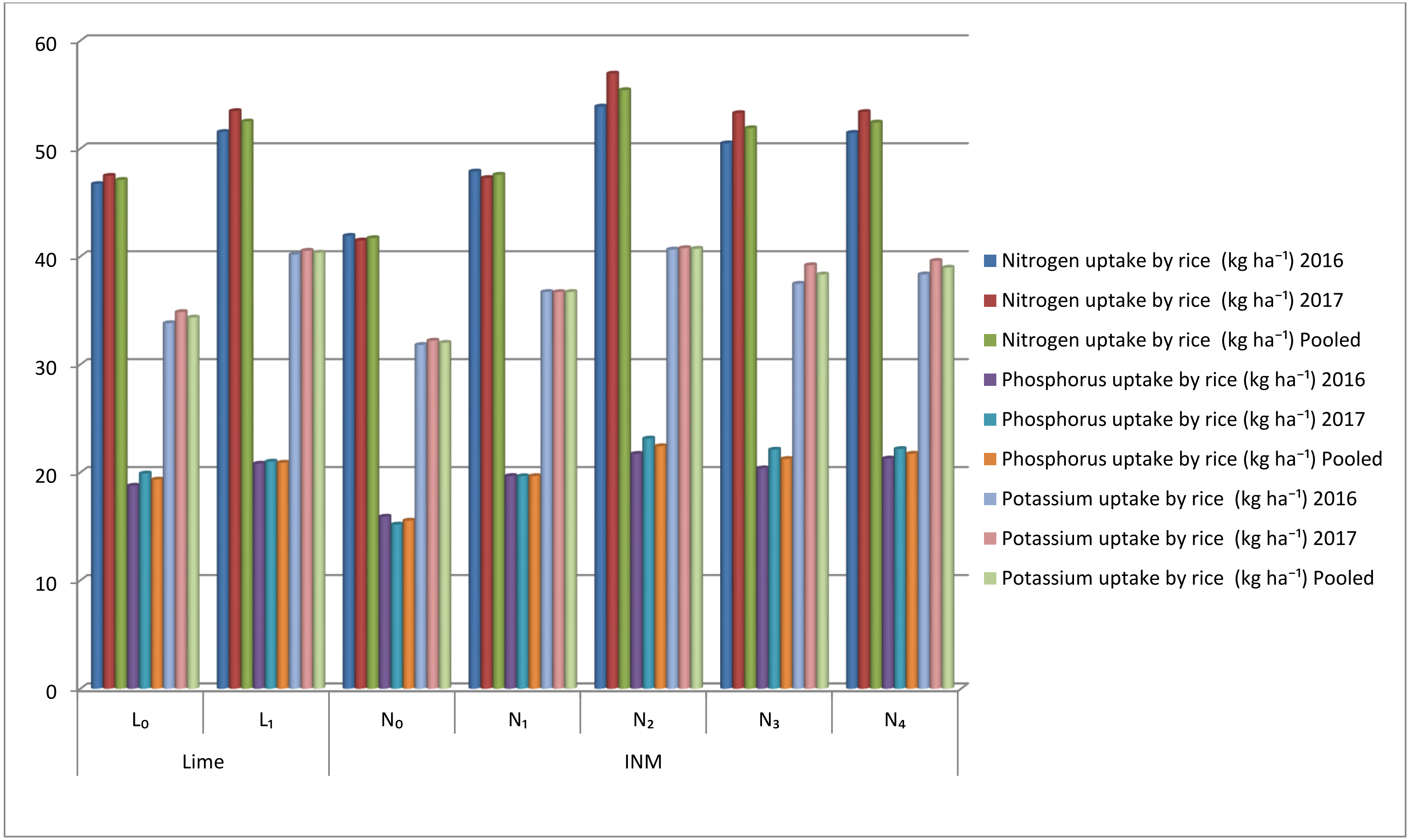


Fig 4.5(a) Effect of lime and integrated nutrient management on nutrient uptake (kg ha^{-1}) by rice

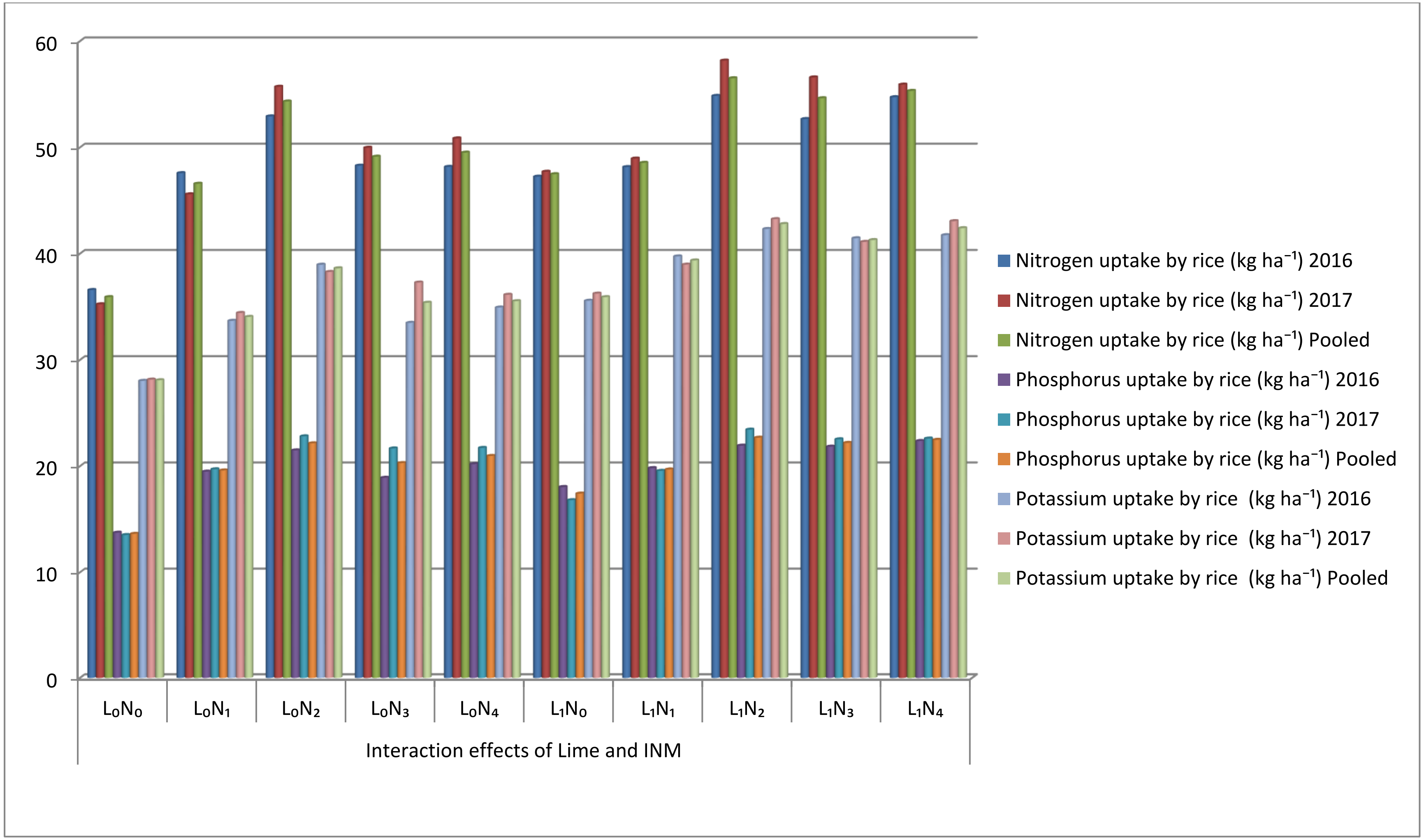


Fig 4.5(b) Interaction effects of lime and integrated nutrient management on nutrient (kg ha^{-1}) uptake by rice

4.5 Soil microbial population after harvest of rice

The data on bacteria, actinomycetes and fungi population due to various treatments between lime and INM are presented in Table 4.15 and their interaction effects are also presented in Table 4.15.

4.5.1 Bacteria (x 10^6 cfu g^{-1} soil)

Lime

The difference in bacterial population in soil was found to be significant under different lime levels during both the years of experiment. During the first year of experiment, the highest bacterial population (23.93 x 10^6 cfu g^{-1} soil) recorded with treatment L_1 (Lime @ 2 q ha^{-1}). The following year also recorded significantly higher bacterial population (27.60 x 10^6 cfu g^{-1} soil) with treatment L_1 (Lime @ 2 q ha^{-1}). Pooled data also recorded significant variation with the same trend of findings. The increase in bacterial population in lime treated plots may be due to addition of lime in the soils that neutralizes the soil acidity and creates better environmental conditions for microbial activity, nutrients release and their availability to plants. Lime application favours neutral soil pH and add Ca which is conducive for bacterial growth as reported by Verma (2017).

INM

The variations in bacterial population in soil due to INM levels were found significant during both the years of experiment. The highest bacterial population (30.67 x 10^6 cfu g^{-1} soil) was recorded for N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_0 (Control). Same trend of findings followed during the second year of experiment with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) giving the highest bacterial population (34.50 x 10^6 cfu g^{-1} soil) in soil. Pooled data complied with the findings of both the years and it was found that N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest bacterial population (32.58 x 10^6 x cfu g^{-1} soil) which was followed by N_4 (RDF (75%) + *Azospirillim* + PSB) while the lowest (10.17 x 10^6 cfu g^{-1} soil) was recorded

Table 4.15 Effect of lime and integrated nutrient management on microbial population after harvest of rice

Treatments	Bacteria (10^6 x cfu g^{-1} soil)			Actinomycetes (10^5 x cfu g^{-1} soil)			Fungi (10^3 x cfu g^{-1} soil)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
Lime									
L_0	18.00	18.87	18.43	1.27	1.27	1.27	12.60	13.73	13.17
L_1	23.93	27.60	25.77	1.80	1.93	1.87	16.73	18.33	17.53
SEm±	1.61	1.76	1.19	0.14	0.17	0.11	1.88	1.75	1.28
CD (P= 0.05)	4.78	5.24	3.42	0.41	0.50	0.31	NS	NS	NS
INM									
N_0	8.17	12.17	10.17	0.83	1.00	0.92	5.33	6.67	6.00
N_1	13.50	11.83	12.67	1.33	1.17	1.25	8.33	8.33	8.33
N_2	30.67	34.50	32.58	1.67	2.00	1.83	24.17	26.33	25.25
N_3	24.67	26.33	25.50	2.00	1.67	1.83	18.67	20.17	19.42
N_4	27.83	31.33	29.58	1.83	2.17	2.00	16.83	18.67	17.75
SEm±	2.54	2.79	1.89	0.22	0.26	0.17	2.98	2.76	2.03
CD (P= 0.05)	7.56	8.28	5.41	0.66	0.78	0.49	8.84	8.21	5.82
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

in control. The profound increase in bacterial population may be attributed due to application of FYM. The addition of FYM resulted in increase in organic matter which acts as a substrate for stimulation of bacterial growth (Kumar *et al.*, 2016). Selvi *et al*. (2004) as well as Verma (2017) also reported the increased bacterial counts with the addition of FYM along with chemical fertilizers. Among the microbes, bacteria constitute the most abundant group of microorganisms in the soil as compared to fungal and actinomycetes due to their high multiplication rate. This finding is in accordance with the findings of Walia *et al.* (2010) and Ndubuisi-Nnaji *et al.* (2011)

Interaction effects

Lime and INM interaction showed non-significant expression in response to lime and INM on rice during both the years of experiment.

4.5.2 Actinomycetes (x 10^5 cfu g^{-1} soil)

Lime

The data on actinomycetes population revealed significant variation due to different lime levels during both the years of experiment. During 2016, the highest actinomycetes population (1.80 x 10^5 cfu g^{-1} soil) was recorded from treatment L_1 (Lime @ 2 q ha^{-1}) over L_0 (without lime). During 2017, the highest actinomycetes population (1.93 x 10^5 cfu g^{-1} soil) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). Pooled data also showed significant variation with the highest actinomycetes population (1.87 x 10^5 cfu g^{-1} soil) recorded from treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest in L_0 (without lime). The increase in actinomycetes growth might be due to liming of acidic soils which creates favourable environment for microbial growth. These findings are in agreement with the findings of Verma (2017).

INM

Among the INM levels, actinomycetes population showed significant variation during both the years of experiment. It is indicated from the data that during 2016, highest actinomycetes population (2.00 x 10^5 cfu g^{-1} soil) was recorded from treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}). During 2017, the highest actinomycetes population (2.17 x 10^5 cfu g^{-1} soil) recorded from treatment N_4 (RDF (75%) + *Azospirillim* + PSB) followed by N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years clearly indicates that highest actinomycetes population (2.00 x 10^5 cfu g^{-1} soil) was recorded from treatment N_4 (RDF (75%) + *Azospirillim* + PSB). This might be due to increased root biomass production and addition of phosphatesolubilizing bacteria which resulted in higher production of root exudates increasing the beneficial actinomycetes population in rhizosphere region. This finding is in conformity with Panchal *et al*. (2018). Khan *et al*. (2017) supported the results that actinomycetes population were high in treatment where combination of organic and inorganic fertilizers were applied compared to 100% NPK and control.

Interaction effects

Lime and INM interaction failed to show significant expression in response to lime and INM on rice during both the years of experiment.

4.5.3 Fungi (x 10^3 cfu g^{-1} soil)

Lime

The differences in fungal population in soil were found to be non-significant under different lime levels during both years of experiment.

INM

The results clearly showed significant differences in fungal population in soil as influenced by different INM treatments during both the years of experiment. The highest mean fungi population of (24.17 x 10^3 cfu g^{-1} soil) and (26.33 x 10^3 cfu g^{-1} soil) was observed in treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) during 2016 and 2017 respectively. The lowest fungal load was recorded in treatment N_0 (Control). Pooled data of both the years showed significant variation with the highest value (25.25×10^3 cfu g^{-1} soil) recorded from N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The reason behind the growth of microorganisms may be due to decomposition of added FYM in soil which provides carbon and nitrogen as energy source and stimulates fungal growth. Similar findings reported by Gudadhe *et al*. (2015). Badole and More (2000) reported a higher fungal population with the application of FYM as compared to other organic as well as inorganic sources.

Interaction effects

Lime and INM interaction failed to show significant expression in response to lime and INM on rice during both the years of experiment.

4.6 Apparent balance sheet of nutrients after harvest of rice

The nutrient balance sheets as influenced by lime and integrated nutrient management during both the years of experiment are presented in Table 4.16.

4.6.1 Soil nitrogen balance sheet

The data showed that the maximum depletion of N (-35.11 kg ha^{-1}) and (-48.46 kg ha^{-1}) was recorded in treatment L_0N_0 (control) during 2016 and 2017 respectively. The maximum buildup of nitrogen (22.99 kg ha^{-1}) and (17.06 kg ha^{-1}) was observed in L_1N_2 (Lime @ 2q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) during 2016 and 2017 respectively. The result indicated that N replenishment through FYM with chemical fertilizer was enough to balance N removal by rice and the N balance was positive. This indicates that immediate crop requirement of nitrogen was met from the inorganic sources and later requirement with mineralization of organic sources, which enhanced the soil N status, this statement was in confirmation with Inbaraj (1995) and Hossain *et al*. (2010). Build-up in soil available N may be due to addition of higher levels of organic matter probability by the mineralization of organic matter leading to N availability. Though such nutrient supply practices enabled greater uptake of nutrients by rice, the balance of N after rice harvest was higher in all integrated

Table 4.16 Effect of lime and integrated nutrient management on nutrient balance sheet in soil after harvest of rice

A. NITROGEN

Treatments	Initial soil N (kg ha^{-1}) (a)		N added through organic and inorganic (kg ha^{-1}) (b)	Total initial (kg ha^{-1}) (c = a+b)		Crop removed N (kg ha^{-1}) (d)		Apparent N balance (kg ha^{-1}) (e = c-d)		Actual balance N after harvest (kg ha^{-1}) (f)		N gain through N fixation (g = f-e)		Depletion (-) / buildup (+) of N (h = f-a)	
	2016	2017		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T_1 (L_0N_0)	263.79	282.18	0	263.79	282.18	36.58	35.24	227.21	246.94	228.68	233.72	1.47	-13.22	-35.11	-48.46
T_2 (L_0N_1)	263.79	282.18	120	383.79	402.18	47.58	45.59	336.21	356.59	253.33	247.38	-82.88	-109.21	-10.46	-34.8
T_3 (L_0N_2)	263.79	282.18	120	383.79	402.18	52.92	55.71	330.87	346.47	282.87	285.56	-48	-60.91	19.08	3.38
T_4 (L_0N_3)	263.79	282.18	120	383.79	402.18	48.28	49.97	335.51	352.21	280.46	284.84	-55.05	-67.37	16.67	2.66
T_5 (L_0N_4)	263.79	282.18	120	383.79	402.18	48.17	50.85	335.62	351.33	277.76	279.71	-57.86	-71.62	13.97	-2.47
T_6 (L_1N_0)	263.79	282.18	0	263.79	282.18	47.25	47.71	216.54	234.47	269.43	271.75	52.89	37.28	5.64	-10.43
T_7 (L_1N_1)	263.79	282.18	120	383.79	402.18	48.15	48.95	335.64	353.23	272.1	276.4	-63.54	-76.83	8.31	-5.78
T_8 (L_1N_2)	263.79	282.18	120	383.79	402.18	54.85	58.17	328.94	344.01	286.78	299.24	-42.16	-44.77	22.99	17.06
T_9 (L_1N_3)	263.79	282.18	120	383.79	402.18	52.67	56.59	331.12	345.59	284.18	291.95	-46.94	-53.64	20.39	9.77
T_{10} (L_1N_4)	263.79	282.18	120	383.79	402.18	54.73	55.91	329.06	346.27	282.39	288.25	-46.67	-58.02	18.6	6.07

B. PHOSPHORUS

Treatments	Initial soil P (kg ha^{-1}) (a)		P added through organic and inorganic (kg ha^{-1}) (b)	Total initial (kg ha^{-1}) (c = a+b)		Crop removed P (kg ha^{-1}) (d)		Apparent P balance (kg ha^{-1}) (e = c-d)		Actual balance P after harvest (kg ha^{-1}) (f)		P gain through P fixation (g = f-e)		Depletion (-) / buildup (+) of P (h = f-a)	
	2016	2017		2016	2017	2016	2017	2016	2016	2017		2016	2017	2016	2017
T_1 (L_0N_0)	18.26	22.42	0	18.26	22.42	13.74	13.52	4.52	8.9	14.52	14.06	10	5.16	-3.74	-8.36
T_2 (L_0N_1)	18.26	22.42	60	78.26	82.42	19.49	19.71	58.77	62.71	18.03	17.56	-40.74	-45.15	-0.23	-4.86
T_3 (L_0N_2)	18.26	22.42	60	78.26	82.42	21.49	22.81	56.77	59.61	23.07	25.35	-33.7	-34.26	4.81	2.93
T_4 (L_0N_3)	18.26	22.42	60	78.26	82.42	18.91	21.67	59.35	60.75	22.52	22.98	-36.83	-37.77	4.26	0.56
T_5 (L_0N_4)	18.26	22.42	65	83.26	87.42	20.19	21.72	63.07	65.7	23.41	23.48	-39.66	-42.22	5.15	1.06
T_6 (L_1N_0)	18.26	22.42	0	18.26	22.42	18.04	16.8	0.22	5.62	22.14	22.63	21.92	17.01	3.88	0.21
T_7 (L_1N_1)	18.26	22.42	60	78.26	82.42	19.82	19.56	58.44	62.86	23.89	25.25	-34.55	-37.61	5.63	2.83
T_8 (L_1N_2)	18.26	22.42	60	78.26	82.42	21.93	23.44	56.33	58.98	26.59	28.45	-29.74	-30.53	8.33	6.03
T_9 (L_1N_3)	18.26	22.42	60	78.26	82.42	21.84	22.53	56.42	59.89	25.06	26.2	-31.36	-33.69	6.8	3.78
T_{10} (L_1N_4)	18.26	22.42	65	83.26	87.42	22.37	22.6	60.89	64.82	26.2	27.28	-34.69	-37.54	7.94	4.86

C. POTASSIUM

Treatments	Initial soil K (kg ha^{-1}) (a)		K added through organic and inorganic (kg ha^{-1}) (b)	Total initial (kg ha^{-1}) (c = a+b)		Crop removed K (kg ha^{-1}) (d)		Apparent K balance (kg ha^{-1}) (e = c-d)		Actual balance K after harvest (kg ha^{-1}) (f)		K gain through K fixation (g = f-e)		Depletion (-) / buildup (+) of K (h = f-a)	
	2016	**2017**		**2016**	**2017**	**2016**	**2017**	**2016**	**2016**	**2017**		**2016**	**2017**	**2016**	**2017**
T_1 (L_0N_0)	185.17	220.42	0	185.17	220.42	28.03	28.15	157.14	192.27	197.77	195.92	40.63	3.65	12.6	-24.5
T_2 (L_0N_1)	185.17	220.42	60	245.17	280.42	33.68	34.42	211.49	246	222.7	210.08	11.21	-35.92	37.53	-10.34
T_3 (L_0N_2)	185.17	220.42	60	245.17	280.42	38.96	38.28	206.21	242.14	246.79	257.5	40.58	15.36	61.62	37.08
T_4 (L_0N_3)	185.17	220.42	60	245.17	280.42	33.49	37.28	211.68	243.14	239.64	242.56	27.96	-0.58	54.47	22.14
T_5 (L_0N_4)	185.17	220.42	45	230.17	265.42	34.93	36.13	195.24	229.29	241.83	252.66	46.59	23.37	56.66	32.24
T_6 (L_1N_0)	185.17	220.42	0	185.17	220.42	35.57	36.24	149.6	184.18	221.6	218.11	72	33.93	36.43	-2.31
T_7 (L_1N_1)	185.17	220.42	60	245.17	280.42	39.74	38.97	205.43	241.45	250.08	263.46	44.65	22.01	64.91	43.04
T_8 (L_1N_2)	185.17	220.42	60	245.17	280.42	42.32	43.25	202.85	237.17	267.87	272.78	65.02	35.61	82.7	52.36
T_9 (L_1N_3)	185.17	220.42	60	244.17	279.42	41.45	41.11	202.72	238.31	267.44	270.24	64.72	31.93	82.27	49.82
T_{10} (L_1N_4)	185.17	220.42	45	230.17	265.42	41.74	43.06	188.43	222.36	264.32	270.04	75.89	47.68	79.15	49.62

nutrient management.

4.6.2 Soil Phosphorus balance sheet

The data showed that in control treatment (L_0N_0), the net gain was in negative side *viz*. (-3.74 kg P ha^{-1}) and (-8.36 kg P ha^{-1}) from the initial N values during 2016 and 2017 respectively. The decline in available P in control plot maybe due to more phosphorus uptake and no application in phosphorus availability. While, maximum build-up of P was recorded in treatment L_1N_2 (8.33 kg P ha^{-1}) and (6.03 kg P ha^{-1}) during 2016 and 2017, respectively. These findings are in agreement with the findings of Sahu (2017) who reported that phosphorus buildup with the application of NPK fertilizers and organics might be due to the release of organic acids produced from decomposition which in turn helped in releasing native phosphorus through solubilizing.

4.6.3 Soil Potassium balance sheet

The data showed that during 2016, potassium depletion was not recorded. The following year, maximum depletion (-24.5 kg ha^{-1}) was recorded in L_0N_0 (Control). The maximum build up of K in soil was recorded under treatment L_1N_2 (82.7 kg ha^{-1}) and (52.36 kg ha^{-1}) during 2016 and 2017, respectively. This might be due to the increased efficiency of utilization of applied K through integrated manner along with neutralization of acidity by liming. This is in line with the findings of Sahu (2017).

Residual effect of lime and INM on Pea

4.7 Residual effect of lime and INM and their interaction effects on growth attributes of succeeding pea

4.7.1 Plant height (cm)

The data on plant height (cm) depicted in Table 4.17(a) showed the residual effects of lime and INM and Table 4.17(b) showed its interaction effects on plant height (cm) at 30, 60 and at harvest for both the years of experimentation.

Lime

Residual effect of lime levels applied to preceding rice influenced significantly the plant height of succeeding pea at various growth stages for both the years of experimentation. During 2016-17, the highest plant height was found to be associated with treatment L_1 (Lime @ 2 q ha^{-1}) at 30, 60 DAS and at harvest *i.e.* 27.65 cm, 31.07 cm and 31.77 cm respectively, while the lowest was recorded with treatment L_0 (without lime). The following year also recorded the highest plant height *i.e.* 27.80 cm, 30.89 cm and 31.84 cm in treatment L_1 (Lime @ 2 q ha^{-1}) over L_0 (without lime). The pooled data for both the years recorded similar trend of findings with the highest plant height recorded from treatment L_1 (Lime @ 2 q ha^{-1}) as compared to L_0 (without lime). The increase in plant height in lime treated plots might be due to improvement of soil pH and other physical properties of soil such as bulk density, porosity and maximum water holding capacity that increases the plant availability of soil nutrients during crop growth period. These findings are in conformity with Meena and Prakasha (2019).

INM

With observation of the data, it further revealed that variations in plant height due to INM levels had significant residual effect on pea at various growth stages in both the years of experiment. During 2016-17, residual treatment of N_2 (RDF @ 75% + FYM @ 6 t ha^{-1}) recorded the highest plant height of 27.91cm, 31.10 cm, 31.89 cm at 30 DAS, 60 DAS and at harvest respectively which was statistically at par with residual treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}). The following year as well as the pooled data also showed significant variation reporting similar trend of findings with superior performance recorded from residue treatment of N_2 (RDF @ 75% + FYM @ 6 t ha^{-1}). The results indicated a profound influence of residual effect of FYM. Cellulose in FYM requires longer time for complete decomposition. Thus nutrients released from FYM have not been fully utilized by the rice crop

Table 4.17(a) Residual effect of lime and integrated nutrient management on plant height (cm) at different growth stages of pea

Treatments	Plant height (cm)								
	30 DAS			60 DAS			At harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime									
L_0	24.80	24.97	24.89	27.54	27.46	27.50	28.36	28.36	28.36
L_1	27.65	27.80	27.72	31.07	30.89	30.98	31.77	31.84	31.80
SEm±	0.30	0.33	0.22	0.25	0.28	0.19	0.27	0.25	0.18
CD (P= 0.05)	0.90	0.98	0.64	0.74	0.83	0.53	0.81	0.73	0.53
INM									
N_0	21.60	21.35	21.48	23.23	22.75	22.99	24.65	24.66	24.65
N_1	26.51	27.17	26.84	30.76	31.06	30.91	30.95	30.08	30.51
N_2	27.91	28.12	28.02	31.10	31.26	31.18	31.89	32.01	31.95
N_3	28.05	27.93	27.99	31.22	30.56	30.89	31.21	32.14	31.68
N_4	27.05	27.36	27.20	30.21	30.24	30.22	31.61	31.63	31.62
SEm±	0.48	0.52	0.35	0.39	0.44	0.29	0.43	0.39	0.29
CD (P= 0.05)	1.42	1.54	1.01	1.16	1.31	0.84	1.28	1.16	0.83

in first crop season and notably benefitted the succeeding pea crop. These results are in line with those of Sindhi *et al*. (2016). Similar findings on the beneficial residual effect of INM under cropping system on growth attributes was reported by Singh *et al*. (2001) in rice-lentil, Gawai and Pawar (2006) in sorghum-chickpea, Gudadhe (2008) in cotton-chickpea as well as Nawle *et al*. (2009) in sorghum-chickpea cropping sequence.

Interaction effects

Interaction between residual effects of different levels of lime and INM in preceding rice crop had significant effect on plant height of succeeding pea crop. During 2016-17, the highest plant height of 28.78 cm and 33.19 cm recorded with residual treatment L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) at 30 DAS and 60 DAS, while highest plant height of 33.86 cm recorded by treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) at harvest. During the year 2017-18, significantly highest plant height of 28.84 cm, 33.05 cm, 33.89 cm reported with residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) at 30, 60 DAS and at harvest respectively. The pooled data of both the years showed significant variation with similar trend of findings with highest plant height from residue treatment L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) at 30 DAS and L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) at 60 DAS and at harvest. The lowest recorded in L_0N_0 (Control) for both the years. The significant increased in plant height of pea might be due to the improvement in soil conditions and increased availability of nutrients through chemical fertilizer, manure and lime application, which is important during initial root growth, nutrient uptake and therefore plant development. Meena and Prakasha (2019) also reported similar findings on cowpea that the residual effect of the soil test value based fertilizer application + FYM + $ZnSO_4$ along with biochar and lime to the previous rice crop have a favorable effect on plant height of succeeding cowpea crop.

Table 4.17(b) Interaction on residual effects of lime and integrated nutrient management on plant height (cm) at different growth stages of pea

Treatments	Plant height (cm)								
	30 DAS			60 DAS			At harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime x INM									
L_0N_0	17.74	17.22	17.48	19.94	19.03	19.49	21.65	21.96	21.80
L_0N_1	25.75	26.65	26.20	29.90	30.47	30.19	30.04	28.17	29.10
L_0N_2	27.11	27.41	27.26	29.24	29.48	29.36	29.93	30.13	30.03
L_0N_3	27.32	27.05	27.19	29.25	29.05	29.15	29.89	31.26	30.58
L_0N_4	26.09	26.52	26.31	29.34	29.27	29.31	30.28	30.30	30.29
L_1N_0	25.46	25.48	25.47	26.52	26.46	26.49	27.65	27.36	27.51
L_1N_1	27.27	27.68	27.47	31.61	31.64	31.63	31.86	31.99	31.93
L_1N_2	28.71	28.84	28.77	32.96	33.05	33.00	33.86	33.89	33.87
L_1N_3	28.78	28.80	28.79	33.19	32.07	32.63	32.54	33.01	32.77
L_1N_4	28.01	28.19	28.10	31.07	31.21	31.14	32.94	32.95	32.94
SEm±	0.68	0.73	0.50	0.55	0.62	0.42	0.61	0.55	0.41
CD (P= 0.05)	2.01	2.18	1.43	1.65	1.85	1.19	1.81	1.64	1.18

4.7.2 Number of branches plant^{-1}

The data on number of branches plant^{-1} depicted in table 4.18 showed the residual effects of lime and INM and table 4.18 also showed its interaction effects on number of branches plant^{-1} at 30, 60 and at harvest for both the years of experimentation.

Lime

The data on number of branches plant^{-1} showed significant residual effect on pea at various growth stages for both the years of experimentation. During 2016, the maximum number of branches plant^{-1} was recorded in treatment L_1 (Lime @ 2 q ha^{-1}) *i.e.* (6.45), (10.58) and (11.98) at 30, 60 DAS and at harvest respectively, while the lowest was recorded with treatment L_0 (without lime). Similar trends were recorded in the second year with maximum number of branches plant^{-1} recorded in treatment L_1 (Lime @ 2 q ha^{-1}) *i.e.* (6.58), (10.94) and (12.31) at 30, 60 DAS and at harvest respectively. Pooled data also recorded similar findings with treatment L_1 (Lime @ 2 q ha^{-1}) giving the maximum number of branches plant^{-1} and lowest in L_0 (without lime). The highest number of branches in residual effect of lime treated plots might be attributed to improvement of soil pH and other soil physico-chemical properties that increases the nutrient availability during crop growth period. Similar results were reported by Meena and Prakasha (2019) on cowpea.

INM

The variations in number of branches plant^{-1} due to INM levels showed significant residual effect on pea at various growth stages during both the years of experiment. It is indicated from the data that during 2016-17, the highest number of branches plant^{-1} (6.54), (10.78) and (12.13) was recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and the lowest in N_0 (Control) and N_1 (RDF). Similarly, during 2017-18, the highest number of branches plant^{-1} (6.67), (11.11) and (12.57) recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}

Table 4.18 Residual effect of lime and integrated nutrient management on number of branches plant^{-1} at different growth stages of pea

Treatments	Number of branches plant^{-1}								
	30 DAS			60 DAS			At harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime									
L_0	5.98	6.04	6.01	8.96	9.30	9.13	10.13	10.25	10.19
L_1	6.45	6.58	6.52	10.58	10.94	10.76	11.98	12.31	12.15
SEm±	0.11	0.09	0.07	0.25	0.25	0.18	0.20	0.23	0.15
CD (P= 0.05)	0.32	0.27	0.20	0.74	0.74	0.51	0.58	0.67	0.43
INM									
N_0	5.59	5.61	5.60	6.89	7.06	6.97	7.74	7.61	7.67
N_1	6.22	6.39	6.31	10.33	10.89	10.61	11.67	12.06	11.86
N_2	6.54	6.67	6.60	10.78	11.11	10.94	12.13	12.57	12.35
N_3	6.43	6.56	6.49	10.61	11.06	10.83	11.69	12.18	11.94
N_4	6.31	6.34	6.32	10.22	10.48	10.35	12.06	11.99	12.02
SEm±	0.17	0.14	0.11	0.40	0.39	0.28	0.31	0.36	0.24
CD (P= 0.05)	0.51	0.42	0.32	1.18	1.17	0.80	0.92	1.06	0.68
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}). Pooled data also showed significant variation with the similar trend of findings on residual INM levels. Sindhi *et al*. (2016) reported that nutrient availability under residual INM treatments resulted into increased conversion of carbohydrates into protein which in turn elaborated into protoplasm and cell wall material increased the size of the cell, which expressed morphologically in number of branches. Similar beneficial residual effect of INM under cropping system on growth attributes of succeeding crops were recorded by Singh *et al*. (2001) in rice-lentil, Gawai and Pawar (2006) in sorghum-chickpea, Gudadhe (2008) in cotton-chickpea as well as Nawle *et al*. (2009) in sorghum-chickpea and Sindhi *et al*.(2016) in maize-greengram cropping sequence.

Interaction effects

Lime and INM interaction in both the years as well as the pooled data showed non-significant variation in response to residual lime and INM on pea at various growth stages.

4.7.3 Dry weight plant^{-1} (g)

The data on dry weight plant^{-1} (g) as influenced by residual levels of lime and different sources of nutrients was recorded at 30, 60 DAS and at harvest and presented in Table 4.19 and Table 4.19 also showed its interaction effects on dry weight plant^{-1} (g).

Lime

The results pertaining to dry weight plant^{-1} due to residual effect of lime levels failed to show significant variation at 60 DAS and at harvest during both the years of experiment. However, significant effect observed at 30 DAS due to residual lime levels during both years of experiment where highest dry weight was observed with treatment L_1 (Lime @ 2 q ha^{-1}), while the lowest was recorded with treatment L_0 (without lime). At 30 DAS showed significant variation with highest dry weight plant^{-1} of (0.64 cm) and (0.68 cm) during 2016-2017 and 2017-18 respectively. Pooled data also recorded significant

Table 4.19 Residual effect of lime and integrated nutrient management on dry weight plant^{-1} at different growth stages of pea

Treatments	Dry weight plant $^{-1}$ (g)								
	30 DAS			60 DAS			At harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime									
L_0	0.56	0.56	0.56	3.91	3.83	3.87	9.45	9.44	9.45
L_1	0.64	0.68	0.66	4.09	4.10	4.10	10.01	10.05	10.03
SEm±	0.01	0.01	0.01	0.10	0.13	0.08	0.38	0.39	0.27
CD (P= 0.05)	0.03	0.04	0.03	NS	NS	NS	NS	NS	NS
INM									
N_0	0.51	0.51	0.51	3.87	3.74	3.80	7.96	7.98	7.97
N_1	0.57	0.58	0.57	3.96	4.06	4.01	10.14	10.17	10.15
N_2	0.66	0.70	0.68	4.13	4.04	4.08	10.28	10.30	10.29
N_3	0.64	0.67	0.65	3.95	4.02	3.99	10.17	10.22	10.20
N_4	0.63	0.65	0.64	4.11	3.99	4.05	10.10	10.09	10.09
SEm±	0.02	0.02	0.01	0.15	0.21	0.13	0.60	0.61	0.43
CD (P= 0.05)	0.05	0.06	0.04	NS	NS	NS	NS	NS	NS
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

variation only at 30 DAS with highest dry weight plant^{-1} of (0.66 cm). The increase in dry weight in residual lime could be related to increase in plant height and number of branches plant^{-1}. Liming facilitates better uptake of nutrients and increased the vegetative growth which resulted in increased dry weight. Similar results were reported by Meena and Prakasha (2019) on residual effect of soil test value based fertilizer application and amendments on cowpea productivity in acidic soil.

INM

The results pertaining to dry weight plant^{-1} due to residual effect of different INM levels failed to show significant variation at 60 DAS and at harvest during both the years of experiment. However, significant variation observed at 30 DAS during both the years with the highest dry weight (0.66 g) and (0.70 g) recorded with residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The lowest was recorded in N_1 (RDF) and N_0 (Control). The increase in dry weight plant^{-1} could be due to the fact that more nutrient availability under residual INM treatments resulted in better plant height, number of branches and ultimately dry matter accumulation. This is in line with the findings of Sindhi *et al*. (2016).

Interaction effects

Lime and INM interaction failed to show significant expression in response to residual lime and INM on pea at various growth stages during both the years of experiment.

4.8 Residual effect of lime and INM on yield attributes of succeeding pea

The data on yield attributes of pea, number of pods plant^{-1}, number of seeds pod^{-1}, test weight (g) due to residual effect of lime and INM treatments are presented in Table 4.20(a) along with Fig 4.6 and 4.7 while their interaction effects are given in table 4.20(b). Finally pod yield (q ha^{-1}), stover yield (q ha^{-1}) and harvest index (%) due to the effects of lime and INM are given in Table

4.21(a) while their interaction effects are given in Table 4.21(b). Fig 4.8(a) and 4.8(b) showed the residual effects of lime and INM and their interaction effects on pod yield (q ha^{-1}).

4.8.1 Number of pods plant^{-1}

Lime

A close scrutiny of the data reveals that variation in lime had significant residual effect on the number of pods plant^{-1} of pea during both the years of experimentation. The highest number of pods plant^{-1} (3.93) and (4.02) of both the years was recorded in treatment L_1 (Lime @ 2 q ha^{-1}), while the lowest recorded with treatment L_0 (without lime). Pooled data of both the years also showed significant variation with the highest number of pods plant^{-1} (3.98) recorded in treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest recorded with treatment L_0 (without lime). The highest number of pods plant^{-1} is due to increased production of branches plant^{-1} with application of lime. These results are in conformity with the findings of Meena and Prakasha (2019) who reported that yield attributes of cowpea increased due to improvement of soil pH and other soil physico-chemical properties and the better nutrient uptake facilitated by liming.

INM

It is clearly evident from the data that there was significant residual impact in number of pods plant^{-1} due to variation in nutrient sources imposed to preceding rice crop. Treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded significantly highest number of pods plant^{-1} of (3.95) and (4.06) respectively in both years. Pooled data of both years reported significant variation with the highest number of pods plant^{-1} (4.00) reported from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest (3.31) in N_0 (Control). Numbers of pods plant^{-1} were significantly influenced due to residual effect of fertilizers and FYM applied in preceding rice. Such effect may be owing to the increased soil nutrient availability of native pool as well as their residual nutrients and improved soil physicochemical properties, water and nutrient-holding capacity of soil. These results are in accordance with Gawai and Pawar (2006) in sorghum-chickpea, Gudadhe (2008) in cotton-chickpea, Patil *et al*. (2008) in sorghum-chickpea, Nawle *et al.* (2009) in sorghum-chickpea, Saha *et al.* (2010) in maize- mustard, Shanwad *et al*. (2010) in maize-bengalgram, and Sindhi *et al*. (2016) in maize-greengram cropping sequence.

Interaction effects

The interaction effect of residual lime and nutrient sources failed to show any significant influence on number of pods plant^{-1} during the two years of study.

4.8.2 Number of seeds pod^{-1}

Lime

Residual effect of lime levels applied to preceding rice influenced significantly the number of seeds pod^{-1} of succeeding pea at various growth stages for both the year of experimentation. Treatment L_1 (Lime @ 2 q ha^{-1}) recorded highest number of seeds pod^{-1} *viz.* (4.69) and (4.77) respectively and the lowest recorded in treatment L_0 (without lime) of both the years. Pooled data of both the years also recorded similar trend of findings with the highest number of seeds pod^{-1} (4.73) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). These results are in conformity with the findings of Meena and Prakasha (2019).

INM

It is clear from the data that nutrient sources had significant residual effect on the number of seeds pod^{-1} during both the years of experiment. Among the nutrient sources, N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) recorded the highest number of seeds pod^{-1} (4.74) followed by N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The following year as well as the pooled data of both the years recorded the similar findings with highest number of seeds pod^{-1}

recorded from N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Lowest number of seeds pod^{-1} was recorded in N_0 (Control) followed by N_1 (RDF). The superiority of residual effect of integrated use of FYM and fertilizer application might be due to efficient utilization of mineralized nutrients from FYM along with atmospheric N fixed by the pea crop itself would have increased the availability of N throughout the growth period and thereby increased the assimilation of photosynthates which in turn better source and sink relationship led to better performance of pea. Latha *et al.* (2019) supported the findings that yield attributes of succeeding *rabi* crops were significantly influenced by the INM which imposed to preceding rice crop.

Interaction effects

The interaction effects of residual lime and INM levels as well as the pooled data on number of seeds pod^{-1} showed non-significant effect during the two years of experiment.

4.8.3 Test weight (g)

Lime

A perusal of the data showed that there was no significant residual effect due to lime application on test weight during the two years of experiment.

INM

It is clear from the data that there was no significant residual impact on test weight of succeeding pea crop by different INM levels during both years of experiment.

Interaction effects

Variation in test weight was found to be non-significant due to interaction effects of lime and INM levels during both the years of experiment.

Table 4.20(a) Residual effects of lime and integrated nutrient management on yield attributes of pea

Treatments	Number of pods plant^{-1}			Number of seeds pod^{-1}			Test weight (g)		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Lime									
L_0	3.49	3.53	3.51	4.12	4.17	4.14	40.32	39.86	40.09
L_1	3.93	4.02	3.98	4.69	4.77	4.73	40.78	41.08	40.93
SEm±	0.07	0.08	0.05	0.08	0.07	0.05	0.48	13.50	6.76
CD (P= 0.05)	0.21	0.24	0.16	0.23	0.21	0.15	NS	NS	NS
INM									
N_0	3.34	3.29	3.31	3.94	3.95	3.94	39.20	38.66	38.93
N_1	3.67	3.78	3.72	4.39	4.45	4.42	40.69	40.24	40.46
N_2	3.95	4.06	4.00	4.56	4.85	4.70	41.01	41.74	41.37
N_3	3.89	3.94	3.92	4.74	4.63	4.68	40.66	40.22	40.44
N_4	3.72	3.83	3.78	4.40	4.46	4.43	41.21	41.48	41.35
SEm±	0.11	0.13	0.09	0.12	0.11	0.08	0.76	21.35	10.68
CD (P= 0.05)	0.34	0.38	0.25	0.37	0.33	0.24	NS	NS	NS

Table 4.20(b) Interaction on residual effects of lime and integrated nutrient management on yield attributes of pea

Treatments	Number of pods plant^{-1}			Number of seeds pod^{-1}			Test weight (g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime x INM									
L_0N_0	2.89	2.78	2.84	3.32	3.33	3.33	38.48	37.79	38.14
L_0N_1	3.44	3.56	3.50	4.22	4.28	4.25	40.04	39.11	39.58
L_0N_2	3.78	3.89	3.84	4.28	4.67	4.47	40.38	41.14	40.76
L_0N_3	3.78	3.78	3.78	4.67	4.33	4.50	41.36	40.10	40.73
L_0N_4	3.56	3.67	3.61	4.11	4.22	4.17	41.35	41.14	41.24
L_1N_0	3.78	3.79	3.79	4.55	4.56	4.56	39.92	39.53	39.73
L_1N_1	3.89	4.00	3.95	4.56	4.61	4.59	41.33	41.37	41.35
L_1N_2	4.11	4.22	4.17	4.83	5.04	4.94	41.65	42.33	41.99
L_1N_3	4.00	4.11	4.05	4.81	4.92	4.86	39.95	40.33	40.14
L_1N_4	3.89	4.00	3.95	4.70	4.71	4.70	41.07	41.83	41.45
SEm±	0.16	0.18	0.12	0.17	0.16	0.12	1.07	30.19	15.10
CD (P= 0.05)	NS	NS	NS	NS	NS	0.34	NS	NS	NS

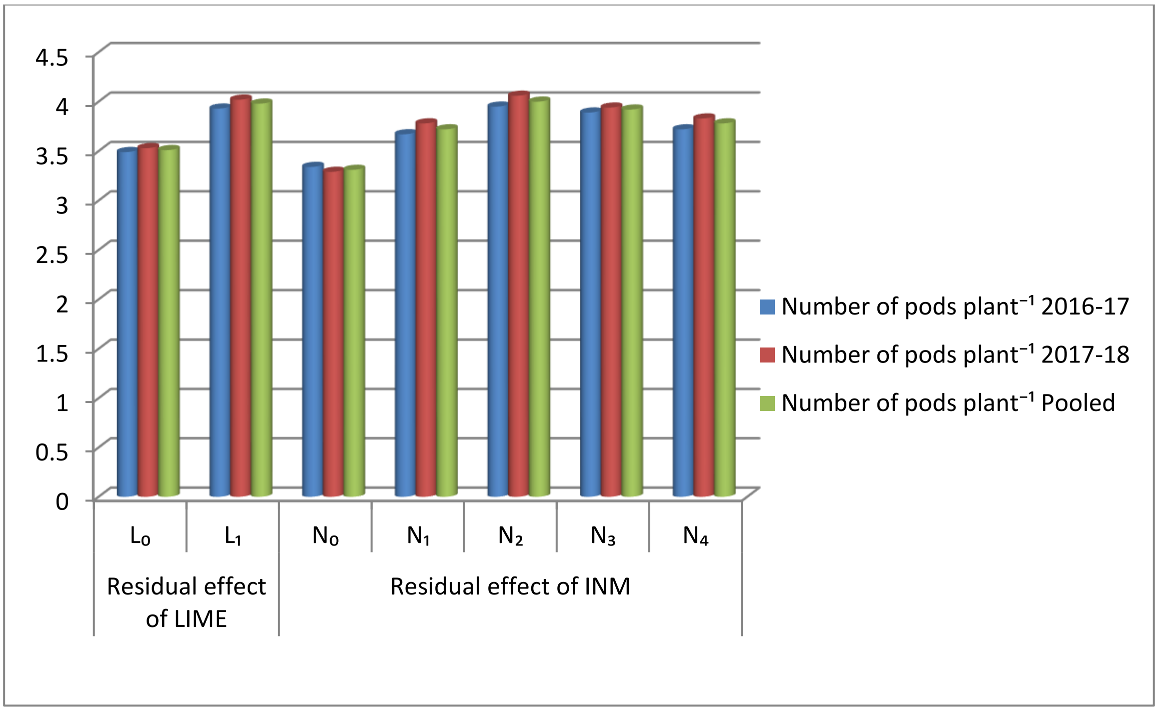


Fig 4.6 Residual effect of lime and integrated nutrient management on number of pods plant^{-1}

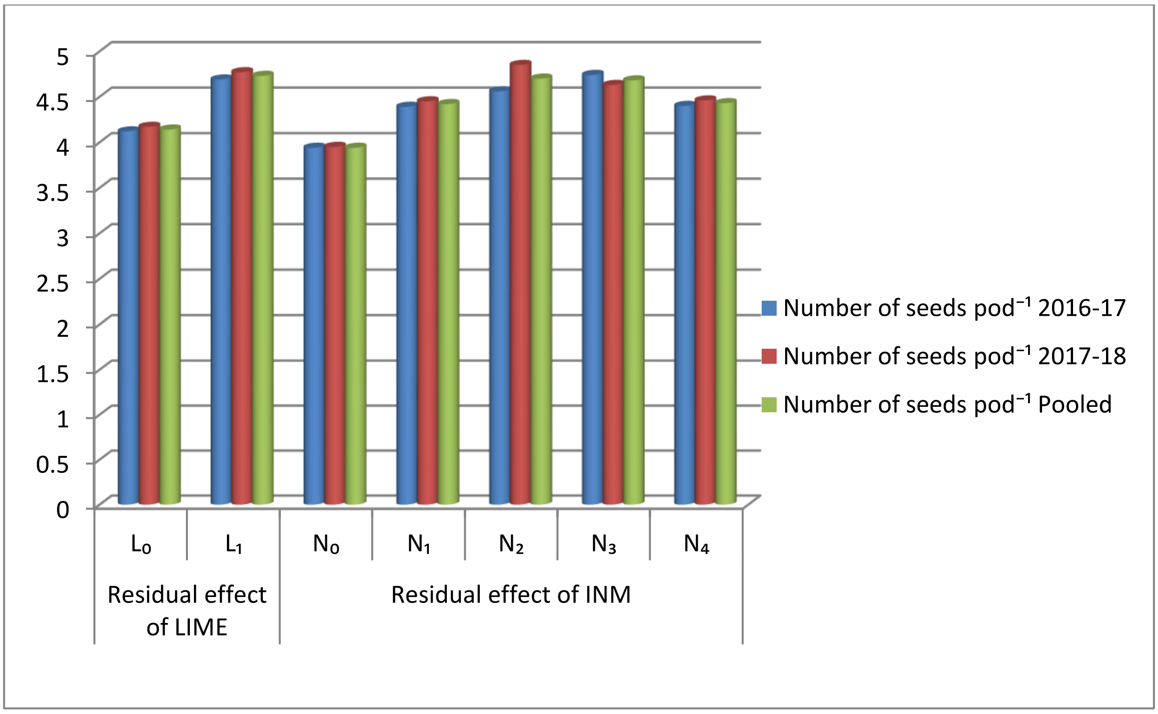


Fig 4.7 Residual effect of lime and integrated nutrient management on number of seeds pod^{-1}

4.8.4 Pod yield (q ha^{-1})

Lime

Variation in pod yield due to lime levels had significant residual effect during both years of study. During the first year of experiment, treatment L_1 (Lime @ 2 q ha^{-1}) recorded significantly higher pod yield (13.13 q ha^{-1}) over treatment L_0 (without lime). The following year also recorded significant variation with higher pod yield (13.54 q ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). Similar trend of findings were recorded for pooled data with the highest value (13.33 q ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). Residual effect of lime increased the pod yield of pea over no lime amended plots might be attributed to amelioration measures of acidic soil by lime application which improve soil pH and decrease exchangeable acidity and Al activity, which in turn resulted in excellent pod filling. The results are in agreement with the findings of Mathew and Thampatti (2007) and Meena and Prakasha (2019) who reported an increased seed yield of cowpea due to better uptake of nutrients facilitated by liming. Halvin *et al.* (2006) also reported that lime application increased and maintained higher grain yields than the control. This was because of the long-term residual effects of lime.

INM

Among the different INM levels, significant residual effect in pod yield observed during both the years of experiment. During the first year of experiment, the highest pod yield (13.46 q ha^{-1}) was recorded with residue treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). During the second year of experiment, significant variation was observed with the highest pod yield (14.10 q ha^{-1}) recorded from residue treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years revealed similar findings with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) giving the highest pod yield (13.78 q ha^{-1}). Residual treatment of N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4

(RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par for both the years. The lowest was recorded in N_0 (Control) followed by N_1 (RDF). The increased green pod yield might be due to addition of FYM to preceding rice due to improvement in soil structure which reduced the soil crusting and also serves as a source of energy for soil microflora which resulted in better root nodulation and nitrogen fixation of pea. The result is in conformation with those reported by Gudadhe *et al.* (2015) and Sindhi *et al.* (2016). Latha *et al.* (2019) also opined that application of INM to preceding rice crop increased *rabi* crop yields by 25-30% when compared to inorganic alone.

Interaction effects

The interaction effects due to lime and INM levels had significant residual impact on pod yield of succeeding pea crop during both the years of study. Application of L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest pod yield over all the treatments during both the years. Pooled data also showed significant variation with the highest pod yield (14.68 q ha^{-1}) observed from residue treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The results clearly indicated that the combined application of chemical fertilizer and FYM with lime significantly increased growth and yield attributes of pea, which ultimately results into higher pod yield. Lokose *et al.* (2015) reported similar findings that residual effect of RDF + FYM + lime recorded the maximum seed yield (0.55 t ha^{-1}) which was at par with residual RDF + FYM and closely followed by RDF + lime and RDF alone.

4.8.5 Stover yield (q ha^{-1})

Lime

Between residual lime levels, significant difference was observed on stover yield during both the years of experiment. Residual treatment L_1 (Lime @ 2 q ha^{-1}) recorded significantly higher stover yield over residual treatment L_0 (without lime) *i.e.* (17.70 q ha^{-1}) and (17.94 q ha^{-1}) in first and second year, respectively. Similar trend of findings were recorded for pooled data with the

Table 4.21(a) Residual effects of lime and integrated nutrient management on yield of pea

Treatments	Pod yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index (%)		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Lime									
L_0	10.97	11.31	11.14	14.57	14.53	14.55	43.10	43.66	43.38
L_1	13.13	13.54	13.33	17.70	17.94	17.82	42.53	42.89	42.71
SEm±	0.19	0.26	0.16	0.40	0.37	0.25	0.91	0.68	0.57
CD (P= 0.05)	0.58	0.77	0.47	1.20	0.90	0.72	NS	NS	NS
INM									
N_0	8.52	8.43	8.47	12.32	12.74	12.53	41.62	40.65	41.13
N_1	12.21	12.68	12.45	16.15	16.42	16.29	43.04	43.42	43.23
N_2	13.46	14.10	13.78	18.01	17.93	17.97	42.77	44.00	43.38
N_3	12.89	13.40	13.15	17.46	17.53	17.49	42.45	43.26	42.85
N_4	13.18	13.53	13.35	16.73	16.57	16.65	44.22	45.04	44.63
SEm±	0.31	0.41	0.26	0.64	0.48	0.40	1.44	1.07	0.90
CD (P= 0.05)	0.91	1.22	0.74	1.90	1.42	1.14	NS	NS	NS

Table 4.21(b) Interaction on residual effects of lime and integrated nutrient management on yield of pea

Treatments	Pod yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime x INM									
L_0N_0	6.30	6.24	6.27	8.54	8.33	8.44	43.16	43.02	43.09
L_0N_1	11.03	11.42	11.22	15.08	15.64	15.36	42.34	42.03	42.18
L_0N_2	12.72	13.04	12.88	17.32	16.72	17.02	42.36	43.76	43.06
L_0N_3	12.00	12.17	12.08	16.39	16.67	16.53	42.24	42.20	42.22
L_0N_4	12.83	13.70	13.27	15.50	15.28	15.39	45.41	47.30	46.36
L_1N_0	10.75	10.61	10.68	16.11	17.14	16.62	40.08	38.27	39.18
L_1N_1	13.39	13.94	13.67	17.22	17.19	17.21	43.73	44.82	44.28
L_1N_2	14.19	15.16	14.68	18.69	19.14	18.92	43.18	44.23	43.71
L_1N_3	13.78	14.64	14.21	18.53	18.39	18.46	42.65	44.32	43.49
L_1N_4	13.53	13.36	13.44	17.96	17.86	17.91	43.03	42.78	42.90
SEm±	0.44	0.58	0.36	0.90	0.84	0.56	2.03	1.52	1.27
CD (P= 0.05)	1.29	1.73	1.04	2.68	2.01	1.62	NS	NS	NS

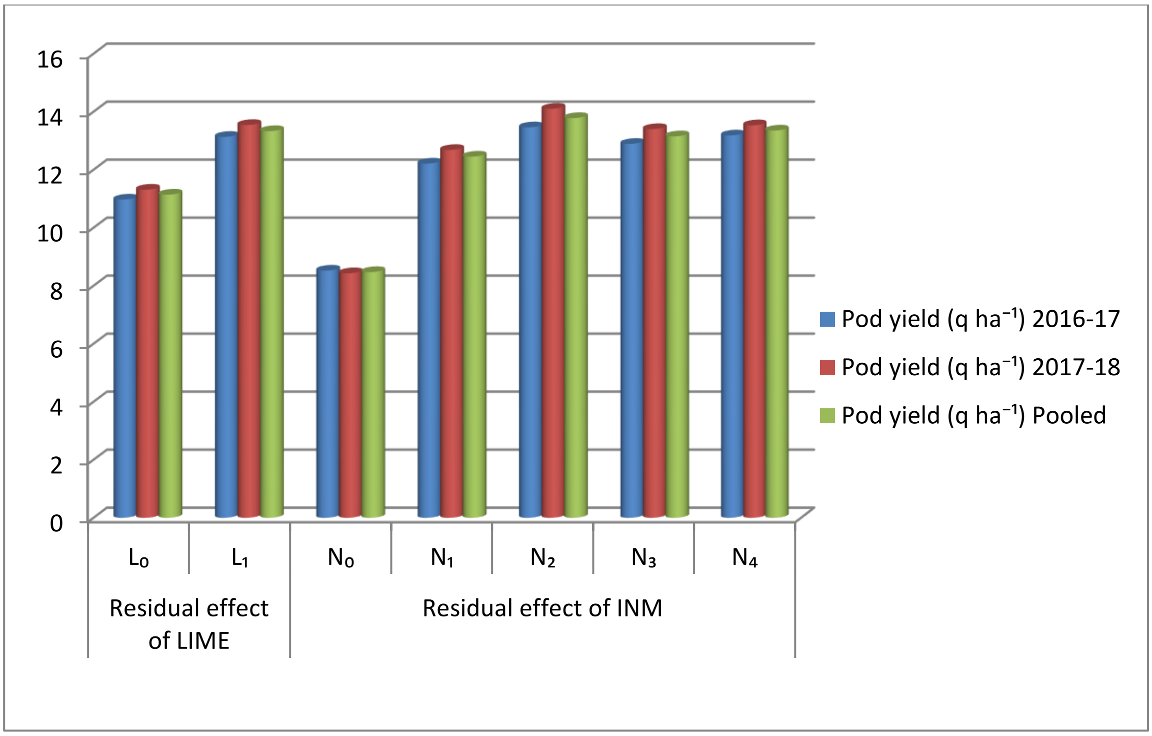


Fig 4.8(a) Residual effect of lime and integrated nutrient management on pod yield (q ha^{-1})

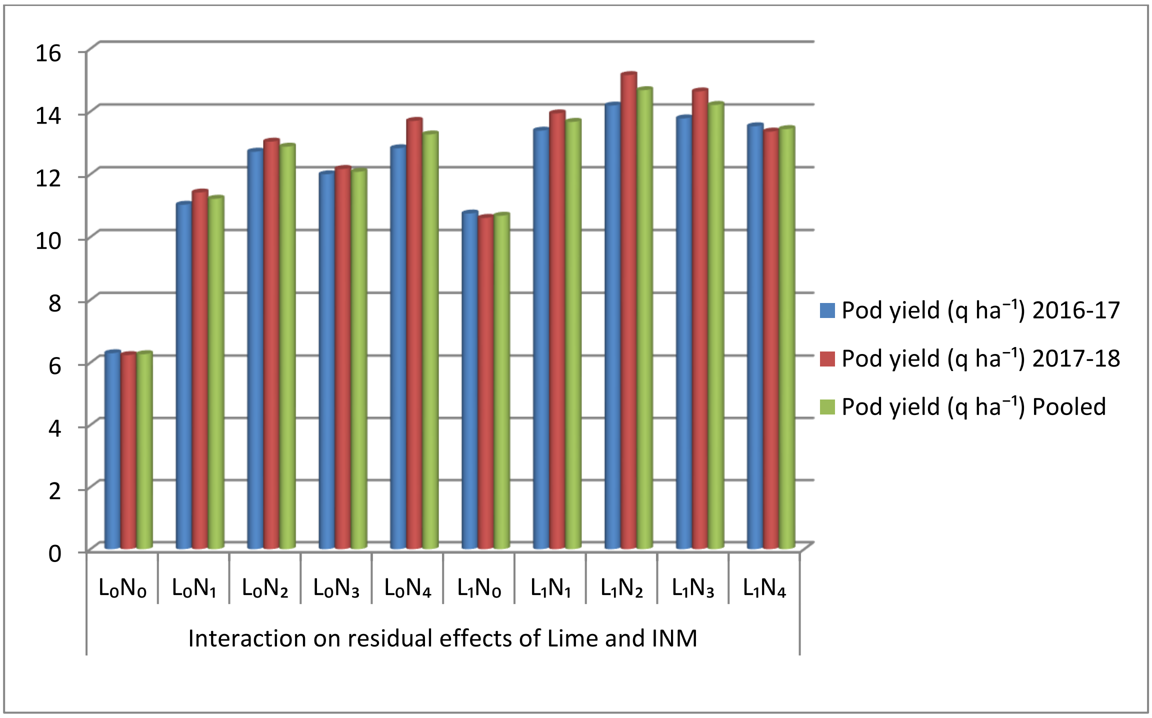


Fig 4.8(b) Interaction on residual effects of lime and integrated nutrient management on pod yield (q ha^{-1})

highest value (17.82 q ha^{-1}) recorded from residue treatment L_1 (Lime @ 2 q ha^{-1}). Increased stover yield of pea due to residual effect of liming in both the years could be attributed to increased plant height and branches $plant^{-1}$. The results are in agreement with the findings of Sorokhaibam *et al*. (2016).

INM

It is indicated from the data that stover yield differed significantly due to different residual INM levels during both the years of experiment. Amongst all the treatment, application of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) to rice recorded the highest stover yield of succeeding pea *i.e*. (18.01 q ha^{-1}) and (17.93 q ha^{-1}) in first and second year, respectively. Pooled data of both the years recorded similar trend of findings with the highest stover yield (17.97 q ha^{-1}) recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Significantly, higher stover yield under combined application of FYM and inorganic fertilizers might be due to increased plant height, number of branches $plant^{-1}$ and dry matter accumulation. The results are in conformity with the findings of Sindhi *et al*. (2016). Similar results also reported earlier by Singh *et al*. (2001) in rice-lentil, Gawai and Pawar (2006) in sorghum-chickpea and Gudadhe (2008) in cotton-chickpea cropping sequence.

Interaction effects

Variation in stover yield was found to be significant due to interaction effects of residual lime and INM levels during both the years of study. The highest stover yield was associated with the interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) followed by L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}). Pooled data of both the years recorded similar findings with the highest stover yield (18.92 q ha^{-1}) recorded from treatment interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). Residual treatment interactions of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par. Residual effect of lime, FYM and chemical fertilizer increased the stover yield of pea which might be due to the improvement in soil conditions and increased availability of nutrients through manure and lime application, and also to the addition of NPK which is important during initial root growth, nutrient uptake and therefore plant development. This is in line with the findings of Meena and Prakasha (2019).

4.8.6 Harvest index (%)

The variations on harvest index (%) among the lime, INM levels as well as their interactions were found to be non-significant during both the years of experiment.

4.9 Soil chemical and nutrient status of the soil after harvest of succeeding pea

The data on soil nutrient status, soil pH, organic carbon (%), available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}) and available potassium (kg ha^{-1}) as affected by residual lime and INM levels are presented in Table 4.22 along with depicted Fig 4.9 and Table 4.22 also showed its interaction effects.

4.9.1 Soil pH

Lime

Variation in soil pH due to lime levels had significant residual effect during both years of study. The residual treatment L_1 (Lime @ 2 q ha^{-1}) recorded significantly higher soil pH over treatment L_0 (without lime) during both the years of experiment. Pooled data of both the years also reported significant variation with the highest soil pH (5.06) recorded from residual treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). These results are in line with the findings of Temesgen *et al*. (2017) who reported that application of lime and its residual effect highly decreased exchangeable acidity and increase in soil pH.

INM

The differences in soil pH due to residual INM levels were found to be significant during both the years of experiment. The highest soil pH was recorded in residual treatment of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) during both the years. Pooled data also recorded similar findings with the highest soil pH (5.06) observed from N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest recorded in N_0 (Control). The results indicate that addition of FYM replenishes the soil with basic cations and increased the soil pH. These results concurs with the findings of Whalen *et al.* (2000) who reported that organic manure amended soil had significantly higher pH than non amended soil.

Interaction effects

The interaction effects as well as the pooled data on soil pH due to lime and INM failed to show significant response during the two years of study.

4.9.2 Organic carbon (%)

Lime

Soil organic carbon (%) due to residual lime levels had significant residual effect during both years of study. Pooled data of both the years showed significant variation with the highest soil organic carbon (1.42 %) recorded from residual lime treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). This could be attributed to the fact that lime-induced increases in root and shoot growth of crop and thus organic residue inputs to soil contribute to increases in soil organic carbon (Bronick & Lal 2005; Briedis *et al*., 2012).

INM

Variation in soil organic carbon (%) due to residual INM levels had significant residual effect during both years of study. Among the INM levels, residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded significantly higher organic carbon compared to other treatments during both years of study. Pooled data of both the years also recorded significantly higher soil organic carbon (1.47 %) recorded from residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB). The lowest soil organic carbon (1.23 %) was shown by N_0 (Control) followed by N_2 (RDF). The results indicated that residual INM treated soil showed significantly higher organic carbon content over 100 % RDF and control during both the years of study. This might be due to application of organic manure with chemical fertilizer which helped for building up of organic carbon. Mekala (2018) also reported similar findings where an absolute value of 0.05 and 0.12 % (relative increase of 9.09 and 19.99 %) higher organic carbon content was accumulated in residual INM plots over 100 % RDF irrespective of *rabi* crops.

Interaction effects

Variations in soil organic carbon due to interaction effects of residual lime and INM were found to be non-significant during both the years of experiment.

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

Lime

A scrutiny of data on available nitrogen in the soil revealed significant variation due to residual lime levels during both the years of study. During the first year, highest available nitrogen (281.96 kg ha^{-1}) in the soil increased with the application of residual lime treatment L_1 (Lime @ 2 q ha^{-1}) as compared to treatment L_0 (without lime). The following year recorded significant variation with the highest available nitrogen (294.79 kg ha^{-1}) recorded from residual lime treatment L_1 (Lime @ 2 q ha^{-1}). Pooled data of both the years also reported significant variation with similar trend of findings. The highest available nitrogen (288.38 kg ha^{-1}) observed from residual treatment L_1 (Lime

@ 2 q ha^{-1}) over treatment L_0 (without lime). Liming is the most widely used long-term method of soil acidity amelioration (Kaitibie *et al.*, 2002) and liming stimulates soil microbial activity and enhances N (Paradelo *et al.*, 2015).

INM

Variation in available nitrogen due to residual INM levels had significant residual effect during both years of study. In both the years, significantly higher available nitrogen in soil (287.83 kg ha^{-1}) and (300.56 kg ha^{-1}) was observed due to application of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) in preceding rice. Pooled data of both the years recorded significantly higher soil available nitrogen (294.19 kg ha^{-1}). Significantly lower availability of N in soil was recorded with application of N_1 (RDF) and N_0 (control) in both the years. This could be attributed to increased availability of N in the soil as a result of conjunctive application of organic and inorganic fertilizer to the preceding rice crop and the complimentary influence of organics in amending the soil conditions and inherent capacity to supply of these nutrients. These results were in agreement with those of Sharma and Dayal (2005) and Kaleeswari *et al.* (2012) who observed an increase in the residual NPK and their uptake by the succeeding crops. Senthilvalavan and Ravichandran (2019) also reported that the superiority of residual effect of FYM and bio-fertilizers through efficient utilization of mineralized N and Zn from FYM along with atmospheric N fixed by the crop itself have increased the availability of N throughout the growth period and thereby increased the assimilation of photosynthates which in turn better source and sink relationship led to better performance of rice fallow blackgram.

Interaction effects

Interaction effects of residual lime and INM levels failed to show significant variation during both years of experimentation.

4.9.4 Available phosphorus (kg ha^{-1})

Lime

The result of the examination further revealed that variations in available phosphorus due to residual lime levels had significant effect on pea during both years of study. During 2016-17, residue lime treatment L_1 (Lime @ 2 q ha^{-1}) recorded the highest available phosphorus (17.52 kg ha^{-1}) over L_0 (without lime). The following year also recorded significant variation with the highest available phosphorus (18.43 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). Pooled data of both the years revealed significant variation with the highest (17.97 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest in L_0 (without lime). The increase in soil pH and the reduction in exchangeable Al^{3+} resulted in increased soil available P (Moody *et al.,* 1998; Kanyanjua *et al*., 2002; The *et al.,* 2006). Due to its slow reactivity, the effects of lime on controlling soil acidity lasted longer than that of P fertilizer to maintain high soil available P. This was due to its long-term residual effects. Similar findings reported by Kisinyo *et al*. (2014).

INM

The result of the examination further revealed that variations in available phosphorus due to residual INM levels had significant residual effect on pea during both years of study. During 2016-17, treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) recorded significantly highest available phosphorus while the following year, treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) was significantly superior over all the treatments. Pooled data of both the years reported significant variation with the highest value (18.49 kg ha^{-1}) recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Residual treatments N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par. This could be attributed to increased availability of P in the soil as a result of conjunctive application of organic and inorganic fertilizer to the preceding rice crop and the complimentary influence of organics in amending the soil conditions and inherent capacity to supply of these nutrients. These results were in agreement with those of Sharma and Dayal (2005) and Kaleeswari *et al.* (2012) who observed an increase in the residual NPK and their uptake by the succeeding crops. The available P contents of the residual soil were depleted considerably as compared to initial. However, the amount of depletion of available P in the control and fertilizer treatment alone was greater than INM.

Interaction effects

Interaction effect of residual lime and INM showed non-significant effect on available phosphorus in the soil during the both years of experiment.

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

Lime

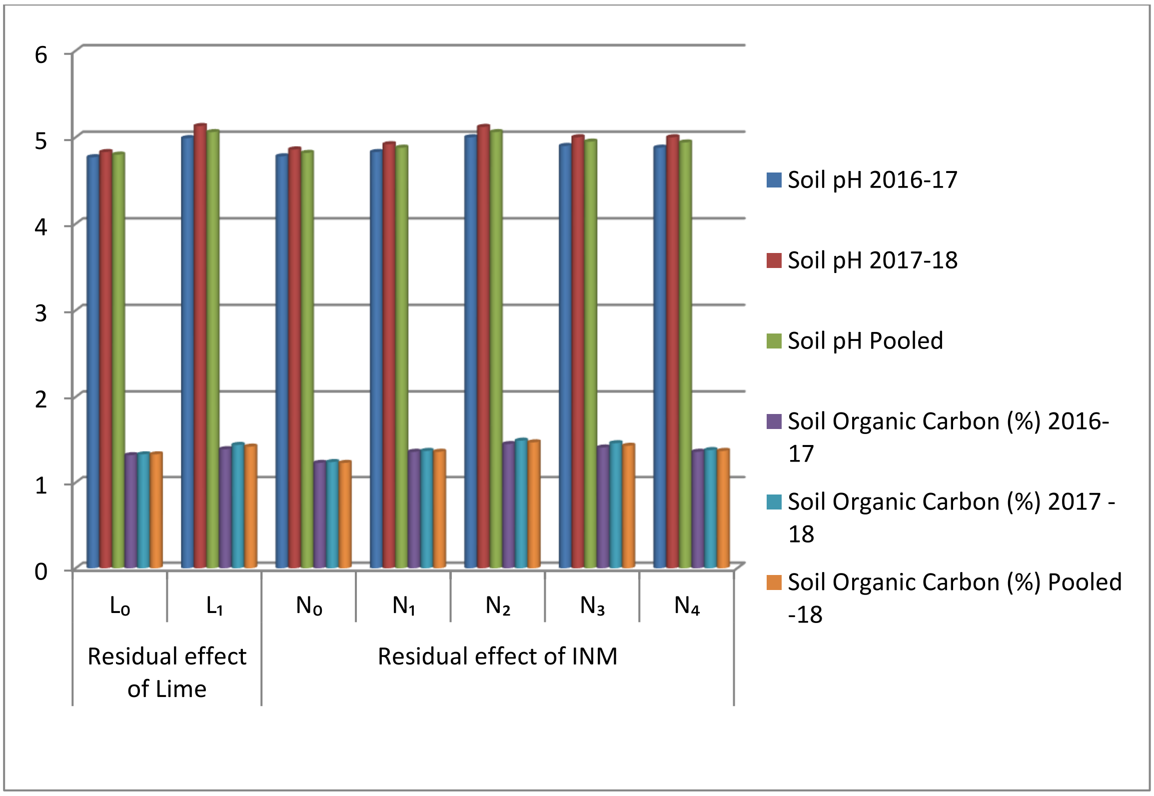
A keen examination of the data indicated that there was a significant effect in available potassium with the application of treatment L_1 (Lime @ 2 q ha^{-1}) compared to the treatment L_0 (without lime) of both the years. Pooled data of both the years also recorded significant variation with the highest available potassium (220.27 kg ha^{-1}) recorded with the application of treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). Liming increases potassium availability, owing to the displacement of exchangeable potassium by calcium. Similar finding was reported by Haynes and Naidu (1998).

INM

Significant effect of residual INM was observed on available potassium in the soil during both years of experiment. Treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded significantly superior on available potassium over the treatment N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB). Pooled data of both the years recorded significant variation with the highest available potassium (219.81 kg ha^{-1}) recorded from

Table 4.22 Residual effect of lime and integrated nutrient management on soil nutrient status after harvest of pea

Treatments	Soil nutrient status after harvest of pea														
	Soil pH			Soil Organic Carbon (%)			Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime															
L_0	4.77	4.83	4.80	1.32	1.33	1.33	266.67	268.49	267.58	14.95	14.79	14.87	197.55	200.02	198.78
L_1	4.99	5.13	5.06	1.39	1.44	1.42	281.96	294.79	288.38	17.52	18.43	17.97	217.21	223.32	220.27
SEm±	0.03	0.04	0.03	0.02	0.01	0.01	3.59	3.09	2.37	0.48	0.76	0.45	1.82	2.55	1.57
CD (P= 0.05)	0.10	0.11	0.07	0.05	0.03	0.03	10.68	9.19	6.80	1.41	2.26	1.29	5.41	7.58	4.50
INM															
N_0	4.78	4.86	4.82	1.23	1.24	1.23	250.89	254.86	252.87	13.01	13.11	13.06	193.01	194.46	193.74
N_1	4.83	4.92	4.88	1.36	1.37	1.36	264.79	269.41	267.10	14.68	14.36	14.52	200.62	203.94	202.28
N_2	5.00	5.12	5.06	1.45	1.49	1.47	287.83	300.56	294.19	17.93	19.05	18.49	216.90	222.73	219.81
N_3	4.90	5.00	4.95	1.41	1.46	1.43	285.27	294.42	289.84	18.04	18.29	18.16	215.45	217.39	216.42
N_4	4.88	5.00	4.94	1.36	1.38	1.37	282.82	288.96	285.89	17.52	18.26	17.89	210.93	219.83	215.38
SEm±	0.05	0.06	0.04	0.03	0.02	0.02	5.68	4.89	3.75	0.75	1.20	0.71	2.88	4.04	2.48
CD (P= 0.05)	0.16	0.18	0.12	0.08	0.05	0.05	16.89	14.53	10.75	2.24	3.57	2.03	8.56	11.99	7.11
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS



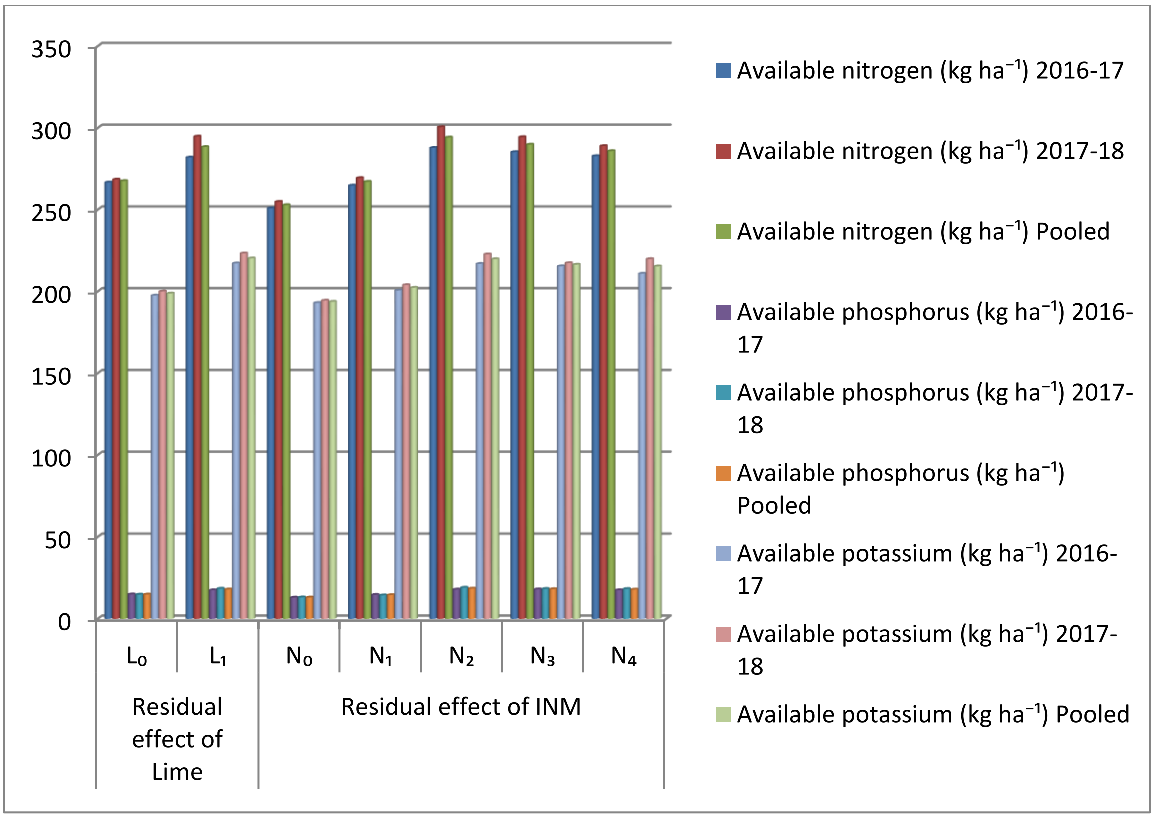


Fig 4.9 Residual effect of lime and integrated nutrient management on soil nutrient status after harvest of pea

treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). This could be due to conjunctive application of organic and inorganic fertilizer to the preceding rice crop and the complimentary influence of organics in amending the soil conditions and inherent capacity to supply of these nutrients. These results were concurred with the report of Sharma and Dayal (2005) and Kaleeswari *et al*. (2012). The available K contents of the residual soil were depleted considerably as compared to initial. However, the amount of depletion of available K in the control and fertilizer treatment alone was greater than the INM.

Interaction effects

Interaction effect of residual lime and INM showed non-significant effect on available potassium in the soil during both the years of experiment.

4.10 Plant analysis: Nutrient uptake (kg ha^{-1}) by succeeding pea

The data on plant nutrient uptake, nitrogen uptake (kg ha^{-1}), phosphorus uptake (kg ha^{-1}) and potassium uptake (kg ha^{-1}) as affected by residual lime and INM levels are presented in Table 4.23(a) to 4.25(a) along with Fig 4.10(a) and Table 4.23(b) to 4.25(b) with Fig 4.10(b) showed its interaction effects.

4.10.1 Nitrogen uptake (kg ha^{-1})

Lime

The variations on nitrogen uptake between residual lime levels were found to be significant during the two years of experiment as well as for the pooled data of both the years. The highest nitrogen uptake (27.79 kg ha^{-1}) was recorded for residual lime treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). The increase in residual lime treated plots can be attributed to increased pod and stover yields and increased N content in pod and stover and the better uptake of nutrients facilitated by liming. Sorokhaibam *et al.* (2016) reported that total N uptake by lathyrus was increased significantly under the liming treatment over no liming.

INM

The effect of residual INM levels on nitrogen uptake by the plant showed significant result during the two years of experiment as well as for pooled data of both the years. The highest uptake (28.46 kg ha^{-1}) was recorded for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) which was at par with N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) while the lowest was recorded with N_0 (Control). The increase in N uptake could be due to increased N availability in the soil as a result of conjunctive application organic and inorganic fertilizer to the preceding rice crop and the complimentary influence of organics in amending the soil conditions and inherent capacity to supply of these nutrients. Sharma and Dayal (2005), Kaleeswari *et al*. (2012) and Senthilvalavan and Ravichandran (2019) reported significantly increase in the residual NPK and their uptake by the succeeding crops.

Interaction effects

The interaction effect between residual lime and INM levels on plant nitrogen uptake was found to be significant during the two years of experiment. Pooled data of both the years also showed significant variation. The highest uptake (29.56 kg ha^{-1}) was recorded for interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The interaction effect of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be at par. These findings are in line with the findings of Basumatary (2018), who reported that residual effect of integrated S in combination with NPK, FYM and lime progressively increased the N uptake by blackgram in rapeseed-blackgram sequence.

Table 4.23(a) Residual effect of lime and integrated nutrient management on plant nitrogen uptake by pea

Treatments	Nitrogen uptake by pea (kg ha^{-1})								
	2016-17			2017-18			Pooled		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Lime									
L_0	12.89	10.79	23.68	12.78	11.06	23.84	12.84	10.92	23.76
L_1	14.97	12.60	27.57	15.16	12.85	28.01	15.06	12.73	27.79
SEm±	0.47	0.37	0.53	0.59	0.37	0.37	0.37	0.42	0.42
CD (P= 0.05)	1.38	1.57	1.56	1.75	1.39	1.96	1.09	1.24	1.21
INM									
N_0	10.62	8.87	19.49	10.06	9.03	19.09	10.34	8.95	19.29
N_1	14.00	11.71	25.71	13.96	11.84	25.79	13.98	11.77	25.75
N_2	15.28	12.83	28.11	15.44	13.37	28.82	15.36	13.10	28.46
N_3	14.65	12.60	27.25	15.31	12.92	28.23	14.98	12.76	27.74
N_4	15.10	12.46	27.56	15.09	12.62	27.71	15.09	12.54	27.63
SEm±	0.74	0.84	0.83	0.93	0.74	1.04	0.58	0.66	0.67
CD (P= 0.05)	2.19	2.49	2.47	2.76	2.19	3.10	1.72	1.96	1.91

Table 4.23(b) Interaction on residual effects of lime and integrated nutrient management on plant nitrogen uptake by pea

Treatments	Nitrogen uptake by pea (kg ha^{-1})								
	2016-17			2017-18			Pooled		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Lime x INM									
L_0N_0	7.37	6.11	13.48	6.27	6.05	12.32	6.82	6.08	12.90
L_0N_1	13.71	11.65	25.36	12.97	11.53	24.50	13.34	11.59	24.93
L_0N_2	14.70	12.11	26.81	14.84	13.09	27.93	14.77	12.60	27.37
L_0N_3	14.22	12.23	26.44	14.93	12.53	27.45	14.57	12.38	26.95
L_0N_4	14.44	11.86	26.30	14.92	12.08	27.00	14.68	11.97	26.65
L_1N_0	13.87	11.64	25.50	13.85	12.01	25.85	13.86	11.82	25.68
L_1N_1	14.29	11.78	26.07	14.94	12.14	27.08	14.62	11.96	26.57
L_1N_2	15.85	13.56	29.41	16.05	13.66	29.70	15.95	13.61	29.56
L_1N_3	15.08	12.98	28.06	15.70	13.31	29.01	15.39	13.14	28.54
L_1N_4	15.76	13.07	28.83	15.25	13.16	28.41	15.51	13.11	28.62
SEm±	1.04	0.84	1.17	1.31	0.84	0.84	0.82	0.93	0.94
CD (P= 0.05)	NS	NS	3.49	NS	NS	4.39	2.43	NS	2.71

4.10.2 Phosphorus uptake (kg ha^{-1})

Lime

The variation on phosphorus uptake between residual lime levels was found to be significant during both the years of experiment. Pooled data showed significant variation in phosphorus uptake with the highest uptake (9.41 kg ha^{-1}) recorded with L_1 (Lime @ 2 q ha^{-1}) and the lowest in L_0 (without lime). Similar results have been reported by Sorokhaibam *et al*. (2016) that liming breaks the Fe and Al phosphates in soil, increase P uptake by the crop which can be attributed to increased seed and stover yields and increased P and K content in seed and stover.

INM

The effect of residual INM levels on phosphorus uptake by the crop was found to be significant during both the year of experiment. During 2016 and 2017, the highest phosphorus uptake was recorded for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_0 (Control). While the pooled data also followed the same trend of finding with the highest phosphorus uptake (9.60 kg ha^{-1}) for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) while the lowest was recorded with N_0 (Control). This finding is in concordance with the findings of Sharma and Dayal (2005), Kaleeswari *et al.* (2012) and Senthilvalavan and Ravichandran (2016) who observed an increase in the residual NPK and their uptake by the succeeding crops.

Interaction effects

The interaction effect between residual lime and INM levels on plant phosphorus uptake was found to be non-significant during the two years of experiment. However, pooled data showed significant variation with the interaction effects between residual lime and INM on total phosphorus uptake with the highest phosphorus uptake (9.91 kg ha^{-1}) recorded from interaction L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The interaction effects of L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1})

Table 4.24(a) Residual effect of lime and integrated nutrient management on plant Phosphorus uptake by pea

Treatments	Phosphorus uptake by pea (kg ha^{-1})								
	2016-17			2017-18			Pooled		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Lime									
L_0	5.01	3.07	8.08	5.00	3.14	8.13	5.00	3.10	8.11
L_1	5.53	3.74	9.27	5.68	3.87	9.55	5.60	3.81	9.41
SEm±	0.17	0.37	0.22	0.17	0.37	0.37	0.10	0.11	0.15
CD (P= 0.05)	0.51	0.46	0.66	0.50	0.38	0.63	0.29	0.34	0.44
INM									
N_0	4.52	2.67	7.19	4.60	2.60	7.21	4.56	2.64	7.20
N_1	5.01	3.34	8.36	5.20	3.40	8.60	5.11	3.37	8.48
N_2	5.74	3.79	9.53	5.74	3.92	9.66	5.74	3.86	9.60
N_3	5.61	3.78	9.39	5.71	3.91	9.62	5.66	3.84	9.51
N_4	5.46	3.46	8.92	5.44	3.69	9.13	5.45	3.57	9.03
SEm±	0.27	0.25	0.35	0.27	0.20	0.33	0.15	0.18	0.24
CD (P= 0.05)	0.81	0.73	1.05	0.79	0.60	0.99	0.46	0.54	0.70

Table 4.24(b) Interaction on residual effects of lime and integrated nutrient management on plant phosphorus uptake by pea

Treatments	Phosphorus uptake by pea (kg ha^{-1})								
	2016-17			2017-18			Pooled		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Lime x INM									
L_0N_0	3.94	1.80	5.74	3.93	1.76	5.69	3.93	1.78	5.72
L_0N_1	4.84	3.13	7.97	4.70	2.98	7.68	4.77	3.06	7.83
L_0N_2	5.59	3.65	9.23	5.64	3.68	9.32	5.61	3.67	9.28
L_0N_3	5.47	3.69	9.16	5.63	3.81	9.44	5.55	3.75	9.30
L_0N_4	5.21	3.10	8.31	5.09	3.44	8.53	5.15	3.27	8.42
L_1N_0	5.09	3.54	8.63	5.28	3.44	8.72	5.19	3.49	8.67
L_1N_1	5.19	3.56	8.75	5.71	3.81	9.51	5.45	3.68	9.13
L_1N_2	5.89	3.93	9.82	5.84	4.16	10.00	5.87	4.05	9.91
L_1N_3	5.76	3.87	9.63	5.79	4.01	9.80	5.78	3.94	9.71
L_1N_4	5.72	3.81	9.53	5.79	3.95	9.74	5.75	3.88	9.63
SEm±	0.39	0.84	0.50	0.38	0.84	0.84	0.22	0.26	0.34
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.99

and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be at par. Similar findings in the P uptake was reported by Basumatary (2018), who found that residual effect of integrated S in combination with NPK, FYM, lime progressively increased the P uptake by blackgram in rapeseed-blackgram sequence.

4.10.3 Potassium uptake (kg ha^{-1})

Lime

The variations on potassium uptake between lime levels were found to be significant during both the years of experiment. During 2016, the highest potassium uptake (13.54 kg ha^{-1}) was recorded with L_1 (Lime @ 2 q ha^{-1}) and the lowest in L_0 (without lime). The following year of experiment recorded similar trend of result with the highest value (13.71 kg ha^{-1}) recorded for treatment L_1 (Lime @ 2 q ha^{-1}) and the lowest recorded in L_1 (without lime). Pooled data also showed significant variation with treatment L_1 (Lime @ 2 q ha^{-1}) giving the highest value (13.62 kg ha^{-1}). Sorokhaibam *et al*. (2016) observed that liming facilitate better nutrient uptake and hence increase K uptake by the crop.

INM

The effect of residual INM levels on potassium uptake by the crop was found to be significant during both the years of experiment. During 2016, the highest potassium uptake (13.99 kg ha^{-1}) was recorded for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_0 (Control). The following year, N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) recorded the highest potassium uptake (14.09 kg ha^{-1}) followed by treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years also showed significant variation with the highest potassium uptake (13.95 kg ha^{-1}) recorded for treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) while the lowest was recorded with N_0 (Control). The higher K uptake could be due to increased K availability in the soil as a result of conjunctive application of organic and inorganic fertilizer to the

Table 4.25(a) Residual effect of lime and integrated nutrient management on plant Potassium uptake by pea

Treatments	Potassium uptake by pea (kg ha^{-1})								
	2016-17			2017-18			Pooled		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Lime									
L_0	8.34	3.61	12.09	8.37	3.46	11.96	8.36	3.54	12.02
L_1	9.69	4.10	13.54	9.85	4.12	13.71	9.77	4.11	13.62
SEm±	0.40	0.37	0.46	0.37	0.37	0.37	0.19	0.11	0.34
CD (P= 0.05)	1.19	0.48	1.35	1.10	0.50	1.50	0.58	0.32	0.98
INM									
N_0	6.64	2.98	10.08	6.48	3.03	9.42	6.56	3.00	9.75
N_1	9.25	4.01	13.22	9.35	3.70	13.49	9.30	3.86	13.35
N_2	9.81	4.06	13.99	9.97	3.92	13.92	9.89	3.99	13.95
N_3	9.81	4.11	13.56	9.94	4.15	14.09	9.88	4.13	13.83
N_4	9.55	4.13	13.23	9.81	4.15	13.23	9.68	4.14	13.23
SEm±	0.63	0.26	0.72	0.58	0.27	0.80	0.31	0.17	0.54
CD (P= 0.05)	1.88	0.76	2.14	1.74	0.80	2.37	0.91	0.50	1.54

Table 4.25(b) Interaction on residual effects of lime and integrated nutrient management on plant potassium uptake by pea

Treatments	Potassium uptake by pea (kg ha^{-1})								
	2016-17			2017-18			Pooled		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Lime x INM									
L_0N_0	4.04	2.01	6.82	3.97	2.11	6.50	4.00	2.06	6.66
L_0N_1	9.17	3.91	12.97	9.03	3.29	12.52	9.10	3.60	12.74
L_0N_2	9.50	3.95	13.70	9.57	3.67	13.27	9.54	3.81	13.49
L_0N_3	9.56	4.08	12.94	9.69	4.11	13.81	9.63	4.10	13.38
L_0N_4	9.42	4.11	14.01	9.60	4.15	13.68	9.51	4.13	13.85
L_1N_0	9.24	3.94	13.35	9.00	3.95	12.35	9.12	3.95	12.85
L_1N_1	9.34	4.11	13.47	9.66	4.11	14.46	9.50	4.11	13.96
L_1N_2	10.12	4.16	14.27	10.37	4.18	14.56	10.24	4.17	14.42
L_1N_3	10.06	4.13	14.18	10.20	4.19	14.38	10.13	4.16	14.28
L_1N_4	9.68	4.14	12.44	10.01	4.15	12.78	9.85	4.15	12.61
SEm±	0.89	0.84	1.02	0.83	0.84	0.84	0.43	0.24	0.76
CD (P= 0.05)	NS	NS	3.03	NS	NS	NS	1.29	0.71	2.18

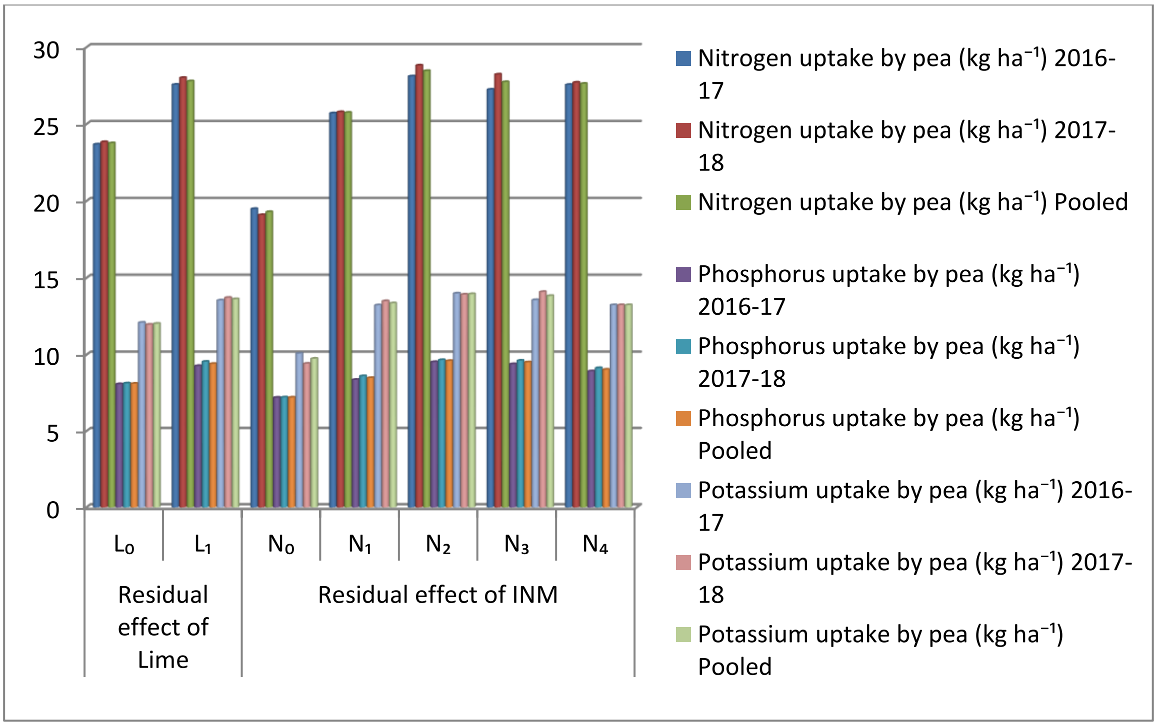


Fig 4.10(a) Residual effect of lime and integrated nutrient management on plant nutrient uptake (kg ha^{-1}) by pea

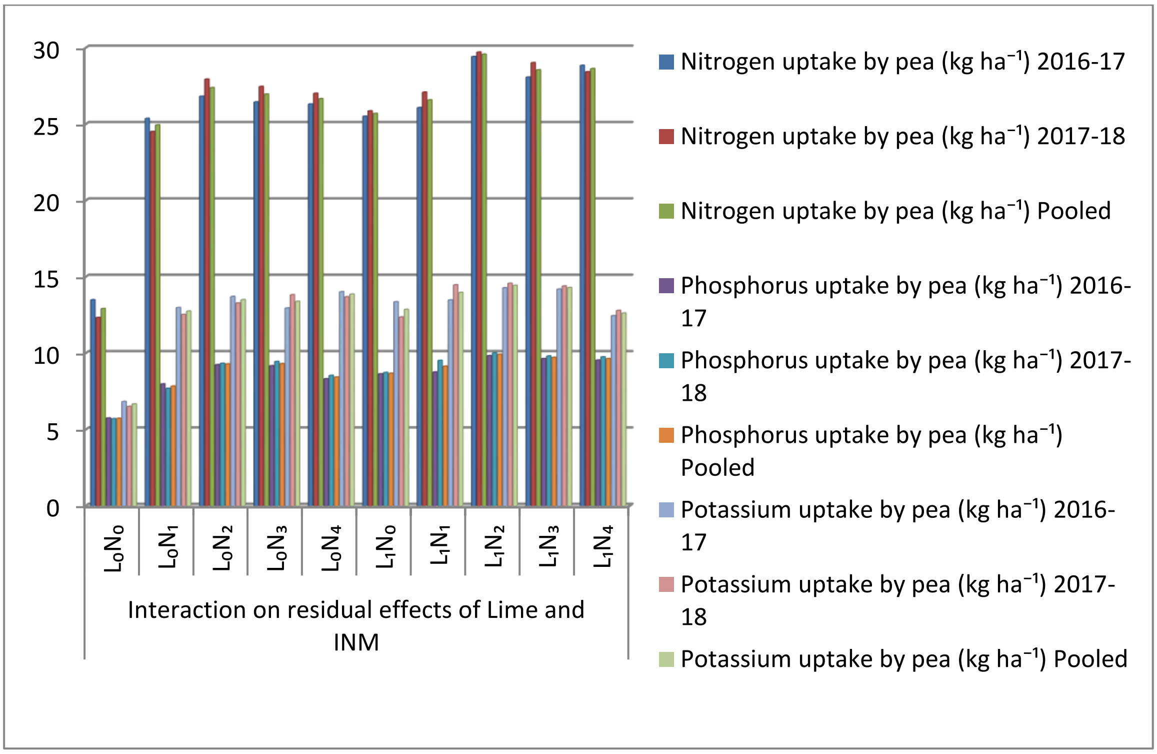


Fig 4.10(b) Interaction on residual effects of lime and integrated nutrient management on plant nutrient uptake (kg ha^{-1}) by pea

preceding rice crop and the complimentary influence of organics in amending the soil conditions and inherent capacity to supply of these nutrients. These results were in agreement with those of Sharma and Dayal, 2005; Kaleeswari *et al*., 2012; Senthilvalavan and Ravichandran, 2019 who observed an increase in the residual NPK and their uptake by the succeeding crops.

Interaction effects

Among the residual lime and INM levels, the effect on potassium uptake by the crop was found to be significant during the first year of experiment with the highest recorded from residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years also showed significant variation with the same trend of findings with the highest potassium uptake (14.42 kg ha^{-1}) recorded from residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). Similar findings uptake pattern of K was reported by Basumatary (2018), who found that residual effect of integrated S in combination with NPK, FYM and lime progressively increased the K uptake by blackgram in rapeseed-blackgram sequence.

4.11 Residual effect of lime and INM on soil microbial population after harvest of succeeding pea

The data on bacteria, actinomycetes and fungi population as affected by residual lime and INM levels are presented in Table 4.26 with Fig 4.38 and its interaction effects are also given in Table 4.26.

4.11.1 Bacteria (x 10^6 cfu g^{-1} soil)

Lime

The variations on bacterial population due to residual effect between lime levels were found to be non-significant during both the years of experiment.

INM

Among the residual effect of INM levels on bacterial population was found to be significant during both the years of experiment. During 2016-17 and 2017-18, the highest bacterial population was recorded in residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years also recorded significant variation with the highest bacterial population (17.42 x 10^6 cfu g^{-1} soil) recorded from residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_0 (control). The results indicated that residual INM treated soil showed significantly superior bacterial population over 100 % RDF and control during both years of study. This might be due to inclusion of organics in INM treatment which favorably improves the bacterial population. Similar findings were reported by Mekala (2018).

Interaction effects

The interaction effects between residual lime and INM levels on bacterial population were found to be non-significant during the two years of experiment.

4.11.2 Actinomycetes (x 10^5 cfu g^{-1} soil)

Lime

The residual effect due to residual lime levels on actinomycetes population was found to be non-significant in both the experiments.

INM

The data clearly indicates that nutrient sources had significant residual impact on actinomycetes population only during the first year of experiment. The highest actinomycetes population was recorded from the residual treatment of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) for both the years. Pooled data of both the years also showed significant variation with the highest actinomycetes population (1.50 x 10^5 cfu g^{-1} soil) recorded from the residual treatment of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The results indicated that residual INM treated soil showed significantly higher actinomycetes population over 100 % RDF and control during both years of study. The INM improves the actinomycetes population favorably with inclusion of organics. Similar findings were also reported by Mekala (2018).

Interaction effects

The interaction effect on actinomycetes population due to residual lime and INM levels were found to be non-significant during both the years of experiment.

4.11.3 Fungi (x 10^3 cfu g^{-1} soil)

Lime

A scrutiny of data on fungal population in the soil revealed non-significant variation due to residual lime levels during both the years of study.

INM

The data clearly indicates that fungal population differed significantly due to different residual INM levels during both the years of experiment. The highest fungal population for both the years recorded significant variation with the highest value recording from residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Pooled data of both the years also recorded significant variation with the highest fungal population (15.83 x 10^3 cfu g^{-1} soil) recorded from residual treatment of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). The results indicated that residual INM treated soil showed significantly higher fungal population over 100 % RDF and control during both years of study. This might be due to inclusion of organics in INM treatment which favorably improves the fungal population. A similar finding wasalso reported by Mekala (2018).

Interaction effects

The interaction effects due to residual lime and INM levels were found to be non-significant during both the years of experiment.

Table 4.26 Residual effect of lime and integrated nutrient management on microbial population after harvest of pea

Treatments	Bacteria (10^6 x cfu g^{-1} soil)			Actinomycetes (10^5 x cfu g^{-1} soil)			Fungi (10^3 x cfu g^{-1} soil)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Lime									
L_0	10.07	13.13	11.60	0.80	1.20	1.00	9.80	10.87	10.33
L_1	9.20	9.93	9.57	0.93	1.40	1.17	11.93	13.27	12.60
SEm±	1.06	1.35	0.86	0.14	0.15	0.10	0.83	0.85	0.59
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
INM									
N_0	3.17	4.17	3.67	0.33	0.83	0.58	6.33	6.33	6.33
N_1	6.17	9.67	7.92	0.67	1.17	0.92	10.67	10.83	10.75
N_2	16.67	18.17	17.42	1.33	1.67	1.50	15.00	16.67	15.83
N_3	9.33	12.33	10.83	0.83	1.50	1.17	11.67	14.83	13.25
N_4	12.83	13.33	13.08	1.17	1.33	1.25	10.67	11.67	11.17
SEm±	1.68	2.13	1.36	0.23	0.24	0.16	1.32	1.34	0.94
CD (P= 0.05)	5.00	6.33	3.89	0.67	NS	0.47	3.91	3.99	2.70
Interaction of L x N	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.12 Apparent balance sheet of nutrients after harvest of succeeding pea

The nutrient balance sheets as influenced by residual lime and integrated nutrient management on succeeding pea during both the years of experiment are presented in Table 4.27.

4.12.1 Soil nitrogen balance sheet

During the first year and second year of experiment, the highest actual balance of nitrogen in the soil after harvest was recorded in residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}), which also recorded the highest nitrogen build up of (3.32 kg ha^{-1}) and (13.77 kg ha^{-1}) during both the years respectively. The highest buildup of nitrogen status in residual treatments of lime, chemical fertilizers and FYM treated plots may be due to maximum population of bacteria which fix atmospheric nitrogen to the soil and add nutrient to the soil. The study results are in line with the findings of Bano and Iqbal (2016).

4.12.2 Soil Phosphorus balance sheet

All the residual treatments showed depletions with the maximum depletion recorded from residual L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) of (-8.27 kg ha^{-1}) and (-8.66 kg ha^{-1}) respectively for both the years of experiment. The depletions of soil P may be due to higher crop uptake and no additions of external inputs resulting in nutrient mining from the native soil reserve. The results are in agreement with the findings of Sanyal *et al.* (2014).

4.12.3 Soil potassium balance sheet

During the first and second year of experiment, all the residual treatments showed depletions. The maximum depletion (-49.32 kg ha^{-1}) recorded from residual L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) during first year. The following year, maximum depletion (-45.8 kg ha^{-1}) recorded from L_1N_1 (Lime @ 2 q ha^{-1} + RDF). The depletions of soil K may be

Table 4.27 Residual effect of lime and integrated nutrient management on nutrient balance sheet in soil after harvest of pea

A. NITROGEN

Treatments	Initial soil N (kg ha^{-1}) (a)		N added through organic and inorganic (kg ha^{-1}) (b)	Total initial (kg ha^{-1}) (c = a+b)		Crop removed N (kg ha^{-1}) (d)		Apparent N balance (kg ha^{-1}) (e = c-d)		Actual balance N after harvest (kg ha^{-1}) (f)		N gain through N fixation (g = f-e)		Depletion (-) / buildup (+) of N (h = f-a)	
	2016-17	2017-18		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1 (L_0N_0)	228.68	233.72	0	228.68	233.72	13.48	12.32	215.2	221.4	229.68	235.39	14.48	13.99	1	1.67
T_2 (L_0N_1)	253.33	247.38	0	253.33	247.38	25.36	24.5	227.97	222.88	254.8	249.32	26.83	26.44	1.47	1.94
T_3 (L_0N_2)	282.87	285.56	0	282.87	285.56	26.81	27.93	256.06	257.63	285.55	288.1	29.49	30.47	2.68	2.54
T_4 (L_0N_3)	280.46	284.84	0	280.46	284.84	26.44	27.45	254.02	257.39	283.18	287.01	29.16	29.62	2.72	2.17
T_5 (L_0N_4)	277.76	279.71	0	277.76	279.71	26.3	27	251.46	252.71	280.15	282.63	28.69	29.92	2.39	2.92
T_6 (L_1N_0)	269.43	271.75	0	269.43	271.75	25.5	25.85	243.93	245.9	272.09	274.32	28.16	28.42	2.66	2.57
T_7 (L_1N_1)	272.1	276.4	0	272.1	276.4	26.07	27.08	246.03	249.32	274.78	289.5	28.75	40.18	2.68	13.1
T_8 (L_1N_2)	286.78	299.24	0	286.78	299.24	29.41	29.7	257.37	269.54	290.1	313.01	32.73	43.47	3.32	13.77
T_9 (L_1N_3)	284.18	291.95	0	284.18	291.95	28.06	29.01	256.12	262.94	287.35	301.83	31.23	38.89	3.17	9.88
T_{10} (L_1N_4)	282.39	288.25	0	282.39	288.25	28.83	28.41	253.56	259.84	285.49	295.29	31.93	35.45	3.1	7.04

B. PHOSPHORUS

Treatments	Initial soil P (kg ha^{-1}) (a)		P added through organic and inorganic (kg ha^{-1}) (b)	Total initial (kg ha^{-1}) (c = a+b)		Crop removed P (kg ha^{-1}) (d)		Apparent P balance (kg ha^{-1}) (e = c-d)		Actual balance P after harvest (kg ha^{-1}) (f)		P gain through P fixation (g = f-e)		Depletion (-) / buildup (+) of P (h = f-a)	
	2016-17	2017-18		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1 (L_0N_0)	14.52	14.06	0	14.52	14.06	5.74	5.69	8.78	8.37	11.06	9.95	2.28	1.58	-3.46	-4.11
T_2 (L_0N_1)	18.03	17.56	0	18.03	17.56	7.97	7.68	10.06	9.88	11.5	10.27	1.44	0.39	-6.53	-7.29
T_3 (L_0N_2)	23.07	25.35	0	23.07	25.35	9.23	9.32	13.84	16.03	17.53	18.3	3.69	2.27	-5.54	-7.05
T_4 (L_0N_3)	22.52	22.98	0	22.52	22.98	9.16	9.44	13.36	13.54	17.73	17.76	4.37	4.22	-4.79	-5.22
T_5 (L_0N_4)	23.41	23.48	0	23.41	23.48	8.31	8.53	15.1	14.95	16.94	17.68	1.84	2.73	-6.47	-5.8
T_6 (L_1N_0)	22.14	22.63	0	22.14	22.63	8.63	8.72	13.51	13.91	14.97	16.27	1.46	2.36	-7.17	-6.36
T_7 (L_1N_1)	23.89	25.25	0	23.89	25.25	8.75	9.51	15.14	15.74	17.86	18.45	2.72	2.71	-6.03	-6.8
T_8 (L_1N_2)	26.59	28.45	0	26.59	28.45	9.82	10	16.77	18.45	18.32	19.79	1.55	1.34	-8.27	-8.66
T_9 (L_1N_3)	25.06	26.2	0	25.06	26.2	9.63	9.8	15.43	16.4	18.35	18.81	2.92	2.41	-6.71	-7.39
T_{10} (L_1N_4)	26.2	27.28	0	26.2	27.28	9.53	9.74	16.67	17.54	18.09	18.83	1.42	1.29	-8.11	-8.45

C. POTASSIUM

Treatments	Initial soil K (kg ha^{-1}) (a)		K added through organic and inorganic (kg ha^{-1}) (b)	Total initial (kg ha^{-1}) (c = a+b)		Crop removed K (kg ha^{-1}) (d)		Apparent K balance (kg ha^{-1}) (e = c-d)		Actual balance K after harvest (kg ha^{-1}) (f)		K gain through K fixation (g = f-e)		Depletion (-) / buildup (+) of K (h = f-a)	
	2016	2017		2016	2017	2016	2017	2016	2016	2017		2016	2017	2016	2017
T_1 (L_0N_0)	197.77	195.92	0	197.77	195.92	6.82	6.5	190.95	189.42	179.75	178.02	-11.2	-11.4	-18.02	-17.9
T_2 (L_0N_1)	222.7	210.08	0	222.7	210.08	12.97	12.52	209.73	197.56	190.61	190.21	-19.12	-7.35	-32.09	-19.87
T_3 (L_0N_2)	246.79	257.5	0	246.79	257.5	13.7	13.27	233.09	244.23	215.24	215.85	-17.85	-28.38	-31.55	-41.65
T_4 (L_0N_3)	239.64	242.56	0	239.64	242.56	12.94	13.81	226.7	228.75	202.67	203.64	-24.03	-25.11	-36.97	-38.92
T_5 (L_0N_4)	241.83	252.66	0	241.83	252.66	14.01	13.68	227.82	238.98	199.46	212.38	-28.36	-26.6	-42.37	-40.28
T_6 (L_1N_0)	221.6	218.11	0	221.6	218.11	13.35	12.35	208.25	205.76	206.28	210.9	-1.97	5.14	-15.32	-7.21
T_7 (L_1N_1)	250.08	263.46	0	250.08	263.46	13.47	14.46	236.61	249	210.62	217.66	-25.99	-31.34	-39.46	-45.8
T_8 (L_1N_2)	267.87	272.78	0	267.87	272.78	14.27	14.56	253.6	258.22	218.55	229.6	-35.05	-28.62	-49.32	-43.18
T_9 (L_1N_3)	267.44	270.24	0	267.44	270.24	14.18	14.38	253.26	255.86	228.22	231.14	-25.04	-24.72	-39.22	-39.1
T_{10} (L_1N_4)	264.32	270.04	0	264.32	270.04	12.44	12.78	251.88	257.26	222.4	227.28	-29.48	-29.98	-41.92	-42.76

due to higher crop uptake and no additions of external inputs resulting in nutrient mining from the native soil reserve. These results were in conformity with findings of Sanyal *et al*. (2014).

4.13 Economics of rice-pea production

The economics including cost of cultivation ha^{-1}, gross return ha^{-1}, net return ha^{-1} and benefit cost ratio was worked out on the basis of prevailing market prices for both the years and data are presented in Table 4.28

4.13.1 Cost of cultivation (₹ ha^{-1})

The data presented revealed that the cost of cultivation differs with the treatments. There was a common cost of cultivation (₹ 54,240) for all the control treatments where no fertilizer doses were applied. In all other remaining treatments cost of cultivation ha^{-1} was slightly varied because of the differences in rate of lime, organic manure, biofertilizers and chemical fertilizers applied. The maximum cost of cultivation (₹ 61,940) involved in RDF (75%) + FYM @ 6 t ha^{-1}) with lime @ 2 q ha^{-1} during both the years of experiment. This might be due to additional cost of lime and FYM. The lowest cost of cultivation ha^{-1} was incurred by L_0N_0 (Control) during both the years.

4.13.2 Gross return (₹ ha^{-1})

The results indicated that the maximum gross return of (₹ 1,41221.5) and (₹1,46962) was recorded during 2016-17 and 2017-18, respectively with treatment application of RDF (75%) + FYM @ 6 t ha^{-1} with lime @ 2 q ha^{-1} while the lowest return of (₹ 70,274.5) and (₹ 68,673) was recorded for L_0N_0 (Control) during both the years of experiment. The highest gross return is obviously due to higher grain and straw yields (Singh *et al.* 2011). Lakshmi *et al*. (2013) reported that the gross return were more in INM treatments than 100 % RDF and control plots. In support of the above findings, Ganapathi *et al*. (2019) reported similar results that the treatment which received RDF + FYM + 50 % lime requirement through granulated lime based on 45% Ca saturation

Table 4.28 Effect of lime and integrated nutrient management interactions on economics of rice-pea production

Interactions	Cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})		Net income (₹ ha^{-1})		Benefit-cost ratio	
		2016-17	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**
T_1 (L_0N_0)	54240	70274.5	68673	16034.5	14433	0.30	0.27
T_2 (L_0N_1)	57840	112212.5	111308	54372.5	53468	0.94	0.92
T_3 (L_0N_2)	59940	125188.5	129131.5	65248.5	69191.5	1.09	1.15
T_4 (L_0N_3)	57840	118724	120550.5	60884	62710.5	1.05	1.08
T_5 (L_0N_4)	56980	122974.5	127946.5	65994.5	70966.5	1.16	1.25
T_6 (L_1N_0)	56240	106906.5	108928.5	50666.5	52688.5	0.90	0.94
T_7 (L_1N_1)	59840	129388.5	134054	69548.5	74214	1.16	1.24
T_8 (L_1N_2)	61940	141221.5	146962	79281.5	85022	1.28	1.37
T_9 (L_1N_3)	59840	134394	139528.5	74554	79688.5	1.25	1.33
T_{10} (L_1N_4)	58980	130994	130059.5	72014	71079.5	1.22	1.21

Note: Cost of urea @ ₹ 10 kg^{-1}, SSP @ ₹ 15 kg^{-1}, MOP @ ₹ 25 kg^{-1}

Price of grain @ ₹ 15.5 kg^{-1}

Price of straw @ ₹ 1 kg^{-1}

Price of pod @ ₹ 50 kg^{-1}

Price of stover @ ₹ 1 kg^{-1}

recorded higher gross returns (₹ 69,945.75) over other treatments.

4.13.3 Net return (₹ ha^{-1})

The results indicated that the maximum net return of (₹ 79,281.5) and (₹ 85,022) was recorded during 2016-17 and 2017-18, respectively with treatment application of RDF (75%) + FYM @ 6 t ha^{-1}) with lime @ 2 q ha^{-1} while the least net return of (₹ 16,034.5) and (₹ 14,433) was recorded in L_0N_0 (Control) during both the years of experiment. The maximum net income is due to higher gross income (Singh *et al*. 2011). Manpreet and Dixit (2017) reported that fertilizer and lime application gave the highest economic returns as compared with the sole or separate application. The high economic return could be realized if lime is applied in acidic soil as reported by Kumar (2015).

4.13.4 Benefit: Cost ratio

The data revealed that application of treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) attained significantly higher benefit cost ratio (1.28) during 2016-17. Similar trend of findings was recorded for 2017-18 where higher benefit cost ratio (1.37) recorded in L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest was recorded in L_0N_0 (Control). The maximum benefit cost ratio is owing to higher grain yield and in turn higher gross and net returns (Singh *et al*., 2011).

4.14 Effect of lime and INM on the performance of rice-pea cropping system

System productivity of rice-pea cropping system as influenced by lime and integrated nutrient management during both the years are presented in Table 4.29(a) with Fig 4.11(a) and their interactions are depicted in Table 4.29(b) with Fig 4.11(b).

4.14.1 Rice equivalent yield of pea (kg ha^{-1})

Lime

Among the lime levels, the highest rice equivalent yield (7735.16 kg ha^{-1}) and (7943.65 kg ha^{-1}) was recorded from treatment L_1 (Lime @ 2 q ha^{-1}) during 2016-17 and 2017-18 respectively. Pooled data of both the years showed significant variation with improved rice equivalent yield (7839.41 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha-^{1}) over treatment L_0 (without lime). The improvement in lime treated plots may be due to increased in grain yield of rice as well as pod yield of pea. Sorokhaibam *et al*. (2016) also reported similar findings that since liming treatment had resulted increase in grain yield of rice as well as seed yield of lathyrus, hence, REY was also increased.

INM

Among the INM levels, the highest rice equivalent yield (7927.82 kg ha^{-1}) and (8269.09 kg ha^{-1}) was recorded from treatment application of RDF (75%) + FYM @ 6 t ha^{-1}) during 2016-17 and 2017-18 respectively followed by N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB). The least was observed in N_1 (RDF) and N_0 (Control). Pooled data of both the years also followed the similar trend of findings with the highest rice equivalent yield (8098.46 kg ha^{-1}) recorded from treatment application of RDF (75%) + FYM @ 6 t ha^{-1}). This was due to inorganic fertilizer application and slow and steady availability of nutrient through FYM to rice and its residual effect on pea. High rice equivalent yield and system productivity due to inclusion of pulses such as pea and lentil after rice has been also reported by Das *et al*. (2014).

Interactions

Interaction effects between lime and INM levels were found to be significant during both the years of experimentation. During 2016-17 and 2017-18, the highest rice equivalent yield was obtained with treatment interactions of L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). The treatment interactions L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par with each other. Pooled data of both the years also recorded similar findings with the highest rice equivalent yield (8567.61 kg ha^{-1}) recorded from treatment application of RDF (75%) + FYM @ 6 t ha^{-1}) with lime @ 2 q ha^{-1}. Results are in conformity with the findings of Verma *et al*. (2019) who reported highest maize equivalent yield with the combination of Lime + NPK (7843 kg ha^{-1}) over RDF and control.

4.14.2 System productivity

Lime

System productivity of the cropping system was influenced significantly under different levels of lime. Among the lime levels, the highest system productivity (11235.69 kg ha^{-1}) and (11518.92 kg ha^{-1}) was recorded from treatment L_1 (Lime @ 2 q ha^{-1}) during (2016-17) and (2017-18) respectively. Pooled data of both the years showed significant variation with higher system productivity (11377.31 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime). The use of lime in rice increased the productivity of rice and also enhanced productivity of succeeding pea thereby improved system productivity. In support of the above findings, Sorokhaibam *et al*. (2016) also reported that application of lime @ 500 kg $CaCO_3$ ha^{-1} before planting rice continuously for two cropping seasons had residual effect on seed and stover yields of succeeding rapeseed resulting in improvement of system productivity in terms of rice equivalent yield (REY) over no liming.

INM

System productivity of the cropping system was significantly influenced under different levels of INM. Among the INM levels, the highest system productivity (11515.33 kg ha^{-1}) and (11989.26 kg ha^{-1}) was recorded from treatment application of N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) during 2016-17 and

2017-18 respectively. The treatments N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par. Pooled data also recorded significant variation with the highest system productivity (11752.29 kg ha^{-1}) recorded from treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_O (control). This may be due to the fact that efficiency of inorganic fertilizers increased when used in combination with organic manures. Acharya and Mondal (2010) reported similar results where highest productivity was recorded under 75% RDF + 25% N through FYM than RDF alone which produced REY of 26.80 t ha^{-1} on rice-cabbage-greengram cropping system.

Interactions

The interaction effect between lime and INM levels were found to be significant during both the years of experiment. The highest system productivity recorded from L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) during 2016-17 and 2017-18. The interaction treatments between interactions L_1N_3 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}) and L_1N_4 (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillim* + PSB) were found to be statistically at par for both the years. Pooled data of both the years also recorded significant variation with the highest system productivity (12400.28 kg ha^{-1}) recorded from treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) and the lowest in N_O (Control). Singh *et al.* (2011) revealed that higher system productivity (9412 kg ha^{-1}) was obtained with combined application of 5 t FYM + 250 kg lime + 20 kg S + 1 kg B ha^{-1} along with 50% RDF than obtained with 100% RDF only (6832 kg ha^{-1}). Swain *et al*. (2019) also reported that integrated use of 75% RDN and 25 % N through FYM along with 0.2 LR lime and biofertilizer consortium recorded the highest system yield of 9.18 t SEY ha^{-1}, being 16 and 32 % more than RDF through inorganic sources and organic practice, respectively.

Table 4.29(a) Effect of lime and integrated nutrient management on system productivity of rice-pea cropping system

Treatments	Rice equivalent yield of pea (kg ha^{-1})			Rice yield (kg ha^{-1})			System productivity (kg ha^{-1})		
	2016-17	**2017-18**	**Pooled**	**2016**	**2017**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Lime									
L_0	6634.22	6760.88	6697.55	3094.00	3133.13	3113.57	9728.22	9894.01	9811.11
L_1	7735.16	7943.65	7839.41	3500.53	3575.27	3537.90	11235.69	11518.92	11377.31
SEm±	59.66	79.94	49.87	24.06	34.19	20.90	65.80	97.42	58.78
CD (P= 0.05)	177.25	237.51	143.04	71.47	101.57	59.95	195.51	289.44	168.59
INM									
N_0	5329.63	5342.58	5336.10	2580.17	2624.83	2602.50	7909.80	7967.41	7938.60
N_1	7320.34	7426.76	7373.55	3382.17	3389.67	3385.92	10702.51	10816.43	10759.47
N_2	7927.82	8269.09	8098.46	3587.50	3720.17	3653.83	11515.33	11989.26	11752.29
N_3	7626.36	7837.28	7731.82	3468.83	3514.17	3491.50	11095.20	11351.45	11223.32
N_4	7719.28	7885.61	7802.44	3467.67	3522.17	3494.92	11186.95	11407.78	11297.36
SEm±	94.33	126.39	78.86	38.04	54.05	33.05	104.04	154.03	92.94
CD (P= 0.05)	280.26	375.54	226.17	113.01	160.60	94.78	309.12	457.64	266.56

Table 4.29(b) Interaction effects of lime and integrated nutrient management on system productivity of rice-pea cropping system

Treatments	Rice equivalent yield of pea (kg ha^{-1})			Grain yield (kg ha^{-1})			System productivity (kg ha^{-1})		
	2016-17	**2017-18**	**Pooled**	**2016**	**2017**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
Lime x INM									
L_0N_0	4220.52	4117.24	4168.88	2189.33	2104.33	2146.83	6409.85	6221.57	6315.71
L_0N_1	6771.99	6704.01	6738.00	3215.00	3127.67	3171.33	9986.99	9831.68	9909.33
L_0N_2	7468.82	7789.78	7629.30	3366.67	3583.33	3475.00	10835.49	11373.12	11104.30
L_0N_3	7204.97	7308.06	7256.52	3334.00	3383.33	3358.67	10538.97	10691.40	10615.19
L_0N_4	7504.78	7885.28	7695.03	3365.00	3467.00	3416.00	10869.79	11352.28	11111.03
L_1N_0	6438.74	6567.91	6503.33	2971.00	3145.33	3058.17	9409.74	9713.25	9561.49
L_1N_1	7868.69	8149.52	8009.10	3549.33	3651.67	3600.50	11418.02	11801.18	11609.60
L_1N_2	8386.83	8748.40	8567.61	3808.33	3857.00	3832.67	12195.16	12605.40	12400.28
L_1N_3	8047.75	8366.51	8207.13	3603.67	3645.00	3624.33	11651.42	12011.51	11831.46
L_1N_4	7933.77	7885.94	7909.85	3570.33	3577.33	3573.83	11504.11	11463.27	11483.69
SEm±	133.40	178.75	111.52	53.79	76.44	46.74	147.14	217.83	131.43
CD (P= 0.05)	396.35	531.09	319.85	159.82	227.12	134.05	437.17	647.21	376.97

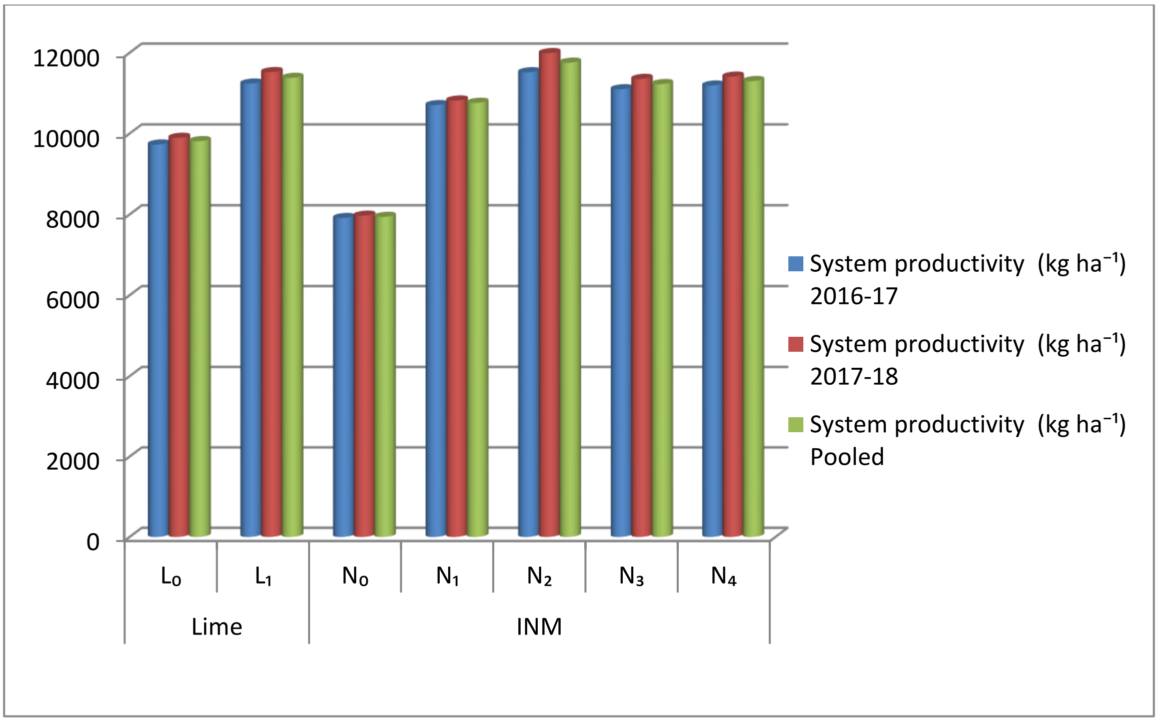


Fig 4.11(a) Effect of lime and integrated nutrient management on system productivity (kg ha^{-1}) of rice-pea cropping system

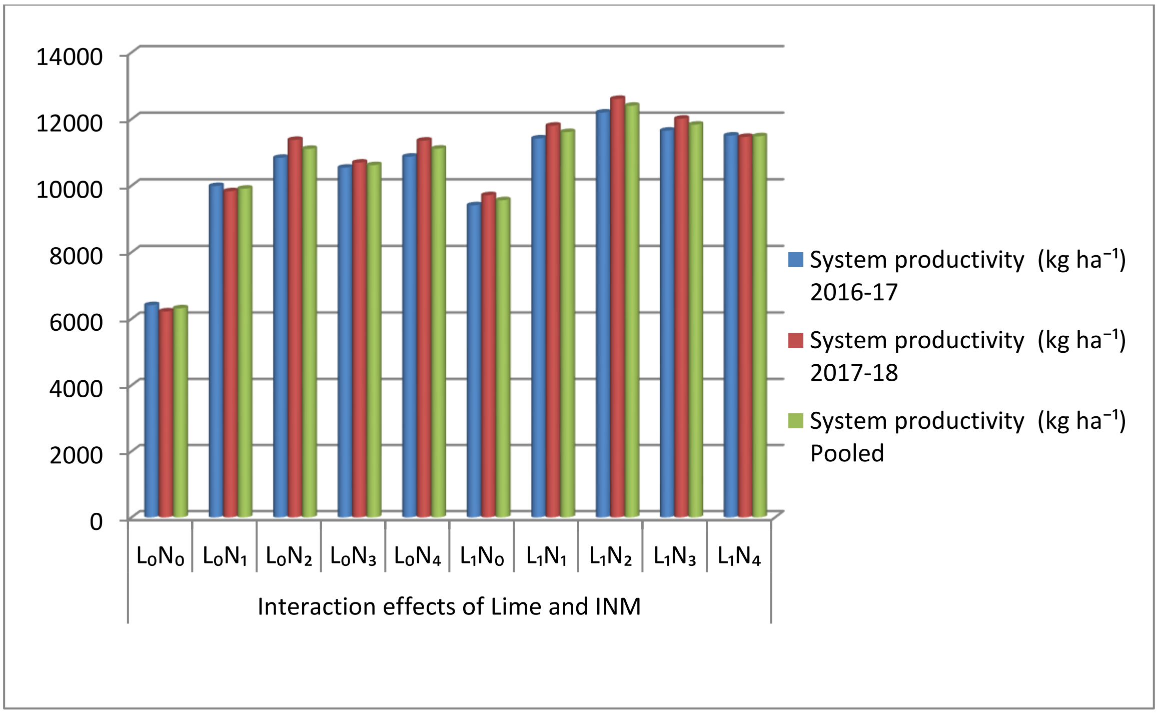


Fig 4.11(b) Interaction effects of lime and integrated nutrient management on system productivity (kg ha^{-1}) of rice-pea cropping system

Plate 1: General view of the experimental plot at tillering stage

Plate 2: General view of the experimental plot at harvest stage

Control

RDF (75%) + FYM @ 6 t ha^{-1}

Lime @ 2 q ha^{-1}

Lime @ 2 q ha^{-1} + RDF (75%) + poultry manure @ 1 t ha^{-1}

Plate 3: Treatment effect at 30 DAS

Control

Lime @ 2 q ha^{-1}

Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}

Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}

Plate 4: Treatment effect at 60 DAS

Control

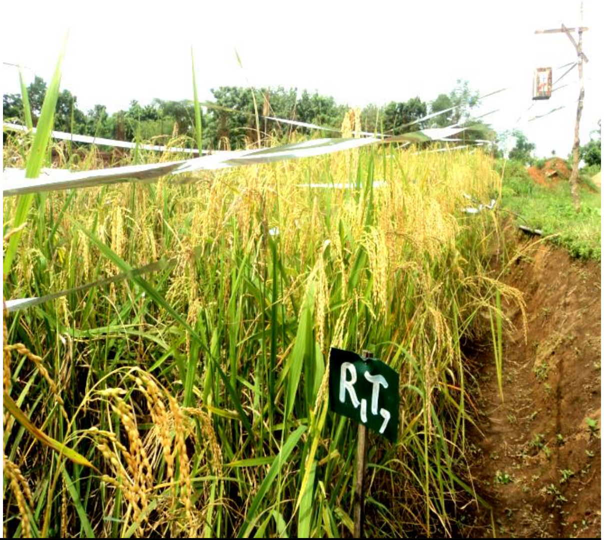
Lime @ 2 q ha^{-1}

Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}

Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB

Plate 5: Treatment effect at 90 DAS

Control



Lime @ 2 q ha^{-1} + RDF (120:60:60 NPK kg ha^{-1})

Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}

Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}

Plate 6: Treatment effect at harvest stage

Plate 7: General view of the experimental plot of pea

Plate 8: Flowering and Pod formation stage of pea

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present investigation entitled **"Response of rice (*Oryza sativa* L.) to integrated nutrient management and liming and their residual effect on succeeding pea (*Pisum sativum* L.)"** was carried out in the experimental research farm of the School of Agricultural Sciences and Rural Development (SASRD), Medziphema, Nagaland University, during *kharif* and *rabi* seasons of 2016-2017 and 2017-2018.

The experiment was laid out in 'Randomized block design' based on three replications with 10 treatments. The factors comprised of two lime levels *viz*. L_0 - without lime and L_1 - Lime @ 2 q ha^{-1} and five fertilizer doses *viz*. N_0 - Control, N_1 - RDF, N_2 - RDF (75%) + FYM @ 6 t ha^{-1}, N_3 - RDF (75%) + Poultry manure @ 1 t ha^{-1}, N_4 - RDF (75%) + *Azospirillum* + PSB. The treatment combinations for rice were T_1 (Control), T_2 (120:60:60 NPK kg ha^{-1} RDF), T_3 (75% RDF + FYM @ 6 t ha^{-1}), T_4 (75% RDF + poultry manure @ 1 t ha^{-1}), T_5 (75% RDF + *Azospirillum* + PSB), T_6 (Lime @ 2 q ha^{-1}), T_7 (Lime @ 2 q ha^{-1} + 120 : 60 : 60 NPK kg ha^{-1} RDF), T_8 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}), T_9 (Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1}), T_{10} (Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB). The plot size was kept as 4 x 3 m^2. Each plot received identical cultural treatments in terms of ploughing, cultivation, seed rate and disease control. The succeeding pea crop was raised exclusively on residual resources of rice crop. Data on its observations such as growth, yield, soil nutrient availability, plant nutrient uptake, apparent nutrient balance sheet, and economics were recorded as per standard procedures for rice and succeeding pea crop.

The investigation was carried out with the following objectives-

1) To study the effect of integrated nutrient management and liming on growth and yield of rice.

2) To study the residual effect of integrated nutrient management and liming on the growth and yield of succeeding pea.

3) To evaluate the economics of different treatments under study.

The salient findings of the present investigation are given here as under:

5.1 Growth characters of rice

Experimental findings revealed that application of Lime @ 2 q ha^{-1} (L_1) produced significantly higher plant height, number of tillers running $meter^{-1}$, green leaf area, leaf area index, shoot dry weight, crop growth rate and dry matter as compared to plots without lime (L_0) during both the years. While in case of nutrient doses, N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded significantly higher plant height, number of tillers running $meter^{-1}$, green leaf area, leaf area index, shoot dry weight, crop growth rate and dry matter during both the years. However, relative growth rate failed to show significant differences during both the years.

Interaction effects of lime and integrated nutrient management recorded significantly higher plant height, number of tillers running $meter^{-1}$, shoot dry weight and dry matter with L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). However interaction effects on green leaf area, leaf area index, crop growth rate and relative growth rate did not register any significant differences during both the years.

5.2 Yield and yield attributing characters of rice

The result of the findings indicated that Lime @ 2 q ha^{-1} (L_1) recorded significantly higher yield on number of panicles m^{-2}, number of filled grains $panicle^{-1}$, filled grain percentage (%), grain yield and straw yield as compared to plots without lime (L_0). The different nutrient doses had significant influence on yield and yield attributes. The highest values on number of panicles m^{-2}, length of panicle, number of filled grains $panicle^{-1}$, filled grain percentage (%), grain yield and harvest index were recorded with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). While for straw yield, the highest value was recorded with N_3 (RDF (75%) +

poultry manure @ 1 t ha^{-1}).

Yield and yield attributing characters such as number of filled grains $panicle^{-1}$, grain yield and straw yield recorded significantly higher number in L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) proving its superiority over other treatments.

5.3 Fertility status after harvest

The results indicated that significantly the maximum soil pH, soil organic carbon, available nitrogen, phosphorus and potassium were obtained by lime application @ 2 q ha^{-1} (L_1) over plots without lime during both the years. Among the nutrient sources, the highest soil pH, soil organic carbon, available nitrogen, phosphorus and potassium were recorded with treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) over other nutrient treatments.

Interaction effect of lime and integrated nutrient management showed significant effect on available nitrogen, phosphorus and potassium with the highest value recorded from L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) over all the other treatments under experiment.

5.4 Nutrient uptake by rice plants

Experimental findings revealed that significantly higher nitrogen, phosphorus and potassium uptake during the experiment was recorded with lime application @ 2 q ha^{-1} (L_1). Among the nutrient sources, treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded significantly higher nitrogen, phosphorus and potassium uptake during the experiment.

In case of interaction effect, application of 75% RDF along with FYM @ 6t ha^{-l} and lime @ 2 q ha^{-1} gave the highest value for nitrogen, phosphorus and potassium uptake as compared to recommended fertilizer alone and other nutrient management treatments.

5.5 Soil microbial population after harvest of rice

Lime application @ 2 q ha^{-1} (L_1) recorded significantly higher microbial population in the soil *viz.* bacteria and actinomycetes as compared to plots without lime. Lime levels failed to register significant difference on fungal population. The data on bacteria and fungi population as influenced by organic and inorganic nutrient sources were found significantly maximum with the highest population recorded in N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Actinomycetes population was found significantly maximum in N_4 (RDF (75%) + *Azospirillim* + PSB) and at par with (RDF (75%) + FYM @ 6 t ha^{-1}) and N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}).

Interaction effect of lime and integrated nutrient management did not register any significant difference on bacteria, actinomycetes and fungal population.

5.6 Apparent nutrient balance sheet of the soil after harvest of rice

The nutrient balance worked out for several treatments indicated that the maximum build up was recorded with L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) and maximum depletion recorded with L_0N_0 (Control) for nitrogen and phosphorus during both the years. The data showed that during first year, potassium depletion was not noticed. However, maximum K depletion in L_0N_0 (Control) was observed only during the second year. The maximum build up of K in soil was recorded under treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) during both the years of experiment.

5.7 Growth and yield characters of succeeding pea

Growth and yield attributes and yield of succeeding *rabi* pea crop were significantly influenced by the lime levels which imposed to preceding rice crop. The plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, pod yield and stover yield recorded highest which received residual lime as compared to plots without lime. However, significant dry weight was recorded only at 30 DAS with the highest recorded from residual lime treated plots.

Among the residual nutrient levels given to preceding rice, the highest plant height, number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, pod yield and stover yield of succeeding pea was recorded from residual (RDF (75%) + FYM @ 6 t ha^{-1}) followed by residual (RDF (75%) + Poultry manure @ 1 t ha^{-1}). Harvest index recorded significantly higher from N_4 (RDF (75%) + *Azospirillim* + PSB). However, significant dry weight was recorded only at 30 DAS with the highest recorded from residual (RDF (75%) + FYM @ 6 t ha^{-1}) treated plots.

During both years of study, the lime and INM treatments given to preceding *kharif* rice had significant influence on succeeding pea plant height (60 DAS and at harvest), pod yield and stover yield was recorded from residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}). However, plant height at 30 DAS was recorded highest from residual treatment (RDF (75%) + Poultry manure @ 1 t ha^{-1}) followed by residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}).

5.8 Fertility status after harvest of succeeding pea

Significant difference was recorded on succeeding pea for soil pH, organic carbon, available nitrogen, phosphorus and potassium due to lime levels applied in preceding rice. The maximum value for soil pH, organic carbon, available nitrogen, phosphorus and potassium were obtained by lime application @ 2 q ha^{-1} (L_1) over plots without lime during both the years. Soil organic carbon, available nitrogen, phosphorus and potassium were recorded significantly highest with residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) in comparison to residual treatments N_3 (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and N_4 (RDF (75%) + *Azospirillum* + PSB).

Residual interactions effect of lime and integrated nutrient management failed to register any significant difference on soil pH, soil organic carbon, available nitrogen, phosphorus and potassium.

5.9 Nutrient uptake by succeeding pea

A significant difference was observed on the nutrient uptake (NPK) due to lime and nutrient levels. Residual lime @ 2 q ha^{-1} (L_1) showed higher nutrient uptake (NPK) than plots without lime application. The nitrogen and phosphorus and potassium uptake of succeeding pea recorded highest in residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) followed by (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and (RDF (75%) + *Azospirillum* + PSB).

Residual interactions effect of lime and integrated nutrient management significantly recorded highest nutrient uptake (NPK) under residual treatment L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) when compared with rest of the treatments under test.

5.10 Soil microbial population after harvest of succeeding pea

Significant difference was recorded due to residual effect of nutrient levels on succeeding pea for microbial population *viz.* bacteria, actinomycetes and fungi. The highest microbial population was recorded in residual treatment N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) during both the years.

Lime levels as well as their interaction failed to register significant difference on bacteria, actinomycetes and fungi.

5.11 Apparent nutrient balance sheet of the soil after harvest of succeeding pea

The nutrient balance worked out for several treatments indicated that the maximum build up of nitrogen was recorded with L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) during both the years. However, the maximum depletion of phosphorus and potassium was recorded with L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) over all the treatments under experiment.

5.12 Economics of the rice- pea production

The analysis of the results revealed that combination of L_1 - Lime @ 2 q ha^{-1} and N_2 - RDF (75%) + FYM @ 6 t ha^{-1} was the best among all the different treatments combination. With regard to gross return ha^{-1}, net return ha^{-1} and benefit-cost ratio, the highest was recorded by treatment combination of lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} with (₹ 141221.5 and ₹ 146962), (₹ 79281.5 and ₹ 85022) and (1.28 and 1.37) in rice-pea during the two consecutive years.

5.13 Rice equivalent yield of pea

Significant difference was recorded due to lime and INM levels on rice equivalent yield of pea. Liming @ 2 q ha^{-1} showed the highest rice equivalent yield (7839.41 kg ha^{-1}) as compared to plots without lime treatment. Among the nutrient sources, N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest rice equivalent yield (8098.46 kg ha^{-1}) followed by (RDF (75%) + Poultry manure @ 1 t ha^{-1}) and (RDF (75%) + *Azospirillum* + PSB) and the least recorded in RDF and control. Significantly, higher rice equivalent yield (8567.61 kg ha^{-1}) was recorded in treatment combination of L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) over all the treatments under experiment.

5.14 System productivity of rice-pea cropping system

Significant difference was recorded due to lime and INM levels on system productivity of rice-pea cropping system. Liming @ 2 q ha^{-1} improved system productivity over no lime treated plots while in case of nutrient sources, N_2 (RDF (75%) + FYM @ 6 t ha^{-1}) recorded the highest system productivity over other nutrient sources.

The interaction effects between liming and INM were found to be significant on system productivity with the highest value (12400.28 kg ha^{-1}) recorded in combination of L_1N_2 (Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1}) over other treatments.

From the findings of the present investigation, the following evidences and conclusions may be drawn:

Conclusion:

1) Performance of rice was significantly influenced by combination of Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} (T_8) followed by Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1} (T_9) and Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB (T_{10}) in rice-pea crop sequence.

2) Nutrient availability, NPK uptake pattern and soil microbial population was significantly higher in combination of Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} (T_8) which are on par with Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1} (T_9) and Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB (T_{10}) in rice-pea crop sequence.

3) Performance of pea was significantly influenced by combination of residual Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} (T_8) followed by Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1} (T_9) and Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB (T_{10}) in rice-pea crop sequence.

4) Nutrient availability, NPK uptake pattern and soil microbial population was significantly higher in combination of residual Lime @ 2 q ha^{-1} + RDF (75%) + FYM @ 6 t ha^{-1} (T_8) which are on par with residual Lime @ 2 q ha^{-1} + RDF (75%) + Poultry manure @ 1 t ha^{-1} (T_9) and Lime @ 2 q ha^{-1} + RDF (75%) + *Azospirillum* + PSB (T_{10}) in rice-pea crop sequence.

5) Integrated application of lime and FYM along with NPK fertilizers recorded the highest economics of rice-pea production, REY and maintained the system productivity and enhanced the sustain ability under rice-pea cropping system in acid soils.

6) It was concluded that integration of organics (*Azospirillum*, PSB, FYM and poultry manure) with inorganic led to 25% saving of inorganic fertilizer without scarifying the yield of rice-pea cropping sequence and improved soil fertility status.

Recommendations:

Based on the results obtained in the present study, some recommendations can be drawn on the following aspects for increasing the production and productivity of rice-pea crop sequence.

1) For better rice growth and development, higher nutrient uptake and higher available nutrient status of the soil and better nutrient balance for sustained production, judicious application of FYM @ 6 t ha^{-1} with 75 % recommended NPK (120- 60- 60 kg ha^{-1}) found superior over recommended dose of fertilizer and other integrated nutrient management. However, in the condition of non availability of FYM, the farmer may adopt poultry manure or *Azospirillum* and PSB along with 75 % recommended NPK level for higher grain yield of upland rice-pea cropping system in the foothill conditions of Nagaland.

2) Integrated use of lime, FYM along with balanced NPK fertilizers was better in terms of obtaining high crop yields and improvement in soil fertility status both in direct and residual phase over application of RDF alone and should be followed for increasing as well as sustaining crop production under rice-pea sequence in acid upland soils of Nagaland.

Areas of further research:

1) Long-term studies on integration of inorganic, organic nutrient sources along with lime on crop productivity and economics of rice and pea production are needed for final recommendation to the farmers.

2) Monitoring the variations in soil fertility, productivity and biological activity as influenced by organic nutrient sources in comparison to chemical fertilizer is needed.

3) A long-term study needs to be considered using higher rates of lime and manure to evaluate change in soil chemical properties and effect on rice-pea cropping system.

4) Further research should be conducted to explore more rates of lime, different types of lime and their effects in long-term basis to determine the optimum liming level of different types of lime for acid upland soils of Nagaland.

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APPENDICES

APPENDIX-A

ANOVA-I (a): Analysis of variance as influenced by lime and INM and their interaction effects on plant height (cm) of rice at 30 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	6.34	3.17	1.38	3.55	NS
Lime	1	241.46	241.46	104.94	4.41	S
INM	4	819.81	204.95	89.07	2.93	S
Lime x INM	4	28.62	7.15	3.11	2.93	S
Error	18	41.42	2.30			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.98	1.49	1.07	3.55	NS
Lime	1	199.49	199.49	143.66	4.41	S
INM	4	773.83	193.46	139.32	2.93	S
Lime x INM	4	18.03	4.51	3.25	2.93	S
Error	18	25.00	1.39			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	9.31	2.33	1.26	2.63	NS
Lime	2	440.94	220.47	119.51	3.26	S
INM	8	1593.64	199.21	107.98	2.21	S
Lime x INM	8	46.65	5.83	3.16	2.21	S
Error	36	66.41	1.84			

ANOVA-I (b): Analysis of variance as influenced by lime and INM and their interaction effects on plant height (cm) of rice at 60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.96	0.48	0.27	3.55	NS
Lime	1	283.67	283.67	161.77	4.41	S
INM	4	988.51	247.13	140.93	2.93	S
Lime x INM	4	30.87	7.72	4.40	2.93	S
Error	18	31.56	1.75			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.84	1.42	0.72	3.55	NS
Lime	1	214.83	214.83	108.86	4.41	S
INM	4	1210.69	302.67	153.38	2.93	S
Lime x INM	4	31.32	7.83	3.97	2.93	S
Error	18	35.52	1.97			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.80	0.95	0.51	2.63	NS
Lime	2	498.50	249.25	133.76	3.26	S
INM	8	2199.19	274.90	147.52	2.21	S
Lime x INM	8	62.19	7.77	4.17	2.21	S
Error	36	67.08	1.86			

ANOVA-I (c): Analysis of variance as influenced by lime and INM and their interaction effects on plant height (cm) of rice at 90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.25	0.63	1.22	3.55	NS
Lime	1	1306.67	1306.67	2547.04	4.41	S
INM	4	4032.20	1008.05	1964.95	2.93	S
Lime x INM	4	23.50	5.88	11.45	2.93	S
Error	18	9.23	0.51			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.61	0.30	0.32	3.55	NS
Lime	1	1233.80	1233.80	1291.59	4.41	S
INM	4	4011.99	1003.00	1049.98	2.93	S
Lime x INM	4	31.99	8.00	8.37	2.93	S
Error	18	17.19	0.96			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.86	0.46	0.63	2.63	NS
Lime	2	2540.47	1270.23	1730.24	3.26	S
INM	8	8044.19	1005.52	1369.67	2.21	S
Lime x INM	8	55.49	6.94	9.45	2.21	S
Error	36	26.43	0.73			

ANOVA-I (d): Analysis of variance as influenced by lime and INM and their interaction effects on plant height (cm) of rice at harvest

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	22.43	11.21	2.19	3.55	NS
Lime	1	1689.45	1689.45	329.93	4.41	S
INM	4	4324.72	1081.18	211.14	2.93	S
Lime x INM	4	63.01	15.75	3.08	2.93	S
Error	18	92.17	5.12			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	24.73	12.36	1.72	3.55	NS
Lime	1	1753.38	1753.38	243.90	4.41	S
INM	4	4970.17	1242.54	172.84	2.93	S
Lime x INM	4	187.05	46.76	6.50	2.93	S
Error	18	129.40	7.19			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	47.15	11.79	1.92	2.63	NS
Lime	2	3442.83	1721.42	279.69	3.26	S
INM	8	9294.89	1161.86	188.77	2.21	S
Lime x INM	8	250.06	31.26	5.08	2.21	S
Error	36	221.57	6.15			

ANOVA-II (a): Analysis of variance as influenced by lime and INM and their interaction effects on number of tillers running meter^{-1} of rice at 30 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	4.20	2.10	2.12	3.55	NS
Lime	1	34.13	34.13	34.52	4.41	S
INM	4	207.80	51.95	52.53	2.93	S
Lime x INM	4	12.87	3.22	3.25	2.93	S
Error	18	17.80	0.99			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.47	1.23	2.95	3.55	NS
Lime	1	43.20	43.20	103.22	4.41	S
INM	4	177.87	44.47	106.25	2.93	S
Lime x INM	4	20.80	5.20	12.42	2.93	S
Error	18	7.53	0.42			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	6.67	1.67	2.37	2.63	NS
Lime	2	77.33	38.67	54.95	3.26	S
INM	8	385.67	48.21	68.51	2.21	S
Lime x INM	8	33.67	4.21	5.98	2.21	S
Error	36	25.33	0.70			

ANOVA-II (b): Analysis of variance as influenced by lime and INM and their interaction effects on number of tillers running meter^{-1} of rice at 60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.07	1.03	2.16	3.55	NS
Lime	1	83.33	83.33	174.42	4.41	S
INM	4	269.47	67.37	141.00	2.93	S
Lime x INM	4	34.00	8.50	17.79	2.93	S
Error	18	8.60	0.48			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	6.07	3.03	2.83	3.55	NS
Lime	1	112.13	112.13	104.76	4.41	S
INM	4	294.87	73.72	68.87	2.93	S
Lime x INM	4	33.53	8.38	7.83	2.93	S
Error	18	19.27	1.07			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	8.13	2.03	2.63	2.63	NS
Lime	2	195.47	97.73	126.26	3.26	S
INM	8	564.33	70.54	91.13	2.21	S
Lime x INM	8	67.53	8.44	10.91	2.21	S
Error	36	27.87	0.77			

ANOVA-II (c): Analysis of variance as influenced by lime and INM and their interaction effects on number of tillers running meter^{-1} of rice at 90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.87	0.93	1.31	3.55	NS
Lime	1	177.63	177.63	249.80	4.41	S
INM	4	338.47	84.62	118.99	2.93	S
Lime x INM	4	38.20	9.55	13.43	2.93	S
Error	18	12.80	0.71			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.40	1.20	0.89	3.55	NS
Lime	1	252.30	252.30	187.15	4.41	S
INM	4	391.53	97.88	72.61	2.93	S
Lime x INM	4	124.20	31.05	23.03	2.93	S
Error	18	24.27	1.35			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	4.27	1.07	1.04	2.63	NS
Lime	2	429.93	214.97	208.78	3.26	S
INM	8	730.00	91.25	88.62	2.21	S
Lime x INM	8	162.40	20.30	19.72	2.21	S
Error	36	37.07	1.03			

ANOVA-II (d): Analysis of variance as influenced by lime and INM and their interaction effects on number of tillers running meter^{-1} of rice at harvest

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.07	1.03	1.27	3.55	NS
Lime	1	158.70	158.70	195.66	4.41	S
INM	4	331.53	82.88	102.18	2.93	S
Lime x INM	4	50.47	12.62	15.55	2.93	S
Error	18	14.60	0.81			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.80	0.90	1.14	3.55	NS
Lime	1	288.30	288.30	365.45	4.41	S
INM	4	475.87	118.97	150.80	2.93	S
Lime x INM	4	144.53	36.13	45.80	2.93	S
Error	18	14.20	0.79			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.87	0.97	1.21	2.63	NS
Lime	2	447.00	223.50	279.37	3.26	S
INM	8	807.40	100.92	126.16	2.21	S
Lime x INM	8	195.00	24.38	30.47	2.21	S
Error	36	28.80	0.80			

ANOVA-III (a): Analysis of variance as influenced by lime and INM and their interaction effects on Green leaf area (cm^2) at 30 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	100.90	50.45	0.52	3.55	NS
Lime	1	2149.35	2149.35	22.20	4.41	S
INM	4	4258.60	1064.65	10.99	2.93	S
Lime x INM	4	1118.90	279.72	2.89	2.93	S
Error	18	1743.01	96.83			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	12.67	6.33	0.03	3.55	NS
Lime	1	2433.24	2433.24	13.12	4.41	S
INM	4	4464.11	1116.03	6.02	2.93	S
Lime x INM	4	1205.29	301.32	1.62	2.93	S
Error	18	3338.69	185.48			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	113.57	28.39	0.20	2.63	NS
Lime	2	4582.59	2291.29	16.23	3.26	S
INM	8	8722.71	1090.34	7.72	2.21	S
Lime x INM	8	2324.18	290.52	2.06	2.21	S
Error	36	5081.71	141.16			

ANOVA-III (b): Analysis of variance as influenced by lime and INM and their interaction effects on Green leaf area (cm^2) at 60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	28.15	14.08	0.18	3.55	NS
Lime	1	3460.00	3460.00	44.74	4.41	S
INM	4	4249.58	1062.40	13.74	2.93	S
Lime x INM	4	466.81	116.70	1.51	2.93	NS
Error	18	1392.00	77.33			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	425.17	212.58	1.78	3.55	NS
Lime	1	3495.31	3495.31	29.33	4.41	S
INM	4	4671.51	1167.88	9.80	2.93	S
Lime x INM	4	992.41	248.10	2.08	2.93	NS
Error	18	2144.89	119.16			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	453.32	113.33	1.15	2.63	NS
Lime	2	6955.31	3477.66	35.40	3.26	S
INM	8	8921.09	1115.14	11.35	2.21	S
Lime x INM	8	1459.22	182.40	1.86	2.21	NS
Error	36	3536.89	98.25			

ANOVA-III (c): Analysis of variance as influenced by lime and INM and their interaction effects on Green leaf area (cm^2) at 90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	157.09	78.55	0.66	3.55	NS
Lime	1	10294.90	10294.90	86.51	4.41	S
INM	4	10099.85	2524.96	21.22	2.93	S
Lime x INM	4	532.03	133.01	1.12	2.93	NS
Error	18	2142.16	119.01			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	128.02	64.01	0.38	3.55	NS
Lime	1	9044.56	9044.56	54.22	4.41	S
INM	4	10047.55	2511.89	15.06	2.93	S
Lime x INM	4	839.70	209.93	1.26	2.93	NS
Error	18	3002.84	166.82			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	285.11	71.28	0.50	2.63	NS
Lime	2	19339.46	9669.73	67.66	3.26	S
INM	8	20147.39	2518.42	17.62	2.21	S
Lime x INM	8	1371.73	171.47	1.20	2.21	NS
Error	36	5145.01	142.92			

ANOVA-IV (a): Analysis of variance as influenced by lime and INM and their interaction effects on Leaf area index (LAI) at 30 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.002	0.001	0.51	3.55	NS
Lime	1	0.05	0.05	22.42	4.41	S
INM	4	0.11	0.03	10.87	2.93	S
Lime x INM	4	0.03	0.01	2.91	2.93	NS
Error	18	0.04	0.002			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.03	3.55	NS
Lime	1	0.06	0.06	13.02	4.41	S
INM	4	0.11	0.03	6.04	2.93	S
Lime x INM	4	0.03	0.01	1.60	2.93	NS
Error	18	0.08	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.00	0.00	0.20	2.63	NS
Lime	2	0.12	0.06	16.24	3.26	S
INM	8	0.22	0.03	7.70	2.21	S
Lime x INM	8	0.06	0.01	2.05	2.21	NS
Error	36	0.13	0.00			

ANOVA-IV (b): Analysis of variance as influenced by lime and INM and their interaction effects on Leaf area index (LAI) at 60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.001	0.000	0.20	3.55	NS
Lime	1	0.09	0.09	44.38	4.41	S
INM	4	0.10	0.03	13.31	2.93	S
Lime x INM	4	0.01	0.00	1.45	2.93	NS
Error	18	0.04	0.00			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	1.75	3.55	NS
Lime	1	0.09	0.09	29.61	4.41	S
INM	4	0.12	0.03	9.84	2.93	S
Lime x INM	4	0.02	0.01	2.06	2.93	NS
Error	18	0.05	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.003	1.14	2.63	NS
Lime	2	0.17	0.09	35.48	3.26	S
INM	8	0.22	0.03	11.22	2.21	S
Lime x INM	8	0.04	0.004	1.82	2.21	NS
Error	36	0.09	0.002			

ANOVA-IV (c): Analysis of variance as influenced by lime and INM and their interaction effects on Leaf area index (LAI) at 90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.58	3.55	NS
Lime	1	0.26	0.26	80.93	4.41	S
INM	4	0.25	0.06	19.98	2.93	S
Lime x INM	4	0.01	0.00	1.09	2.93	NS
Error	18	0.06	0.00			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.48	3.55	NS
Lime	1	0.22	0.22	55.02	4.41	S
INM	4	0.25	0.06	15.61	2.93	S
Lime x INM	4	0.02	0.00	1.17	2.93	NS
Error	18	0.07	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.008	0.00	0.52	2.63	NS
Lime	2	0.48	0.24	66.36	3.26	S
INM	8	0.51	0.06	17.52	2.21	S
Lime x INM	8	0.03	0.00	1.13	2.21	NS
Error	36	0.13	0.00			

ANOVA-V (a): Analysis of variance as influenced by lime and INM and their interaction effects on shoot dry weight (g plant^{-1}) at 30 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	3.52	3.55	NS
Lime	1	1.22	1.22	404.45	4.41	S
INM	4	2.03	0.51	168.46	2.93	S
Lime x INM	4	0.06	0.02	5.19	2.93	S
Error	18	0.05	0.003			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	2.04	3.55	NS
Lime	1	1.28	1.28	430.89	4.41	S
INM	4	2.04	0.51	171.64	2.93	S
Lime x INM	4	0.03	0.01	2.84	2.93	NS
Error	18	0.05	0.003			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.03	0.01	2.78	2.63	S
Lime	2	2.50	1.25	417.60	3.26	S
INM	8	4.07	0.51	170.04	2.21	S
Lime x INM	8	0.10	0.01	4.02	2.21	S
Error	36	0.11	0.003			

ANOVA-V (b): Analysis of variance as influenced by lime and INM and their interaction effects on shoot dry weight (g plant^{-1}) at 60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.03	1.01	1.14	3.55	NS
Lime	1	38.15	38.15	43.06	4.41	S
INM	4	64.90	16.22	18.31	2.93	S
Lime x INM	4	11.34	2.84	3.20	2.93	S
Error	18	15.95	0.89			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	8.85	4.42	3.45	3.55	NS
Lime	1	55.79	55.79	43.55	4.41	S
INM	4	97.46	24.36	19.02	2.93	S
Lime x INM	4	11.53	2.88	2.25	2.93	NS
Error	18	23.06	1.28			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	10.87	2.72	2.51	2.63	NS
Lime	2	93.94	46.97	43.35	3.26	S
INM	8	162.35	20.29	18.73	2.21	S
Lime x INM	8	22.88	2.86	2.64	2.21	S
Error	36	39.01	1.08			

ANOVA-V (c): Analysis of variance as influenced by lime and INM and their interaction effects on shoot dry weight (g plant^{-1}) at 90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.68	0.34	0.11	3.55	NS
Lime	1	234.03	234.03	78.54	4.41	S
INM	4	224.62	56.16	18.85	2.93	S
Lime x INM	4	68.50	17.13	5.75	2.93	S
Error	18	53.63	2.98			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	7.83	3.91	2.49	3.55	NS
Lime	1	292.03	292.03	185.69	4.41	S
INM	4	324.86	81.21	51.64	2.93	S
Lime x INM	4	59.89	14.97	9.52	2.93	S
Error	18	28.31	1.57			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	8.51	2.13	0.93	2.63	NS
Lime	2	526.06	263.03	115.56	3.26	S
INM	8	549.48	68.69	30.18	2.21	S
Lime x INM	8	128.39	16.05	7.05	2.21	S
Error	36	81.94	2.28			

ANOVA-V (d): Analysis of variance as influenced by lime and INM and their interaction effects on shoot dry weight (g plant^{-1}) at harvest

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.75	1.38	0.45	3.55	NS
Lime	1	314.09	314.09	102.08	4.41	S
INM	4	302.73	75.68	24.60	2.93	S
Lime x INM	4	43.52	10.88	3.54	2.93	S
Error	18	55.38	3.08			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	8.32	4.16	0.97	3.55	NS
Lime	1	327.23	327.23	76.20	4.41	S
INM	4	507.15	126.79	29.52	2.93	S
Lime x INM	4	91.48	22.87	5.33	2.93	S
Error	18	77.30	4.29			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	11.07	2.77	0.75	2.63	NS
Lime	2	641.31	320.66	87.00	3.26	S
INM	8	809.88	101.23	27.47	2.21	S
Lime x INM	8	134.99	16.87	4.58	2.21	S
Error	36	132.68	3.69			

ANOVA VI (a): Analysis of variance as influenced by lime and INM and their interaction effects on Crop Growth Rate (g m^{-2} day^{-1}) at 30-60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	4.55	2.28	0.90	3.55	NS
Lime	1	71.46	71.46	28.14	4.41	S
INM	4	123.96	30.99	12.20	2.93	S
Lime x INM	4	28.34	7.08	2.79	2.93	NS
Error	18	45.71	2.54			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	15.49	7.75	1.57	3.55	NS
Lime	1	93.81	93.81	18.97	4.41	S
INM	4	166.13	41.53	8.40	2.93	S
Lime x INM	4	39.85	9.96	2.01	2.93	NS
Error	18	89.03	4.95			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	20.05	5.01	1.34	2.63	NS
Lime	2	165.27	82.63	22.08	3.26	S
INM	8	290.09	36.26	9.69	2.21	S
Lime x INM	8	68.19	8.52	2.28	2.21	S
Error	36	134.74	3.74			

ANOVA VI (b): Analysis of variance as influenced by lime and INM and their interaction effects on Crop Growth Rate (g m^{-2} day^{-1}) at 60-90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	47.46	23.73	1.31	3.55	NS
Lime	1	118.76	118.76	6.55	4.41	S
INM	4	53.03	13.26	0.73	2.93	NS
Lime x INM	4	132.33	33.08	1.82	2.93	NS
Error	18	326.43	18.14			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	52.90	26.45	1.99	3.55	NS
Lime	1	288.61	288.61	21.69	4.41	S
INM	4	206.69	51.67	3.88	2.93	S
Lime x INM	4	56.22	14.06	1.06	2.93	NS
Error	18	239.53	13.31			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	100.36	25.09	1.60	2.63	NS
Lime	2	407.37	203.69	12.96	3.26	S
INM	8	259.72	32.47	2.07	2.21	NS
Lime x INM	8	188.55	23.57	1.50	2.21	NS
Error	36	565.96	15.72			

ANOVA VII (a): Analysis of variance as influenced by lime and INM and their interaction effects on dry matter (g) at 30 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.030	0.015	1.81	3.55	NS
Lime	1	1.83	1.83	219.31	4.41	S
INM	4	2.27	0.57	67.91	2.93	S
Lime x INM	4	0.06	0.01	1.70	2.93	NS
Error	18	0.15	0.01			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	2.71	3.55	NS
Lime	1	1.94	1.94	464.39	4.41	S
INM	4	2.71	0.68	162.50	2.93	S
Lime x INM	4	0.02	0.01	1.24	2.93	NS
Error	18	0.08	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.05	0.01	2.11	2.63	NS
Lime	2	3.77	1.88	300.94	3.26	S
INM	8	4.98	0.62	99.42	2.21	S
Lime x INM	8	0.08	0.01	1.55	2.21	NS
Error	36	0.23	0.01			

ANOVA VII (b): Analysis of variance as influenced by lime and INM and their interaction effects on dry matter (g) at 60 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.57	1.29	1.39	3.55	NS
Lime	1	45.63	45.63	49.21	4.41	S
INM	4	79.71	19.93	21.49	2.93	S
Lime x INM	4	12.27	3.07	3.31	2.93	S
Error	18	16.69	0.93			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	8.35	4.17	3.12	3.55	NS
Lime	1	63.89	63.89	47.74	4.41	S
INM	4	116.31	29.08	21.73	2.93	S
Lime x INM	4	13.04	3.26	2.44	2.93	NS
Error	18	24.09	1.34			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	10.92	2.73	2.41	2.63	NS
Lime	2	109.52	54.76	48.34	3.26	S
INM	8	196.02	24.50	21.63	2.21	S
Lime x INM	8	25.31	3.16	2.79	2.21	S
Error	36	40.78	1.13			

ANOVA VII (c): Analysis of variance as influenced by lime and INM and their interaction effects on dry matter (g) at 90 DAS

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.06	0.03	0.01	3.55	NS
Lime	1	368.76	368.76	129.87	4.41	S
INM	4	317.99	79.50	28.00	2.93	S
Lime x INM	4	51.70	12.93	4.55	2.93	S
Error	18	51.11	2.84			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.62	0.31	0.12	3.55	NS
Lime	1	348.98	348.98	129.28	4.41	S
INM	4	319.09	79.77	29.55	2.93	S
Lime x INM	4	53.23	13.31	4.93	2.93	S
Error	18	48.59	2.70			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.69	0.17	0.06	2.63	NS
Lime	2	717.74	358.87	129.58	3.26	S
INM	8	637.09	79.64	28.76	2.21	S
Lime x INM	8	104.94	13.12	4.74	2.21	S
Error	36	99.70	2.77			

ANOVA VII (d): Analysis of variance as influenced by lime and INM and their interaction effects on dry matter (g) at harvest

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	3.50	1.75	0.42	3.55	NS
Lime	1	447.76	447.76	108.57	4.41	S
INM	4	398.34	99.59	24.15	2.93	S
Lime x INM	4	37.66	9.42	2.28	2.93	NS
Error	18	74.24	4.12			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	10.26	5.13	0.99	3.55	NS
Lime	1	459.58	459.58	88.59	4.41	S
INM	4	665.52	166.38	32.07	2.93	S
Lime x INM	4	95.24	23.81	4.59	2.93	S
Error	18	93.38	5.19			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	13.77	3.44	0.74	2.63	NS
Lime	2	907.34	453.67	97.44	3.26	S
INM	8	1063.87	132.98	28.56	2.21	S
Lime x INM	8	132.90	16.61	3.57	2.21	S
Error	36	167.61	4.66			

ANOVA VIII: Analysis of variance as influenced by lime and INM and their interaction effects on number of panicles^{-2} of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	594.16	297.08	1.30	3.55	NS
Lime	1	4808.27	4808.27	20.99	4.41	S
INM	4	19190.34	4797.58	20.94	2.93	S
Lime x INM	4	1905.14	476.28	2.08	2.93	NS
Error	18	4123.33	229.07			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	39.47	19.73	0.06	3.55	NS
Lime	1	6900.83	6900.83	19.46	4.41	S
INM	4	22496.33	5624.08	15.86	2.93	S
Lime x INM	4	3169.67	792.42	2.23	2.93	NS
Error	18	6383.87	354.66			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	633.63	158.41	0.54	2.63	NS
Lime	2	11709.10	5854.55	20.06	3.26	S
INM	8	41686.67	5210.83	17.85	2.21	S
Lime x INM	8	5074.81	634.35	2.17	2.21	NS
Error	36	10507.20	291.87			

ANOVA IX: Analysis of variance as influenced by lime and INM and their interaction effects on length of panicles (cm) of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	5.56	2.78	1.78	3.55	NS
Lime	1	0.63	0.63	0.41	4.41	NS
INM	4	32.91	8.23	5.27	2.93	S
Lime x INM	4	2.78	0.69	0.44	2.93	NS
Error	18	28.12	1.56			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	6.04	3.02	1.35	3.55	NS
Lime	1	5.40	5.40	2.41	4.41	NS
INM	4	34.69	8.67	3.87	2.93	S
Lime x INM	4	2.15	0.54	0.24	2.93	NS
Error	18	40.29	2.24			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	11.60	2.90	1.53	2.63	NS
Lime	2	6.04	3.02	1.59	3.26	NS
INM	8	67.61	8.45	4.45	2.21	S
Lime x INM	8	4.92	0.62	0.32	2.21	NS
Error	36	68.41	1.90			

ANOVA X: Analysis of variance as influenced by lime and INM and their interaction effects on number of filled grains panicle^{-1} of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	28.09	14.04	0.05	3.55	NS
Lime	1	12066.09	12066.09	44.48	4.41	S
INM	4	31037.12	7759.28	28.60	2.93	S
Lime x INM	4	140.58	35.14	0.13	2.93	NS
Error	18	4882.82	271.27			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	115.17	57.59	0.23	3.55	NS
Lime	1	10213.92	10213.92	40.12	4.41	S
INM	4	23482.32	5870.58	23.06	2.93	S
Lime x INM	4	3209.65	802.41	3.15	2.93	S
Error	18	4582.12	254.56			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	143.26	35.82	0.14	2.63	NS
Lime	2	22280.01	11140.01	42.37	3.26	S
INM	8	54519.44	6814.93	25.92	2.21	S
Lime x INM	8	3350.22	418.78	1.59	2.21	NS
Error	36	9464.94	262.91			

ANOVA XI: Analysis of variance as influenced by lime and INM and their interaction effects on filled grains percentage (%) of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.39	0.69	0.40	3.55	NS
Lime	1	48.60	48.60	28.32	4.41	S
INM	4	242.97	60.74	35.40	2.93	S
Lime x INM	4	4.55	1.14	0.66	2.93	NS
Error	18	30.89	1.72			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.18	0.59	0.09	3.55	NS
Lime	1	41.99	41.99	6.06	4.41	S
INM	4	256.34	64.09	9.25	2.93	S
Lime x INM	4	14.89	3.72	0.54	2.93	NS
Error	18	124.68	6.93			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	2.57	0.64	0.15	2.63	NS
Lime	2	90.59	45.30	10.48	3.26	S
INM	8	499.32	62.41	14.44	2.21	S
Lime x INM	8	19.44	2.43	0.56	2.21	NS
Error	36	155.57	4.32			

ANOVA XII: Analysis of variance as influenced by lime and INM and their interaction effects on grain yield (q ha^{-1}) of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.91	0.45	0.52	3.55	NS
Lime	1	123.95	123.95	142.80	4.41	S
INM	4	398.49	99.62	114.77	2.93	S
Lime x INM	4	30.96	7.74	8.92	2.93	S
Error	18	15.62	0.87			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.93	0.47	0.27	3.55	NS
Lime	1	146.61	146.61	83.63	4.41	S
INM	4	432.58	108.15	61.69	2.93	S
Lime x INM	4	80.46	20.11	11.47	2.93	S
Error	18	31.55	1.75			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.84	0.46	0.35	2.63	NS
Lime	2	270.56	135.28	103.23	3.26	S
INM	8	831.07	103.88	79.27	2.21	S
Lime x INM	8	111.42	13.93	10.63	2.21	S
Error	36	47.18	1.31			

ANOVA XIII: Analysis of variance as influenced by lime and INM and their interaction effects on straw yield (q ha^{-1}) of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	75.83	37.91	2.07	3.55	NS
Lime	1	148.12	148.12	8.07	4.41	S
INM	4	800.34	200.09	10.90	2.93	S
Lime x INM	4	397.27	99.32	5.41	2.93	S
Error	18	330.34	18.35			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	87.13	43.56	1.68	3.55	NS
Lime	1	225.50	225.50	8.69	4.41	S
INM	4	631.72	157.93	6.08	2.93	S
Lime x INM	4	360.03	90.01	3.47	2.93	S
Error	18	467.32	25.96			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	162.95	40.74	1.84	2.63	NS
Lime	2	373.62	186.81	8.43	3.26	S
INM	8	1432.07	179.01	8.08	2.21	S
Lime x INM	8	757.30	94.66	4.27	2.21	S
Error	36	797.67	22.16			

ANOVA XIV: Analysis of variance as influenced by lime and INM and their interaction effects on harvest index (%) of rice

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	11.34	5.67	1.95	3.55	NS
Lime	1	12.57	12.57	4.33	4.41	NS
INM	4	47.37	11.84	4.08	2.93	S
Lime x INM	4	42.78	10.70	3.68	2.93	S
Error	18	52.28	2.90			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	8.93	4.47	1.08	3.55	NS
Lime	1	12.15	12.15	2.95	4.41	NS
INM	4	51.69	12.92	3.14	2.93	S
Lime x INM	4	16.64	4.16	1.01	2.93	NS
Error	18	74.12	4.12			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	20.28	5.07	1.44	2.63	NS
Lime	2	24.72	12.36	3.52	3.26	S
INM	8	99.07	12.38	3.53	2.21	S
Lime x INM	8	59.42	7.43	2.12	2.21	NS
Error	36	126.39	3.51			

ANOVA XV: Analysis of variance as influenced by effect of lime and INM and their interaction effects on soil nutrient status after harvest of rice

ANOVA XV (a): Soil Ph

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	19.57	9.79	0.26	3.55	NS
Lime	1	1545.85	1545.85	40.53	4.41	S
INM	4	5690.48	1422.62	37.30	2.93	S
Lime x INM	4	1549.34	387.34	10.16	2.93	S
Error	18	686.54	38.14			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	94.51	47.25	1.08	3.55	NS
Lime	1	2786.73	2786.73	63.61	4.41	S
INM	4	7358.83	1839.71	42.00	2.93	S
Lime x INM	4	1111.88	277.97	6.35	2.93	S
Error	18	788.51	43.81			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	114.08	28.52	0.70	2.63	NS
Lime	2	4332.59	2166.29	52.87	3.26	S
INM	8	13049.31	1631.16	39.81	2.21	S
Lime x INM	8	2661.23	332.65	8.12	2.21	S
Error	36	1475.06	40.97			

ANOVA XV (b): Soil organic carbon (%)

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.01	3.28	3.55	NS
Lime	1	0.08	0.08	48.87	4.41	S
INM	4	0.15	0.04	23.39	2.93	S
Lime x INM	4	0.02	0.00	2.89	2.93	NS
Error	18	0.03	0.00			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	0.64	3.55	NS
Lime	1	0.16	0.16	35.02	4.41	S
INM	4	0.40	0.10	22.09	2.93	S
Lime x INM	4	0.02	0.01	1.21	2.93	NS
Error	18	0.08	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.02	0.00	1.33	2.63	NS
Lime	2	0.24	0.12	38.61	3.26	S
INM	8	0.55	0.07	22.43	2.21	S
Lime x INM	8	0.04	0.01	1.65	2.21	NS
Error	36	0.11	0.00			

ANOVA XV (c): Available nitrogen (kg ha^{-1})

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	19.57	9.79	0.26	3.55	NS
Lime	1	1545.85	1545.85	40.53	4.41	S
INM	4	5690.48	1422.62	37.30	2.93	S
Lime x INM	4	1549.34	387.34	10.16	2.93	S
Error	18	686.54	38.14			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	94.51	47.25	1.08	3.55	NS
Lime	1	2786.73	2786.73	63.61	4.41	S
INM	4	7358.83	1839.71	42.00	2.93	S
Lime x INM	4	1111.88	277.97	6.35	2.93	S
Error	18	788.51	43.81			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	114.08	28.52	0.70	2.63	NS
Lime	2	4332.59	2166.29	52.87	3.26	S
INM	8	13049.31	1631.16	39.81	2.21	S
Lime x INM	8	2661.23	332.65	8.12	2.21	S
Error	36	1475.06	40.97			

ANOVA XV (d): Available phosphorus (kg ha^{-1})

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.18	0.09	0.23	3.55	NS
Lime	1	149.59	149.59	383.26	4.41	S
INM	4	192.92	48.23	123.57	2.93	S
Lime x INM	4	28.98	7.25	18.56	2.93	S
Error	18	7.03	0.39			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.26	0.63	0.57	3.55	NS
Lime	1	208.77	208.77	188.25	4.41	S
INM	4	282.81	70.70	63.75	2.93	S
Lime x INM	4	41.63	10.41	9.38	2.93	S
Error	18	19.96	1.11			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.44	0.36	0.48	2.63	NS
Lime	2	358.36	179.18	239.02	3.26	S
INM	8	475.73	59.47	79.33	2.21	S
Lime x INM	8	70.61	8.83	11.77	2.21	S
Error	36	26.99	0.75			

ANOVA XV (e): Available potassium (kg ha^{-1})

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	326.52	163.26	2.26	3.55	NS
Lime	1	4508.00	4508.00	62.52	4.41	S
INM	4	9398.50	2349.63	32.59	2.93	S
Lime x INM	4	53.04	13.26	0.18	2.93	NS
Error	18	1297.79	72.10			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	157.11	78.55	1.91	3.55	NS
Lime	1	5542.82	5542.82	134.81	4.41	S
INM	4	13876.79	3469.20	84.38	2.93	S
Lime x INM	4	1423.88	355.97	8.66	2.93	S
Error	18	740.07	41.12			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	483.63	120.91	2.14	2.63	NS
Lime	2	10050.82	5025.41	88.78	3.26	S
INM	8	23275.29	2909.41	51.40	2.21	S
Lime x INM	8	1476.92	184.62	3.26	2.21	S
Error	36	2037.86	56.61			

ANOVA XVI: Analysis of variance as influenced by effect of lime and INM and their interaction effects on nutrient uptake by rice

ANOVA XVI (a): Nitrogen uptake (kg ha^{-1})

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	9.47	4.73	1.04	3.55	NS
Lime	1	174.58	174.58	38.52	4.41	S
INM	4	501.08	125.27	27.64	2.93	S
Lime x INM	4	95.76	23.94	5.28	2.93	S
Error	18	81.58	4.53			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.27	0.64	0.60	3.55	NS
Lime	1	269.52	269.52	255.97	4.41	S
INM	4	896.03	224.01	212.75	2.93	S
Lime x INM	4	93.97	23.49	22.31	2.93	S
Error	18	18.95	1.05			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	10.74	2.69	0.96	2.63	NS
Lime	2	444.10	222.05	79.51	3.26	S
INM	8	1397.11	174.64	62.53	2.21	S
Lime x INM	8	189.73	23.72	8.49	2.21	S
Error	36	100.54	2.79			

ANOVA XVI (b): Phosphorus uptake (kg ha^{-1})

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.26	1.13	2.65	3.55	NS
Lime	1	31.05	31.05	72.65	4.41	S
INM	4	128.82	32.20	75.35	2.93	S
Lime x INM	4	17.07	4.27	9.98	2.93	S
Error	18	7.69	0.43			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	5.29	2.64	1.80	3.55	NS
Lime	1	9.06	9.06	6.17	4.41	S
INM	4	248.94	62.24	42.34	2.93	S
Lime x INM	4	9.95	2.49	1.69	2.93	NS
Error	18	26.46	1.47			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	7.55	1.89	1.99	2.63	NS
Lime	2	40.11	20.06	21.14	3.26	S
INM	8	377.76	47.22	49.78	2.21	S
Lime x INM	8	27.02	3.38	3.56	2.21	S
Error	36	34.15	0.95			

ANOVA XVI (c): Potassium uptake (kg ha^{-1})

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.92	0.46	0.52	3.55	NS
Lime	1	301.97	301.97	342.63	4.41	S
INM	4	254.15	63.54	72.09	2.93	S
Lime x INM	4	19.91	4.98	5.65	2.93	S
Error	18	15.86	0.88			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	5.63	2.81	0.85	3.55	NS
Lime	1	241.63	241.63	72.94	4.41	S
INM	4	279.19	69.80	21.07	2.93	S
Lime x INM	4	18.89	4.72	1.43	2.93	NS
Error	18	59.63	3.31			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	6.55	1.64	0.78	2.63	NS
Lime	2	543.60	271.80	129.62	3.26	S
INM	8	533.33	66.67	31.79	2.21	S
Lime x INM	8	38.80	4.85	2.31	2.21	S
Error	36	75.49	2.10			

ANOVA XVII: Analysis of variance as influenced by effect of lime and INM and their interaction effects on microbial population after harvest of rice

ANOVA XVII (a): Bacteria (10^6 x cfu g^{-1} soil)

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	211.67	105.83	2.73	3.55	NS
Lime	1	264.03	264.03	6.80	4.41	S
INM	4	2247.13	561.78	14.47	2.93	S
Lime x INM	4	21.13	5.28	0.14	2.93	NS
Error	18	699.00	38.83			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	216.87	108.43	2.33	3.55	NS
Lime	1	572.03	572.03	12.27	4.41	S
INM	4	2727.53	681.88	14.63	2.93	S
Lime x INM	4	21.80	5.45	0.12	2.93	NS
Error	18	839.13	46.62			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	428.53	107.13	2.51	2.63	NS
Lime	2	836.07	418.03	9.78	3.26	S
INM	8	4974.67	621.83	14.55	2.21	S
Lime x INM	8	42.93	5.37	0.13	2.21	NS
Error	36	1538.13	42.73			

ANOVA XVII (b): Actinomycetes (10^5 x cfu g^{-1} soil)

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.07	0.03	0.11	3.55	NS
Lime	1	2.13	2.13	7.29	4.41	S
INM	4	5.13	1.28	4.39	2.93	S
Lime x INM	4	0.87	0.22	0.74	2.93	NS
Error	18	5.27	0.29			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.80	0.90	2.15	3.55	NS
Lime	1	3.33	3.33	7.96	4.41	S
INM	4	6.20	1.55	3.70	2.93	S
Lime x INM	4	0.33	0.08	0.20	2.93	NS
Error	18	7.53	0.42			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.87	0.47	1.31	2.63	NS
Lime	2	5.47	2.73	7.69	3.26	S
INM	8	11.33	1.42	3.98	2.21	S
Lime x INM	8	1.20	0.15	0.42	2.21	NS
Error	36	12.80	0.36			

ANOVA XVII (c): Fungi (10^3 x cfu g^{-1} soil)

ANOVA for First year 2016						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	17.27	8.63	0.16	3.55	NS
Lime	1	128.13	128.13	2.41	4.41	NS
INM	4	1429.00	357.25	6.72	2.93	S
Lime x INM	4	59.53	14.88	0.28	2.93	NS
Error	18	956.73	53.15			

ANOVA for Second year 2017						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	218.87	109.43	2.39	3.55	NS
Lime	1	158.70	158.70	3.46	4.41	NS
INM	4	1662.80	415.70	9.08	2.93	S
Lime x INM	4	60.13	15.03	0.33	2.93	NS
Error	18	824.47	45.80			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	236.13	59.03	1.19	2.63	NS
Lime	2	286.83	143.42	2.90	3.26	NS
INM	8	3091.80	386.48	7.81	2.21	S
Lime x INM	8	119.67	14.96	0.30	2.21	NS
Error	36	1781.20	49.48			

ANOVA XVIII (a): Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on plant height (cm) of pea at 30 DAS

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.49	0.25	0.18	3.55	NS
Lime	1	60.58	60.58	43.95	4.41	S
INM	4	169.73	42.43	30.79	2.93	S
Lime x INM	4	44.81	11.20	8.13	2.93	S
Error	18	24.81	1.38			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.29	0.65	0.40	3.55	NS
Lime	1	59.81	59.81	36.96	4.41	S
INM	4	193.71	48.43	29.92	2.93	S
Lime x INM	4	55.81	13.95	8.62	2.93	S
Error	18	29.13	1.62			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.78	0.45	0.30	2.63	NS
Lime	2	120.39	60.19	40.17	3.26	S
INM	8	363.45	45.43	30.32	2.21	S
Lime x INM	8	100.63	12.58	8.39	2.21	S
Error	36	53.94	1.50			

ANOVA XVIII (b): Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on plant height (cm) of pea at 60 DAS

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	4.59	2.29	2.49	3.55	NS
Lime	1	93.70	93.70	101.75	4.41	S
INM	4	280.08	70.02	76.03	2.93	S
Lime x INM	4	24.08	6.02	6.54	2.93	S
Error	18	16.58	0.92			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	2.56	1.28	1.10	3.55	NS
Lime	1	88.03	88.03	75.93	4.41	S
INM	4	313.69	78.42	67.64	2.93	S
Lime x INM	4	35.21	8.80	7.59	2.93	S
Error	18	20.87	1.16			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	7.15	1.79	1.72	2.63	NS
Lime	2	181.74	90.87	87.36	3.26	S
INM	8	593.77	74.22	71.36	2.21	S
Lime x INM	8	59.29	7.41	7.13	2.21	S
Error	36	37.45	1.04			

ANOVA XVIII (c): Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on plant height (cm) of pea at harvest

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.76	0.38	0.34	3.55	NS
Lime	1	87.45	87.45	78.68	4.41	S
INM	4	222.86	55.72	50.13	2.93	S
Lime x INM	4	16.00	4.00	3.60	2.93	S
Error	18	20.01	1.11			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.16	0.58	0.63	3.55	NS
Lime	1	90.55	90.55	98.86	4.41	S
INM	4	238.37	59.59	65.06	2.93	S
Lime x INM	4	11.34	2.84	3.10	2.93	S
Error	18	16.49	0.92			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.92	0.48	0.47	2.63	NS
Lime	2	178.00	89.00	87.79	3.26	S
INM	8	461.23	57.65	56.87	2.21	S
Lime x INM	8	27.34	3.42	3.37	2.21	S
Error	36	36.49	1.01			

ANOVA XIX (a): Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on number of branches of pea at 30 DAS

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.21	0.10	0.60	3.55	NS
Lime	1	1.66	1.66	9.52	4.41	S
INM	4	3.28	0.82	4.71	2.93	S
Lime x INM	4	0.41	0.10	0.58	2.93	NS
Error	18	3.13	0.17			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.18	0.09	0.77	3.55	NS
Lime	1	2.14	2.14	17.90	4.41	S
INM	4	4.11	1.03	8.60	2.93	S
Lime x INM	4	0.57	0.14	1.19	2.93	NS
Error	18	2.15	0.12			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.39	0.10	0.67	2.63	NS
Lime	2	3.80	1.90	12.93	3.26	S
INM	8	7.39	0.92	6.29	2.21	S
Lime x INM	8	0.97	0.12	0.83	2.21	NS
Error	36	5.28	0.15			

ANOVA XIX (b): Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on number of branches of pea at 60 DAS

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.55	0.28	0.29	3.55	NS
Lime	1	19.72	19.72	20.95	4.41	S
INM	4	63.29	15.82	16.82	2.93	S
Lime x INM	4	6.66	1.66	1.77	2.93	NS
Error	18	16.94	0.94			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	4.36	2.18	2.35	3.55	NS
Lime	1	20.02	20.02	21.62	4.41	S
INM	4	71.80	17.95	19.38	2.93	S
Lime x INM	4	9.47	2.37	2.56	2.93	NS
Error	18	16.67	0.93			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	4.91	1.23	1.32	2.63	NS
Lime	2	39.74	19.87	21.28	3.26	S
INM	8	135.09	16.89	18.09	2.21	S
Lime x INM	8	16.13	2.02	2.16	2.21	NS
Error	36	33.61	0.93			

ANOVA XIX (c): Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on number of branches of pea at harvest

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.34	0.17	0.30	3.55	NS
Lime	1	25.74	25.74	45.04	4.41	S
INM	4	83.68	20.92	36.60	2.93	s
Lime x INM	4	6.33	1.58	2.77	2.93	NS
Error	18	10.29	0.57			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.39	0.20	0.26	3.55	NS
Lime	1	31.91	31.91	41.86	4.41	S
INM	4	102.18	25.55	33.51	2.93	S
Lime x INM	4	8.36	2.09	2.74	2.93	NS
Error	18	13.72	0.76			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.16	0.79	0.93	2.63	NS
Lime	2	56.83	28.42	33.31	3.26	S
INM	8	189.54	23.69	27.77	2.21	S
Lime x INM	8	14.11	1.76	2.07	2.21	NS
Error	36	30.71	0.85			

ANOVA XX: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on dry weight plant^{-1} (g) of pea at 30 DAS

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	2.20	3.55	NS
Lime	1	0.05	0.05	27.06	4.41	S
INM	4	0.09	0.02	12.32	2.93	S
Lime x INM	4	0.00	0.00	0.31	2.93	NS
Error	18	0.03	0.00			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.00	0.00	0.13	3.55	NS
Lime	1	0.10	0.10	36.52	4.41	S
INM	4	0.14	0.03	12.28	2.93	S
Lime x INM	4	0.01	0.00	0.49	2.93	NS
Error	18	0.05	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.96	2.63	NS
Lime	2	0.15	0.08	32.71	3.26	S
INM	8	0.23	0.03	12.30	2.21	S
Lime x INM	8	0.01	0.00	0.42	2.21	NS
Error	36	0.08	0.00			

ANOVA XXI: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on number of pods plant^{-1} of pea

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.38	0.19	2.49	3.55	NS
Lime	1	1.47	1.47	19.12	4.41	S
INM	4	1.38	0.34	4.47	2.93	S
Lime x INM	4	0.41	0.10	1.34	2.93	NS
Error	18	1.39	0.08			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.05	0.03	0.25	3.55	NS
Lime	1	1.80	1.80	18.22	4.41	S
INM	4	2.10	0.53	5.32	2.93	S
Lime x INM	4	0.52	0.13	1.32	2.93	NS
Error	18	1.78	0.10			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.43	0.11	1.23	2.63	NS
Lime	2	3.27	1.64	18.62	3.26	S
INM	8	3.48	0.43	4.94	2.21	S
Lime x INM	8	0.93	0.12	1.33	2.21	NS
Error	36	3.17	0.09			

ANOVA XXII: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on number of seeds pod^{-1} of pea

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.23	0.12	1.28	3.55	NS
Lime	1	2.44	2.44	26.82	4.41	S
INM	4	2.11	0.53	5.81	2.93	S
Lime x INM	4	1.02	0.26	2.81	2.93	NS
Error	18	1.64	0.09			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.12	0.06	0.82	3.55	NS
Lime	1	2.71	2.71	36.18	4.41	S
INM	4	2.68	0.67	8.97	2.93	S
Lime x INM	4	0.78	0.20	2.62	2.93	NS
Error	18	1.35	0.07			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.35	0.09	1.07	2.63	NS
Lime	2	5.14	2.57	31.05	3.26	S
INM	8	4.80	0.60	7.24	2.21	S
Lime x INM	8	1.81	0.23	2.73	2.21	S
Error	36	2.98	0.08			

ANOVA XXIII: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on pod yield (q ha^{-1}) of pea

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.27	0.14	0.24	3.55	NS
Lime	1	34.75	34.75	61.11	4.41	S
INM	4	98.50	24.62	43.29	2.93	S
Lime x INM	4	12.10	3.02	5.32	2.93	S
Error	18	10.24	0.57			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.29	0.14	0.14	3.55	NS
Lime	1	37.27	37.27	36.74	4.41	S
INM	4	126.27	31.57	31.12	2.93	S
Lime x INM	4	17.01	4.25	4.19	2.93	S
Error	18	18.26	1.01			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.56	0.14	0.18	2.63	NS
Lime	2	72.03	36.01	45.49	3.26	S
INM	8	224.76	28.10	35.49	2.21	S
Lime x INM	8	29.11	3.64	4.60	2.21	S
Error	36	28.50	0.79			

ANOVA XXIV: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on stover yield (q ha^{-1}) of pea

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.61	0.31	0.13	3.55	NS
Lime	1	73.73	73.73	30.18	4.41	S
INM	4	120.85	30.21	12.37	2.93	S
Lime x INM	4	37.89	9.47	3.88	2.93	S
Error	18	43.98	2.44			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.30	0.65	0.47	3.55	NS
Lime	1	87.52	87.52	63.83	4.41	S
INM	4	101.69	25.42	18.54	2.93	S
Lime x INM	4	55.58	13.89	10.13	2.93	S
Error	18	24.68	1.37			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.91	0.48	0.25	2.63	NS
Lime	2	161.25	80.62	42.28	3.26	S
INM	8	222.54	27.82	14.59	2.21	S
Lime x INM	8	93.47	11.68	6.13	2.21	S
Error	36	68.65	1.91			

ANOVA XXV: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on soil nutrient status after harvest of pea

ANOVA XXV (a): Soil pH

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.03	0.01	0.81	3.55	NS
Lime	1	0.36	0.36	20.41	4.41	S
INM	4	0.17	0.04	2.37	2.93	NS
Lime x INM	4	0.01	0.00	0.11	2.93	NS
Error	18	0.32	0.02			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.04	0.02	0.95	3.55	NS
Lime	1	0.67	0.67	31.76	4.41	S
INM	4	0.24	0.06	2.79	2.93	NS
Lime x INM	4	0.02	0.01	0.25	2.93	NS
Error	18	0.38	0.02			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.07	0.02	0.89	2.63	NS
Lime	2	1.03	0.51	26.60	3.26	S
INM	8	0.40	0.05	2.60	2.21	S
Lime x INM	8	0.03	0.00	0.19	2.21	NS
Error	36	0.70	0.02			

ANOVA XXV (b): Soil organic carbon (%)

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.02	0.01	1.45	3.55	NS
Lime	1	0.05	0.05	9.45	4.41	S
INM	4	0.17	0.04	7.94	2.93	S
Lime x INM	4	0.00	0.00	0.08	2.93	NS
Error	18	0.09	0.01			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.01	0.00	2.24	3.55	NS
Lime	1	0.10	0.10	52.40	4.41	S
INM	4	0.24	0.06	32.01	2.93	S
Lime x INM	4	0.00	0.00	0.39	2.93	NS
Error	18	0.03	0.00			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.02	0.01	1.66	2.63	NS
Lime	2	0.15	0.07	20.59	3.26	S
INM	8	0.40	0.05	14.18	2.21	S
Lime x INM	8	0.00	0.00	0.16	2.21	NS
Error	36	0.13	0.00			

ANOVA XXV (c): Available nitrogen (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	135.05	67.53	0.35	3.55	NS
Lime	1	1753.23	1753.23	9.04	4.41	S
INM	4	6085.58	1521.40	7.85	2.93	S
Lime x INM	4	1643.03	410.76	2.12	2.93	NS
Error	18	3489.33	193.85			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	945.01	472.50	3.29	3.55	NS
Lime	1	5188.20	5188.20	36.17	4.41	S
INM	4	8649.73	2162.43	15.08	2.93	S
Lime x INM	4	1008.04	252.01	1.76	2.93	NS
Error	18	2581.75	143.43			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1080.06	270.01	1.60	2.63	NS
Lime	2	6941.43	3470.71	20.58	3.26	S
INM	8	14735.32	1841.91	10.92	2.21	S
Lime x INM	8	2651.07	331.38	1.97	2.21	NS
Error	36	6071.08	168.64			

ANOVA XXV (d): Available phosphorus (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	12.26	6.13	1.81	3.55	NS
Lime	1	49.31	49.31	14.52	4.41	S
INM	4	123.33	30.83	9.08	2.93	S
Lime x INM	4	37.71	9.43	2.78	2.93	NS
Error	18	61.12	3.40			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	16.31	8.16	0.94	3.55	NS
Lime	1	99.26	99.26	11.48	4.41	S
INM	4	172.50	43.12	4.99	2.93	S
Lime x INM	4	67.88	16.97	1.96	2.93	NS
Error	18	155.68	8.65			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	28.57	7.14	1.19	2.63	NS
Lime	2	148.57	74.28	12.33	3.26	S
INM	8	295.83	36.98	6.14	2.21	S
Lime x INM	8	105.60	13.20	2.19	2.21	NS
Error	36	216.80	6.02			

ANOVA XXV (d): Available potassium (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	74.41	37.21	0.75	3.55	NS
Lime	1	2901.03	2901.03	58.26	4.41	S
INM	4	2522.41	630.60	12.66	2.93	S
Lime x INM	4	540.48	135.12	2.71	2.93	NS
Error	18	896.35	49.80			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	251.16	125.58	1.29	3.55	NS
Lime	1	4070.04	4070.04	41.65	4.41	S
INM	4	3465.15	866.29	8.86	2.93	S
Lime x INM	4	432.56	108.14	1.11	2.93	NS
Error	18	1758.98	97.72			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	325.57	81.39	1.10	2.63	NS
Lime	2	6971.07	3485.54	47.26	3.26	S
INM	8	5987.56	748.45	10.15	2.21	S
Lime x INM	8	973.04	121.63	1.65	2.21	NS
Error	36	2655.33	73.76			

ANOVA XXVI: Analysis of variance as influenced by effect of lime and INM and their interaction effects on nutrient uptake by pea

ANOVA XXVI (a): Nitrogen uptake (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	16.42	8.21	1.99	3.55	NS
Lime	1	113.84	113.84	27.53	4.41	S
INM	4	301.22	75.31	18.21	2.93	S
Lime x INM	4	127.40	31.85	7.70	2.93	S
Error	18	74.44	4.14			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	44.28	22.14	3.38	3.55	NS
Lime	1	130.42	130.42	19.93	4.41	S
INM	4	381.73	95.43	14.59	2.93	S
Lime x INM	4	165.59	41.40	6.33	2.93	S
Error	18	117.77	6.54			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	60.70	15.17	2.84	2.63	S
Lime	2	244.26	122.13	22.87	3.26	S
INM	8	682.96	85.37	15.99	2.21	S
Lime x INM	8	292.99	36.62	6.86	2.21	S
Error	36	192.21	5.34			

ANOVA XXVI (b): Phosphorus uptake (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.61	0.80	1.07	3.55	NS
Lime	1	10.61	10.61	14.13	4.41	S
INM	4	21.73	5.43	7.24	2.93	S
Lime x INM	4	5.87	1.47	1.96	2.93	NS
Error	18	13.51	0.75			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.22	0.11	0.17	3.55	NS
Lime	1	15.14	15.14	22.62	4.41	S
INM	4	24.61	6.15	9.19	2.93	S
Lime x INM	4	6.73	1.68	2.51	2.93	NS
Error	18	12.04	0.67			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.83	0.46	0.64	2.63	NS
Lime	2	25.75	12.87	18.13	3.26	S
INM	8	46.34	5.79	8.16	2.21	S
Lime x INM	8	12.60	1.57	2.22	2.21	S
Error	36	25.56	0.71			

ANOVA XXVI (c): Potassium uptake (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	5.31	2.66	0.85	3.55	NS
Lime	1	15.90	15.90	5.11	4.41	S
INM	4	58.34	14.58	4.68	2.93	S
Lime x INM	4	55.00	13.75	4.42	2.93	S
Error	18	56.05	3.11			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	8.16	4.08	1.07	3.55	NS
Lime	1	22.97	22.97	6.01	4.41	S
INM	4	89.85	22.46	5.88	2.93	S
Lime x INM	4	38.13	9.53	2.49	2.93	NS
Error	18	68.82	3.82			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	13.48	3.37	0.97	2.63	NS
Lime	2	38.87	19.43	5.60	3.26	S
INM	8	148.19	18.52	5.34	2.21	S
Lime x INM	8	93.14	11.64	3.36	2.21	S
Error	36	124.87	3.47			

ANOVA XXVII: Analysis of variance as influenced by residual effect of lime and INM and their interaction effects on soil microbial population after harvest of pea

ANOVA XXVII (a): Bacteria (10^6 x cfu g^{-1} soil)

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.67	0.83	0.05	3.55	NS
Lime	1	5.63	5.63	0.33	4.41	NS
INM	4	681.80	170.45	10.04	2.93	S
Lime x INM	4	96.20	24.05	1.42	2.93	NS
Error	18	305.67	16.98			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	44.87	22.43	0.82	3.55	NS
Lime	1	76.80	76.80	2.82	4.41	NS
INM	4	633.80	158.45	5.82	2.93	S
Lime x INM	4	78.20	19.55	0.72	2.93	NS
Error	18	489.80	27.21			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	46.53	11.63	0.53	2.63	NS
Lime	2	82.43	41.22	1.87	3.26	NS
INM	8	1315.60	164.45	7.44	2.21	S
Lime x INM	8	174.40	21.80	0.99	2.21	NS
Error	36	795.47	22.10			

ANOVA XXVII (b): Actinomycetes (10^5 x cfu g^{-1} soil)

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.47	0.23	0.76	3.55	NS
Lime	1	0.13	0.13	0.43	4.41	NS
INM	4	3.80	0.95	3.09	2.93	S
Lime x INM	4	1.53	0.38	1.25	2.93	NS
Error	18	5.53	0.31			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	0.60	0.30	0.89	3.55	NS
Lime	1	0.30	0.30	0.89	4.41	NS
INM	4	2.47	0.62	1.83	2.93	NS
Lime x INM	4	2.87	0.72	2.13	2.93	NS
Error	18	6.07	0.34			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.07	0.27	0.83	2.63	NS
Lime	2	0.43	0.22	0.67	3.26	NS
INM	8	6.27	0.78	2.43	2.21	S
Lime x INM	8	4.40	0.55	1.71	2.21	NS
Error	36	11.60	0.32			

ANOVA XXVII (c): Fungi (10^3 x cfu g^{-1} soil)

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	1.87	0.93	0.09	3.55	NS
Lime	1	34.13	34.13	3.29	4.41	NS
INM	4	230.13	57.53	5.54	2.93	S
Lime x INM	4	76.53	19.13	1.84	2.93	NS
Error	18	186.80	10.38			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	36.47	18.23	1.68	3.55	NS
Lime	1	43.20	43.20	3.99	4.41	NS
INM	4	380.20	95.05	8.78	2.93	S
Lime x INM	4	67.13	16.78	1.55	2.93	NS
Error	18	194.87	10.83			

ANOVA Pooled

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	38.33	9.58	0.90	2.63	NS
Lime	2	77.33	38.67	3.65	3.26	S
INM	8	610.33	76.29	7.20	2.21	S
Lime x INM	8	143.67	17.96	1.69	2.21	NS
Error	36	381.67	10.60			

ANOVA XXVIII: Analysis of variance as influenced by effect of lime and INM and their interaction effects on system productivity of rice-pea cropping system

ANOVA XXVIII (a): Rice equivalent yield of pea (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	61768.59	30884.29	0.58	3.55	NS
Lime	1	9090548.59	9090548.59	170.28	4.41	S
INM	4	26956538.32	6739134.58	126.23	2.93	S
Lime x INM	4	2699955.77	674988.94	12.64	2.93	S
Error	18	960953.00	53386.28			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	12721.37	6360.68	0.07	3.55	NS
Lime	1	10492237.26	10492237.26	109.46	4.41	S
INM	4	32428032.46	8107008.11	84.58	2.93	S
Lime x INM	4	470957543	1177393.86	12.28	2.93	S
Error	18	1725342	95852.33			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	74489.96	18622.49	0.25	2.63	NS
Lime	1	19582785.84	9791392.92	131.22	3.26	S
INM	4	59384570.77	7423071.35	99.48	2.21	S
Lime x INM	4	7409531.20	926191.40	12.41	2.21	S
Error	18	2686295.01	74619.31			

ANOVA XXVIII (b): System productivity (kg ha^{-1})

ANOVA for First year 2016-17						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	113609.30	56804.65	0.87	3.55	NS
Lime	1	17043599.03	17043599.03	262.42	4.41	S
INM	4	51633459.79	12908364.95	198.75	2.93	S
Lime x INM	4	4760163.71	1190040.93	18.32	2.93	S
Error	18	1169066.96	64948.16			

ANOVA for Second year 2017-18						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	32514.07	16257.03	0.11	3.55	NS
Lime	1	19802536.06	19802536.06	139.11	4.41	S
INM	4	60407533.47	15101883.37	106.09	2.93	S
Lime x INM	4	9213874.37	2303468.59	16.18	2.93	S
Error	18	2562286.54	142349.25			

ANOVA Pooled						
Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	2	146123.37	36530.84	0.35	2.63	NS
Lime	1	36846135.09	18423067.54	177.75	3.26	S
INM	4	112040993.26	14005124.16	135.12	2.21	S
Lime x INM	4	13974038.08	1746754.76	16.85	2.21	S
Error	18	3731353.50	103648.71			

APPENDIX-B

Cost of cultivation (₹ ha^{-1})

(A) Common cost of cultivation of rice on hectare^{-1} basis				
Sl. No	**Items**	**No. of units**	**Rate (₹ $Unit^{-1}$)**	**Total (₹ ha^{-1})**
1.	Field preparation			
	Summer ploughing twice by tractor	2	1500	3000
	Levelling and seed bed preparation	5 labours	200	1000
2.	Seeds	80 kg	15.5	1240
3.	Furrow opening and Sowing	20 labours	200	4000
4.	Application of manures and fertilizers	15 labours	200	3000
5.	Thinning and weeding	20 labours	200	4000
6.	Plant protection	-	-	1000
7.	Chemical application	5 labours	200	1000
8.	Harvesting, threshing and winnowing	15 labours	200	3000
9.	Drying	5 labours	200	1000
10.	Miscellaneous	-	-	500
Total				22740

(B) Cost of variable inputs				
Sl. No	**Inputs**	**Quantity ha^{-1}**	**Rate(₹ ha^{-1})**	**Total (₹ ha^{-1})**
B_1	a) Urea	120 kg ha^{-1}	10	1200
	b) SSP	60 kg ha^{-1}	15	900
	c) MOP	60 kg ha^{-1}	25	1500
Total				3600
B_2	a) Urea	90 kg ha^{-1}	10	900
	b) SSP	45 kg ha^{-1}	15	675
	c) MOP	45 kg ha^{-1}	25	1125
	d) FYM	6 t ha^{-1}	500	3000
Total				5700
B_3	a) Urea	90 kg ha^{-1}	10	900
	b) SSP	45 kg ha^{-1}	15	675
	c) MOP	45 kg ha^{-1}	25	1125
	d) Poultry manure	1 t ha^{-1}	900	900
Total				3600
B_4	a) Urea	90 kg ha^{-1}	10	900
	b) SSP	45 kg ha^{-1}	15	675
	c) MOP	45 kg ha^{-1}	25	1125
	d) Azospirillum	2	10	20
	e) Phosphorus Solubilising Bacteria	2	10	20
Total				2740
B_5	Lime	200 kg ha^{-1}	10	2000
Total				2000

(C) Common cost of cultivation of pea on hectare^{-1} basis				
Sl. No	**Items**	**No. of units**	**Rate (₹ Unit^{-1})**	**Total (₹ ha^{-1})**
1.	Furrow opening and Sowing	20 labours	200	4000
2.	Seeds	100 kg	225	22500
3.	Weeding and earthing up	10 labours	200	2000
4.	Harvesting	15 labours	200	3000
Total				31500