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Research Article

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Effect of Lime and Integrated Nutrient Management on Rice-pea Cropping System

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Abstract

The field experiment was conducted to study the individual and synergistic effects of lime, NPK and manure application on rice–pea productivity during the *kharif* and *rabi* seasons of 2016–17 and 2017–18 from June to January in the experimental farm of SASRD, Nagaland University, Nagaland State, India. The experiment was laid out in Factorial Randomized Block Design with two levels of lime viz. without lime, Lime @ 2 q ha^{-1} and four levels of integrated nutrient management viz. Recommended Dose of Fertilizers, Recommended Dose of Fertilizers (75%)+Farm Yard Manure @ 6 t ha^{-1}, Recommended Dose of Fertilizers (75%)+Poultry manure @ 1 t ha^{-1} and Recommended Dose of Fertilizers (75%)+*Azospirillum*+Phosphorus Solubilizing Bacteria and replicated thrice. Results revealed that the application of lime @ 2 q ha^{-1} brought about a significant increase in the growth and yield attributes of rice and pea. Among the nutrient sources, the application of Recommended Dose of Fertilizers (75%)+Farm Yard Manure@ 6 t ha^{-1} proved superior in terms of growth and yield over other treatments. With regard to economics like gross return ha^{-1}, net return ha^{-1}, benefit-cost ratio, system productivity and Rice Equivalent Yield (REY) treatment interactions of lime @ 2 q ha^{-1} and Recommended dose of fertilizers (75%)+farm yard manure @ 6 t ha^{-1} performed better by recording the highest.

Keywords: Liming, integrated nutrient management, rice, pea, yield, economics

1. Introduction

In the global context, India stands first in the rice cultivated area with 43.8 mha, second in production with 112.76 mt and average productivity of 2.57 t ha^{-1} (Anonymous, 2019). In Nagaland, rice being the most important of the people, it is grown throughout the entire state and covers an area of 214450 ha with a production of 5,35040 t out of which upland rainfed occupies an area of 91,040 ha with a production of 1,81,080 t. Another crop, pea (*Pisum sativum* L.) is an important *rabi* pulse crop in Nagaland. Nagaland has an area of 7200 ha under pea production with a productivity of 1.1 t ha (Anonymous, 2018). In Nagaland's condition, the importance of pea crop is mainly due to the reason that pea being a *rabi* season crop requires very less irrigation and Nagaland which is completely dependent on rainfed proved to be the best crop for this particular region. The cropping intensity of the North Eastern Region (NER) of India is low (134%) mainly due to the non-utilization of fallow lands after harvesting rainy season rice (*Oryza sativa* L.). Pea (*Pisum sativum* L.) is one of the most potential leguminous field crops for crop diversification and

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enhancing the productivity of rice-based cropping systems in NER. Thus, the introduction of pea in rice fallows with appropriate production technologies may increase cropping intensity, improve soil health and productivity in the fragile NER of the country.

Pea is sensitive to soil acidity and liming is the only option for increasing yield in such soil conditions (Gupta et al., 2000). About 11.7 mha of land in India is left as fallow after *kharif* rice (rainy season) harvest (Gumma et al., 2016). The rice fallow areas are 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 low input requirements, short duration and ability to establish even with surface broadcast, besides soil fertility restoration through BNF, narrow C: N ratio enriched crop residues and leaf fall, etc. are ideal for rice fallows. These are soil-building crops capable of transforming our dominant cereal-based cropping systems to an ideal and sustainable system in time to come (Praharaj et al., 2017). Generally, the monocropping system of rice cultivation is practiced in the northeast hill region of India (Das et al., 2018). This system has led to a number of problems including depletion in soil fertility and productivity of the soil, increase infestation of pests, diseases and weeds.

Soil acidity management and crop productivity improvement on acid soils are important for enhancing food security globally and regionally. The lime application works very slowly to release nutrients from fixation. Therefore, plants are unable to access the required amount of nutrients in the critical yield forming period. Hence, an integrated approach, combining the application of lime, fertilizer and manure application is a good strategy for enhancing crop development, growth under acidic soils (Kumar et al., 2012). The efficiency of applied chemical fertilizers is also increased when applied along with organic manures (Kumar et al., 2014). Therefore, the combined use of organic manure and inorganic fertilizer help in maintaining yield stability through correction of marginal deficiencies of secondary and micronutrients, enhancing efficiency of applied nutrients and providing favorable soil physical condition (Singh and Singh, 2014). In India, out of 25 mha of problematic acid soils with below pH 5.5, the north-eastern region represents 54% of the total area whereas; it occupies only 8% of the total geographical area. Liming is an important practice to achieve optimum yields of all crops grown on acid soils (Nduwumuremyi, 2013). Liming increases the soil pH, improves the availability of plant nutrients and crop growth, increases nutrient uptake, stimulates biological activity, decreases extractable Al^{3+} and reduces the 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% of the soils of Nagaland are considered strongly acidic soils (Panda, 1998). Acidity–induced soil fertility problems coupled with traditionally minimal use of mineral fertilizers are often held responsible for low levels of crop productivity in the state (Saha et al., 2010). In Nagaland, the agricultural production system always creates 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 viable cropping system approach with feasible and profitable crop management is the need of the hour for sustaining productivity of the land and also for sustaining production for human consumption. Therefore, a technological breakthrough in agro-techniques especially in the cropping system, nutrient and lime management is essential to improve productivity under rice-based cropping systems. Within this context, the primary objective of this study was to study the effect of lime and Integrated nutrient management on rice-pea cropping system.

2. Materials and Methods

The field experiments were carried out in the experimental research farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Campus, Medziphema, India during *kharif* season (June–October) of 2016 and 2017 for Rice and *Rabi* season (October–January) of 2016–2017 and 2017–2018 for garden Peas. The experimental farm is located in the foothill of Nagaland at an altitude of 310 above mean sea level with the geographical location at 25°45′43” N latitude and 95°53’04” E longitude. The climatic condition of the experimental site is sub-tropical with high humidity and moderate temperature, having medium to high rainfall. The mean temperature ranges from 21°–32°C during summer and rarely goes below 8°C in winter due to high atmospheric humidity. The annual rainfall ranges from 2500 mm, spread over six months i.e., from April–September, while the remaining period from October to March is virtually dry. The RDF of rice and pea, in general, is 120:60:60 and 20:60:40 NPK kg ha^{-1}. In general, the soil type of the experimental site was categorized as sandy loam in texture and well-drained. The initial soil pH and organic carbon were 4.73 and 1.26%, while the NPK was 263.79 kg ha^{-1}, 18.26 kg ha^{-1} and 185.17 kg ha^{-1}. The placement of each treatment was done in a randomized manner. The different treatment combinations are Control T_1 (L_0N_0), T_2 (L_0N_1) No lime+RDF (120: 60: 60 NPK kg ha^{-1}), T_3 (L_0N_2) No lime+RDF (75%)+FYM @ 6 t ha^{-1}), T_4 (L_0N_3) No lime+RDF (75%)+poultry manure @ 1 t ha^{-1}, T_5 (L_0N_4) No lime+RDF (75%)+*Azospirillum*+PSB, T_6 (L_1N_0) Lime @ 2 q ha^{-1}, T_7 (L_1N_1) Lime @ 2 q ha^{-1}+RDF (120: 60: 60 NPK kg ha^{-1}, T_8 (L_1N_2) Lime@ 2 q ha^{-1}+RDF (75%)+FYM @ 6 t ha^{-1}, T_9 (L_1N_3) Lime @ 2 q ha^{-1}+RDF (75%)+Poultry manure @ 1 t ha^{-1}, T_{10} (L_1N_4) Lime @ 2 q ha^{-1}+RDF (75%)+*Azospirillum*+PSB. The rice variety used was Longkumtsuk which is a local cultivar and grown during *kharif* season. It matures in 155–160 days and yield 4 t ha^{-1}. The colour of the grain is pale yellow. Seeds were obtained from Yisemyong (Mokokchung district). The spacing used for rice was 20×10 cm^2. Every cultural operation was carried out based on the calendar of agronomic management practices. The experimental design used was FRBD.

3. Results and Discussion

3.1. Rice

3.1.1. Growth parameters

The pooled data revealed the highest plant height recorded in L_1 (Lime @ 2 q ha^{-1}) with 162.66 cm and the lowest in L_0 (without lime) with 147.51 cm (Table 1). The increase in plant height in lime-treated plots might be due to the indirect effect of increasing the nitrogen availability to the plants through increased nitrification by moderating the pH in acid soil. The positive effects of liming on crops have been reported to increase plant height in acidic soil. The work done by Alfaons et al. (2008) and Ferdous et al. (2018) was found to be in conformity with the above observation. The increase in plant height might be owing 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) also reported that integration of 25 or 50% FYM with 50 or 75% inorganic release slow and continuous nutrients to the plant and improved soil environment for better root penetration leading to better absorption of moisture and nutrients and produced better plant height and growth. These findings are also in close agreement with those of Revathi et al. (2014).

Table 1: Effect of lime and integrated nutrient management on different growth and yield attributes and yield of rice

Treatments	PHH	NTRMH	SDWPH	CGR	NP	LP	NFGP	TW	GY	SY	HI
Lime											
L_0	147.51	31.73	29.65	10.94	200.67	25.47	113.33	30.22	31.14	64.77	32.40
L_1	162.66	37.13	36.19	11.88	228.50	26.04	127.96	32.00	35.38	69.74	33.68
SEm±	0.45	0.16	0.35	0.61	3.12	0.25	0.75	0.50	0.21	0.86	0.34
CD (*p*=0.05)	1.30	0.47	1.01	NS	8.95	NS	2.14	NS	0.60	2.46	0.98
INM											
N_0	130.86	27.25	26.03	9.82	163.17	23.85	93.80	29.05	26.03	58.25	30.84
N_1	157.74	35.42	32.84	10.56	217.68	25.61	124.54	30.98	33.86	67.42	33.51
N_2	165.60	37.25	36.34	13.45	233.50	26.91	128.90	32.08	36.54	70.15	34.30
N_3	158.93	35.83	35.22	13.24	226.25	25.88	127.88	31.83	34.92	72.19	32.63
N_4	162.31	36.42	34.18	10.00	232.33	26.55	128.10	31.60	34.95	68.27	33.90
SEm±	0.72	0.26	0.55	0.97	4.93	0.40	1.18	0.79	0.33	1.36	0.54
CD (*p*=0.05)	2.05	0.74	1.59	NS	14.15	1.14	3.38	NS	0.95	3.90	1.55

PHH: Plant height (cm) at harvest; NTRMH: No. of tillers running meter^{-1} at harvest; SDWPH: Shoot dry weight plant^{-1} (g) at harvest; CGR: Crop growth rate (g m^{-2} day^{-1}) 90 DAS– harvest; NP: No. of panicles m^{-2}; LP: Length of panicle (cm); NFGP: No. of filled grains panicle^{-1}; TW: Test weight (g); GY: Grain yield (q ha^{-1}); SY: Straw yield (q ha^{-1}); HI: Harvest index (%)

Pooled data on the number of tillers per running meter at harvest showed the highest tillers (37.13) in the L_1 (Lime @ 2 q ha^{-1}) treatment. The increase in the number of tillers might be due to an increase in soil pH. These results supported the previous findings of Cifu et al. (2004) and Caires et al. (2008) that lime is effective in alleviating soil acidity. The data due to INM levels were found to be significant. The highest number of tillers running meter^{-1} (37.25) was found with N_2 (RDF (75%) + FYM @ 6 t ha^{-1}). Higher radiation interception, as well as better nutrition of crop plants due to FYM application, might have increased the photosynthesis rate which was reflected in a significant increase in the number of tillers. Similar findings were reported by Puli et al. (2016). The 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.

The variation on shoot dry weight plant^{-1} (g) due to lime levels was found to be significant. The highest shoot dry weight plant^{-1} in treatment L_1 (Lime @ 2 q ha^{-1}) at harvest as compared to treatment L_0 (without lime). Seng et al. (2007) reported that shoot dry matter responded strongly to lime application.

Pooled data of both the years recorded the highest shoot dry weight of 36.34 g at harvest with N_2 (RDF (75%)+FYM @ 6 t ha^{-1}). According to the results obtained, significantly highest shoot dry weight in the combination of FYM along with inorganic fertilizers would be attributed to better physiological growth of plants as an addition of organic matter from FYM increased the soil water holding capacity and CEC, improved availability of nutrients and improved soil physical properties under upland conditions. These findings were supported by

Dobermann and Fairhust (2000) and Naing (2010).

The variation on the dry matter due to lime levels was found to be significant during both the years of the experiment at all stages of observation. Pooled data also recorded a 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 the toxic concentration of acidic cations by liming enhanced the vegetative growth of rice which resulted in increased dry biomass yield. Similar results were reported by Ameyu (2019).

The variations in the dry matter during both the years of the experiment were found to be significant. Interception, as well as better nutrition of crop plants due to FYM application, might have increased the photosynthesis rate which was reflected in a significant increase in the dry matter accumulation at all the dates of observation. Priyanka et al. (2013) study results are in line with the above observation. Tiwari et al. (2019) also reported that the progressive increase in dry matter production with NPK levels incorporated with FYM might be due to increased plant height, leaf area and leaf area index which are an indicator of higher chlorophyll per unit area improving accumulation which in turn resulted in higher dry matter accumulation of plants.

3.1.2. Yield parameters

The variation in the number of panicles m^{-2} due to the lime application was found to be significant during both years of the experiment (Table 2). The pooled result thus obtained recorded the highest number of panicles (228.50) with treatment L_1 (Lime @ 2 q ha^{-1}) for both the years. A significant increase in the number of panicles m^{-2} was probably due to liming of acid soil. Slattery and Conventry (1993) and Moody et al. (1995) has suggested liming as the most efficient practice to attain and maintain a suitable pH for the growth of panicle of crops.

The variation in the number of panicles m^{-2} due to variation in INM levels showed significant variation. The 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}). An increase in panicles m^{-2} through FYM was supported by Mirza et al. (2005), Barik et al. (2006) and Revathi et al. (2014).

Variations in the length of panicle due to INM levels were found to be significant during both years. The longest panicle (26.91 cm) was recorded with 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 (23.85 cm) was recorded with treatment N_0 (Control). Arif et al. (2014) reported that an increase in panicle length in response to balanced use of organic and inorganic fertilizers might be due to more availability of macro as well as micronutrients.

The variation in the number of filled grains panicle^{-1} due to lime levels showed significant variation during both the years of the experiment. The highest number of filled grains panicle^{-1} (127.96) were recorded in treatment L_1 (Lime @ 2 q ha^{-1}), while the lowest was recorded with treatment L_0 (without lime). These results indicate that lime application had a positive effect on filled grain which ultimately produced a higher yield. These observations agree with the findings of

Table 2: Effect of lime and integrated nutrient management on different growth and yield attributes and yield of pea (Pooled data)

Treatments	Plant height (cm) at harvest	No. of branches plant^{-1}	Dry weight plant^{-1} (g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test weight (g)	Pod yield (q ha^{-1})	Stover yield (q ha^{-1})
Lime								
L_0	28.36	10.57	9.45	3.51	4.14	40.09	11.11	14.58
L_1	31.80	12.51	10.03	3.98	4.73	40.93	13.33	17.82
SEm±	0.18	0.17	0.27	0.05	0.05	6.76	0.15	0.26
CD (p=0.05)	0.53	0.48	NS	0.16	0.15	NS	0.43	0.74
INM								
N_0	24.65	8.01	7.97	3.31	3.94	38.93	8.47	12.53
N_1	30.51	12.39	10.15	3.72	4.42	40.46	12.36	16.37
N_2	31.95	12.68	10.29	4.00	4.70	41.37	13.78	17.97
N_3	31.68	12.27	10.20	3.92	4.68	40.44	13.15	17.49
N_4	31.62	12.36	10.09	3.78	4.43	41.35	13.35	16.65
SEm±	0.29	0.27	0.43	0.09	0.08	10.68	0.24	0.41
CD (p=0.05)	0.83	0.76	NS	0.25	0.24	NS	0.69	1.17

Ferdous et al. (2018).

The mean data of the number of filled grains panicle^{-1} showed a significant variation due to the application of different INM levels. The 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 the maximum number of filled grains panicle^{-1} (%) may be due to the application of FYM and inorganic fertilizers which provide K in adequate amounts. K increases the number of filled spikelets panicle^{-1} (Dobermann and Fairhurst, 2000; Bahmaniar et al., 2007). The findings of the present investigation were in close proximity with Singh et al. (2018), who reported that all the yield attributes were higher with the substitution of FYM / green manure or wheat straw in combination with 50-75% RDF due to slow release and continuous supply of nutrients in balance quantity throughout the various growth stages and enables the rice plants to assimilate sufficient photosynthetic products and thus, resulted in superior grain yield attributing characters which in turn increases the number of filled grains panicle^{-1} (%). Positive responses of lime on different crop yields in acid soil were reported (Westermann, 1992; Venkatesh et al., 2002; Caires et al., 2008, Reddy and Subramanian, 2016).

Mondal et al. (2015) reported that weight is a very stable varietal character and does not vary much among the nutrient management practices.

3.1.3. Yield

The variation in grain yield due to lime levels reported significant variation during both the years of the experiment (Table 1). Pooled data recorded the same trend of findings for both years. The grain yield benefits can be ascribed due to the increase in soil pH from the application of lime along with the associated improvement in nutrients availability, reduced Fe availability and many other attributes of soil fertility (Venkatesh et al., 2002; Cifu et al., 2004; Costa and Rosolem, 2007; Kumar et al., 2012). Reduction of grain yield in control treatment might be attributed due to a significant reduction in fertile tillers running meter^{-1} and filled grains panicle^{-1}.

The variations in grain yields due to INM levels were found to be significant. 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 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 panicles^{-1}. Improved yields were due to instantaneous and rapid supply of nutrients through chemical fertilizers and steady supply through mineralization of FYM for a prolonged period. Similar results on rice yields due to the integrated application of chemical fertilizer and organic manures were reported by (Sharma et al., 2016; Singh et al., 2018; Tang et al., 2018). Sravan and Singh (2019) also found that the application of recommended nutrients in an integrated approach (75% RDF+25% FYM) enhanced rice grain yield. The results indicate that organic and inorganic based fertilizer along with lime had a more influential effect on rice grain due to the higher available nutrients and optimum soil properties. Similar findings were also reported by Mitu et al. (2017).

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}). These results indicated that straw yields of rice increased with the application of lime. Similar results due to liming have been reported by Caires et al. (2008) 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. The variations on straw yield due to INM levels were found significant during both the years of the experiment. The highest straw yield (72.61 q ha^{-1}) 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). 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 slow release and continuous supply of nutrients in balance quantity throughout the various growth stages and enables the rice plants to assimilate sufficient photosynthetic products and thus, resulted in increased of yield attributes and finally increased straw yield. Urkurkar et al. (2010) and Alim (2012) also reported similar findings. The variations in harvest index due to lime and INM levels were found to be significant during both the years of the experiment. Similar findings have been reported by Singh et al. (2018).

3.2. Residual effect on pea

3.2.1. Growth parameters

The residual effect of lime levels applied to preceding rice influenced significantly the plant height of succeeding pea at various growth stages for both the year of experimentation (Table 2). The pooled data indicated that the highest plant height was found to be associated with treatment L_1 (Lime @ 2 q ha^{-1}), while the lowest was recorded with treatment 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 the crop growth period.

The pooled data also showed significant variation with a superior performance recorded from residue treatment of N_2 (RDF @ 75%+FYM @ 6 t ha^{-1}). The results indicated a profound influence of the residual effect of FYM. Cellulose is a highly persistent composition material, which requires a longer time for decomposition. Thus, FYM has not been fully utilized by the rice crop in the first crop season and notably benefitted the succeeding pea crop. These results are in conformity with the findings of Sindhi et al. (2016). Similarly, the beneficial residual effect of INM under cropping system on growth attributes recorded by Singh et al. (2002) in rice-lentil, Gawai and Pawar (2006) in sorghum-chickpea as well as Nawle et al. (2009) in sorghum-chickpea cropping sequence. The combined application of lime with FYM and chemical fertilizer significantly increased plant height of pea, which 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.

The treatment L_1 (Lime @ 2 q ha^{-1}) gave the maximum number of branches $plant^{-1}$ and lowest in L_0 (without lime). The highest number of branches in the residual effect of lime treated plots might be attributed to the improvement of soil pH and other physic-chemical properties of soil that increases the plant availability of soil nutrients during the crop growth period. The variations in the number of branches $plant^{-1}$ due to INM levels had a significant residual effect on pea at various growth stages during both the years of the experiment. It is indicated from the data that the highest number of branches $plant^{-1}$ (12.68) was recorded from treatment N_2 (RDF (75%) +FYM @ 6 t ha^{-1}) followed by N_1 (RDF) and the lowest in N_0 (Control). It may be due to the fact that more nutrient availability under residual INM treatments resulted in the 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 the number of branches. The beneficial residual effect of INM under cropping system on growth attributes of succeeding crops was recorded by Singh et al. (2002) in rice-lentil, Gawai and Pawar (2006) in sorghum-chickpea as well as Nawle et al. (2009) in sorghum-chickpea, Sindhi et al. (2016) in maize-greengram cropping sequence.

The results pertaining to dry weight $plant^{-1}$ due to the residual effect of lime levels failed to show significant variation during both the years of the experiment. The increase in dry weight in residual lime could be related to an increase in plant height and the number of branches $plant^{-1}$. The better uptake of nutrients facilitated by liming has increased vegetative growth and resulted in increased dry weight.

The results pertaining to dry weight $plant^{-1}$ due to the residual effect of different INM levels showed the significant variation during both the years with the highest dry weight (10.29 g) recorded with residual treatment N_2 (RDF (75%)+FYM @ 6 t ha^{-1}). The lowest was recorded in N_0 (Control). It may be due to the fact that more nutrient availability under INM treatments resulted in the 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 terms of plant height, the number of branches and ultimately dry matter accumulation. This is in line with the findings of Sindhi et al. (2016).

3.2.2. Yield attributes

A scrutiny of the data revealed that variation in lime had a significant residual effect on the number of pods $plant^{-1}$ of pea during both the years of experimentation (Table 2). 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 the application of lime.

There was a significant residual impact in the number of pods $plant^{-1}$ due to variation in nutrient sources imposed to preceding rice crop. 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).The number of pods $plant^{-1}$ were significantly influenced due to the residual effect of fertilizers and FYM applied in preceding rice. Such effect may be owing to increased availability of nutrients in the soil from the native pool as well as their residual effect through mineralization and improvement of physico-chemical properties of soil and thereby improving water and nutrient holding capacity of the soil. These results are in accordance with, Gawai and Pawar (2006) in sorghum–chickpea, Patil (2008) in sorghum–chickpea, Nawle (2009) in sorghum–chickpea, Saha et al. (2010) in maize–mustard, Shanwad (2010) in maize–bengalgram, and Sindhi et al. (2016) in maize–greengram cropping sequence.

The 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. Pooled data of both the years also recorded a similar trend of findings with the highest number of seeds pod^{-1} (4.73) recorded from treatment L_1 (Lime @ 2 q ha^{-1}).

It is clear from the data that nutrient sources had a significant residual effect on the number of seeds pod^{-1} during both the years of the experiment. Among the nutrient sources, N_2 (RDF (75%)+FYM @ 6 t ha^{-1}) recorded the highest number of seeds pod^{-1} (4.70) followed by N_3 (RDF (75%)+ poultry manure @ 1 t ha^{-1}). The 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 cowpea.

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

3.2.3. Yield

Variation in pod yield due to lime levels had a significant residual effect during both years of study (Table 2). A similar trend of findings was recorded for pooled data with the highest value (13.33 q ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}). The 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 improves soil pH and decreases 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) who reported that the better uptake of nutrients facilitated by liming increased vegetative growth and resulted in increased dry matter production and ultimately seed yield of cowpea.

Among the different INM levels, a significant residual effect in pod yield was observed during both the years of the experiment. 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 the addition of FYM to preceding rice resulting in 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. The result is in conformation with those reported by Gudadhe et al. (2015) and Sindhi et al. (2016).

Between residual lime levels, a significant difference was observed in stover yield during both the years of the experiment. A similar trend of findings was recorded for pooled data with the 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 the 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).

Pooled data of both the years recorded a 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 the above treatments might be due to an increase in vegetative growth in terms of plant height, the number of branches and dry matter accumulation. Present results are in conformity with the findings of Sindhi et al. (2016). Similar results were also reported earlier by Singh et al. (2002) in rice–lentil, Gawai and Pawar (2006) in sorghum–chickpea.

3.3. Economics of rice–pea production

There is a common cost of cultivation (₹ 4,240) for all the control treatments where no fertilizer doses were applied (Table 3). In all other remaining treatments cost of cultivation, ha^{-1} is slightly varied because of the differences in the 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 the experiment. This might be due to the additional cost of lime and FYM. The lowest cost of cultivation ha^{-1} was incurred by L_0N_0 (Control) during both years. The highest gross return recorded in the treatment RDF (75%)+FYM @ 6 t ha^{-1}) with lime @ 2 q ha^{-1} is due to the highest grain obtained from it (Singh et al., 2011). In support of the above findings, Lakshmi et al. (2013) also reported that the gross return was more in INM treatments than 100 % RDF and control plots. The maximum net income from L_1N_2 was due to higher gross income. The high economic return could be realized if lime is applied in acidic soil was also reported by Kumar (2015). The data revealed that application of treatment L_1N_2 (Lime @ 2 q ha^{-1}+RDF (75%)+FYM @ 6 t ha^{-1}) attained a significantly higher benefit cost ratio (1.33) 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.

Table 3: Effect of lime and integrated nutrient management interactions on the economics of rice-pea production (Pooled)

Interactions	Cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	Benefit cost ratio
T_1 (L_0N_0)	54240	69473	15233	0.29
T_2 (L_0N_1)	57840	111760	53920	0.93
T_3 (L_0N_2)	59940	127160	67220	1.12
T_4 (L_0N_3)	57840	119637	61797	1.07
T_5 (L_0N_4)	56980	125460	68480	1.21
T_6 (L_1N_0)	56240	107917	51677	0.92
T_7 (L_1N_1)	59840	131721	71881	1.2
T_8 (L_1N_2)	61940	144091	82151	1.33
T_9 (L_1N_3)	59840	136961	77121	1.29
T_{10} (L_1N_4)	58980	130526	71546	1.22

1 US$= 65.89 average of October 2016 and 2017; January of 2017 and 2018

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

Among the lime levels, the highest rice equivalent yield (7839.41 kg ha^{-1}) recorded from treatment L_1 (Lime @ 2 q ha^{-1}) over treatment L_0 (without lime) (Table 4). The improvement in lime-treated plots may be due to an increase in grain yield of rice as well as pod yield of a pea. Sorokhaibam et al. (2016) also reported similar findings that since the liming treatment had resulted in an increase in grain yield of rice as well as seed yield of Lathyrus, hence, REY was also increased.

Among the INM levels, the highest rice equivalent yield (8098.46 kg ha^{-1}) recorded from treatment application of RDF (75%)+FYM @ 6 t ha^{-1}) with lime @ 2 q ha^{-1}. Acharya and Mondal (2010) reported similar results from a study on a rice-cabbage-greengram cropping system where higher rice equivalent yield (REY) of 32.33 t ha^{-1} was recorded under 75% RDF+25% N through FYM to all the crops than RDF alone which produced REY of 26.80 t ha^{-1}.

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) (Table 4). The use of lime in rice increased the productivity of rice and also enhanced the 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 a 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.

Table 4: 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})
Lime			
L_0	6697.55	3113.57	9811.11
L_1	7839.41	3537.90	11377.31
SEm±	49.87	20.90	58.78
CD (p=0.05)	143.04	59.95	168.59
INM			
N_0	5336.10	2602.50	7938.60
N_1	7373.55	3385.92	10759.47
N_2	8098.46	3653.83	11752.29
N_3	7731.82	3491.50	11223.32
N_4	7802.44	3494.92	11297.36
SEm±	78.86	33.05	92.94
CD (p=0.05)	226.17	94.78	266.56

System productivity of the cropping system was influenced significantly under different levels of INM. Among the INM levels, the highest system productivity (11752.29 kg ha^{-1}) recorded from treatment N_2 (RDF (75%)+FYM @ 6 t ha^{-1}) with lime @ 2q ha^{-1}) and the lowest in N_0 (control). Acharya and Mondal (2010) reported similar results where the 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.

4. Conclusion

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 sustainability under rice-pea cropping system in acid soils.

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