EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL PROPERTIES, GROWTH AND YIELD OF RAJMASH IN ACID SOILS OF NAGALAND

A

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By

T ESTHER LONGKUMER
Reg. No. 428/2011

DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL SCIENCE
School of Agricultural Sciences and Rural Development
NAGALAND UNIVERSITY
Medziphema Campus
Medziphema-797106 (Nagaland)

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DECLARATION

I, T ESTHER LONGKUMER, 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.

Date:
Place:

(T ESTHER LONGKUMER)
Candidate

Supervisor

(P. K. SINGH)
Assistant Professor (Stage-III)
Department of Agricultural Chemistry and Soil Science
Nagaland University (SASRD)
Medziphema-797106
Nagaland

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Place:

Date: *T Esther Longkumer*

CERTIFICATE

This is to certify that the thesis entitled, '"Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of Nagaland" submitted for fulfilment of the requirements for the award of Doctor of Philosophy (Agriculture) under Nagaland University, Medziphema is a record of bonifide research work carried out by Ms. T Esther Longkumer, Reg. No. 428/2011 under my guidance and supervision.

The candidate has fulfilled all the requirements under the Ph. D regulations of Nagaland University and the thesis or part of it has not been submitted to any other University for any degree or distinction.

Supervisor

Date :

Place :

(P. K. SINGH)
Assistant Professor (Stage III)
Department of Agricultural Chemistry and Soil Science
Nagaland University (SASRD)
Medziphema-797106
Nagaland

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LIST OF ABBREVIATIONS

%	Percentage
@	At the rate of
BCR	Benefit cost ratio
Ca	Calcium
CD	Critical difference
CEC	Cation exchange capacity
cm	Centimeter
Cu	Copper
d.f	Degree of freedom
DAS	Days after sowing
$dS\ m^{-1}$	deciSiemens per meter
EC	Electrical conductivity
et al	and others
FAO	Food and Agricultural University
Fe	Iron
Fig.	Figure
FYM	Farmyard manure
g	Gram
ha	Hectare
i.e	That is
ICAR	Indian Council of Agricultural Research
K	Potassium
Kg	Kilogram
M.S.S	Mean sum of square
Mg	Magnesium
Mm	Millimeter
Mn	Manganese
MOP	Muriate of potash
N	Nitrogen
NS	Non-significant
NU	Nagaland University
^{O}C	Degree celsius
OC	Organic carbon
P	Phosphorus
q	Quintal
S	Sulphur
S.S	Sum of square
SASRD	School of Agricultural Science and Rural Development
SEd $\pm$	Standard error of mean difference
SSP	Single super phosphate
viz.,	Namely
Zn	Zinc

CHAPTER – I

INTRODUCTION

Cultivation of pulses is gaining importance all over the World due to their increasing demand and high market value. In India, pulses are grown mostly on marginal and sub-marginal lands without proper inputs occupying first in pulse production with 23 Million hectare. Among pulse crops, Rajmash is becoming popular with the farmers due to its high profit in comparison to other pulses and unlike other pulse crop, Rajmash is a stable cash crop free from insect pests and diseases. Rajmash (*Phaseolus vulgaris* L) belongs to the Leguminosae family and is also known as French bean, kidney bean, common bean. Rajmash is consumed as green vegetables as well as grain pulse. For vegetable purpose, round podded type with more flesh and less string is preferred. Among all the beans, it is the most extensively grown bean because of its short duration and nutritive value. It is a valuable source of protein, vitamins and minerals (Ramana *et al*. 2011). The protein from pulses is easily digestible and relatively cheaper and has high biological value besides they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in furthering sustainable agriculture (Kannaiyan 1999). Globally, French bean is cultivated over an area of 29.92 million hectares with an annual production of 23.23 million tons while in India it is commercially cultivated in Nagaland, and other North-Eastern states and peninsular India, Himachal Pradesh, Jammu and Kashmir, hills of Uttrakhand covering an area of 10.80 million hectares with an annual production of 4.87 million tons (Anonymous 2010). In Nagaland, kholar bean is cultivated over an area of 14840 hectares with an annual production of 18590 MT (Anonymous 2014).

Sustainability of crop production system mainly depends on adequacy and balanced supply of nutrients. Decline in productivity is attributed to soil degradation through nutrient depletion and loss of soil quality. Soil fertility management includes maintenance of essential plant nutrients in proportions and amounts for optimum growth of different crop species. Soil fertility can be restored, maintained and sustained by addition of organic residues, strengthening the soil biological process and use of synthetic fertilizers and soil amendments as per the needs. Thus, to enhance soil productivity and lessen the burden of economic and environmental concerns, while replenishing lost fertility, a renewed but vigorous emphasis on integrated application of natural nutrient sources and chemical fertilizers is a viable option.

Integrated Nutrient Management (INM) envisages the use of chemical fertilizers in conjunction with organic manures, legumes in cropping systems, use of biofertilizer and supply and use of plant nutrients from chemical fertilizers and organic manures has shown to produce higher crop yields when each is applied alone. Continuous use of high analysis chemical fertilizers increased the crop yield during the initial years and adversely affected the sustainability at a later stage. The decline in soil fertility and the resultant productivity are the matter of nutrient imbalance which has been recognized as one of the most important factors limiting yields (Nambiar and Ghosh 1984). Results showed that with regular application of recommended doses of NPK, productivity stagnated or declined after initially increasing for 5-6 years (Nambiar 1995). Indiscriminate and continuous use of such chemical fertilizers lead to instability in yield and also poses a threat to soil health particularly due to micronutrient deficiency and fertilizer related environment pollution (Kalloo 2003). Therefore, use of chemical fertilizers alone may not keep pace with time in maintenance of soil health for sustaining the productivity. Since, organic materials hold great promise due to their locally availability as a source of major as well as micronutrients and ability to improve soil properties (Patra *et al*. 1997). Organic matter prevents nutrient loss and environmental pollution and above all helps to maintain resilience of soil nutrient balance, which is the basic attribute for sustainability. Organic recycling and use of organic manure to previous crop considerably influence the nutrient supply to the succeeding crop. Hence, integrating their use in soil fertility management is a must. Integration of chemical and organic sources and their management have shown promising results not only in sustaining the productivity but have also proved to be effective in maintaining soil health and enhancing nutrient use efficiency (Laxminarayana *et al*. 2011, Kumar *et al*. 2012). Integration of chemical and organic sources like manures, biofertilizers etc. and their efficient management does not only help in sustaining the productivity and physical and biological health of soil but also meets a part of the chemical fertilizer requirement of crops (Babu *et al*. 2007). Value of collective use of organic materials and chemical fertilizers on sustainable crop production has been tested and proved through several long term experiments. It is generally agreed that at least a part of the nutrients left over in the soil is utilized by the succeeding crop raised in the same field. Such residual effects depend on the characteristics of the previous crops, and the kind and quantities of fertilizers applied. Thus, all the major sources of plant nutrient such as soil, mineral, organic and biological should be utilized in an efficient and judicious manner for sustainable crop production.

Good crop production can be achieved in such soil only after ensuring balanced quantity of nutrients through balanced fertilization (Sharif *et al*. 2004). On the other hand, Tolessa *et al.* (2001) reported that inclusion of organic sources of nutrients in the fertilization program, besides nutrient supply, improves the nutrient use efficiency of the added synthetic fertilizers by reducing their loss and enhancing their availability to the associated crop. Kumar and Puri (2001) and Chan *et al*. (2007) also verified the results of Tolessa *et al.* (2001) by reporting increased crop production through application of organic manures at different rates along with different rates of inorganic fertilizers.

The soils of Nagaland having diversified topography and landscape are generally acidic in reaction and the major problems are shifting cultivation practices, acidity, low base status and landslides in hill slopes. Under the prevailing acidity, productivity of various crops is much low due to non-availability and toxicity of some nutrients. To combat this problem, the maintenance of soil fertility is to be relied upon regulation of natural soil processes and use of certain mineral additives besides addition of organic manures.

However, farmers of this area are not able to harness full potential of this crop due to non-adoption of high yielding varieties and non-application of fertilizers. The use of chemical fertilizers in Phek district is nil and farm yard manure (FYM) is the only source of nutrition to the crop. On the basis of easy availability of organic manures, it is felt necessary to assess the alternative nutritional sources and their impact on soil productivity.

With this perspective in view, the present research work entitled **“Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of Nagaland”** was undertaken with the following objectives:-

i) To assess the changes in physico-chemical characteristics of the soil under different Integrated Nutrient Management (INM) treatments.

ii) To study the major, secondary and micronutrient status of the soil.

iii) To study the effect of different treatments of INM on the crop yield.

iv) To study the nutrient uptake pattern in Rajmash under different INM treatments.

v) To study the best INM treatments for Rajmash in acid soils of Nagaland.

CHAPTER- II

REVIEW OF LITERATURE

Integrated Nutrient Supply System (INSS) is a diverse source of plant nutrients which are use to boost the crop production and to maintain the soil fertility status in a sustainable manner on long term basis. The use of nutrient sources represents great diversity in physical and chemical condition and other natural phenomena which ultimately affect the crop production. Thus, it brings economy and efficiency in fertilizer use. Integration of chemical and organic sources and their efficient management has shown promise in not only sustaining the productivity and soil health but also in meeting a part of chemical fertilizer requirement of crops (Hegde and Dwivedi 1993). Conjoint use of organics manures and chemical fertilizers is very essential as this not only sustains higher level of productivity but also improves soil health and enhances the nutrient use efficiency (Kumar *et al.* 2015). Integrated Nutrient Supply, use or management of all the major components of plant nutrient sources, chemical fertilizers in conjunction with organic materials of plant and animal origin are required for sustainability of soil fertility status. Organic matter prevents nutrient loss and environmental pollution and above all helps to maintain resilience of soil nutrient balance, which is the basic attribute for sustainability**.** Beneficial effects of integrated use of nutrients in association with biofertilizers on content and uptake of nutrients have also been reported by several researches (Gupta and Chhonkar, 1995 and Sakal *et al.* 2000). Integrated Nutrient management and nutrient cycling through organic manure and crop residue management can enhance soil fertility and crop productivity, guard against emergence of multiple nutrient deficiencies and deterioration of soil health. In commercial agriculture, the use of chemical fertilizers cannot be ruled out completely. However, there is a need for integrated application of alternate sources of nutrient for sustaining the desired crop productivity (Tiwari 2002). Addition of manures and inorganic fertilizers augments the efficiency of both the nutrient sources to maintain a high level of soil productivity (Ayoola and Adeniyan 2006). Neither organic manure nor crop residues alone nor chemical fertilizers can achieve the yield sustainability where nutrients turnover in soil plant is high or when crops are grown in soils that are poor in organic matter and fertility status. Integrated supply of nutrients had significant influence on the physico-chemical characteristics of the soil.

Some of the experimental evidences of performance of Integrated Nutrient Supply System on soil properties and productivity are briefly reviewed in this chapter.

2.1. Soil acidity and its constraints

Acidity refers to concentration of hydrogen cations in a solution (FAO 2006), the pH values range from 0 to 14, in which below 7 indicates an acid solution, above 7 alkaline and 7 neutral solutions (Crawford *et al*. 2008).

The neutral pH of a soil depends on the nature of the material from which it was developed. Table 1 shows classification of soils according to the level of pH.

Table 1: **Classification of soil acidity according to the level of pH**

Soil acidity class	**pH range**
Extremely acidic	< 4.5
Strongly acidic	4.5-5.0
Moderately acidic	5.0-6.0
Slightly acidic	6.0-6.5
Near neutral	6.5-7.0

Source: Kanyanjua *et al.* (2002)

In low pH soils, containing high amounts of Al and Fe oxides, P is deficient in the soil solution because it is precipitated or surface adsorbed with Al and Fe as insoluble compounds (Kanyanjua *et al*. 2002).

Several other essential plant nutrients, which are present in the soil solution as cations, are deficient. To enable crop production in acid soils, several means to correct nutrient deficiency can be adopted. These include liming, addition of organic matter and fertilization with mineral fertilizers (Masarirambi *et al*. 2012).

Liming reduces Al^{3+} and H^+ ions as it reacts with water leading to the production of OH^- ions, which react with Al^{3+} and H^+ in the acid soil to form $Al\ (OH)_3$

and H_2O. The precipitation of Al^{3+} and H^+ by lime causes the pH to increase, enhances microbial activity and nutrient availability (Onwonga *et al*. 2008).

Rajmash as leguminous crop depends on microbial nitrogen fixation as source of N. However, under acid soils, the population of *rhizobia* bacteria is reduced and consequently nodulation and N fixation is impaired. This affects negatively on crop nutrition and yields. Therefore, liming acid soils improves soil condition for microorganism development. Mineral fertilizers increase nutrient availability in the soil solution since they are readily available, and the addition of organic matter acts as supply of microorganism's food enhancing their population and therefore mineralization (Crawford *et al*. 2008).

2.2. Effect of FYM, biofertilizer, lime and NPK fertilizer

2.2.1. FYM

Organic fertilizers are derived from plants and animal parts and have a wide role in agricultural production system. The application of farm yard manure (FYM) as one of the components of integrated nutrient management had significant effect on pulse crop. Among all the sources, FYM proved to be the best in improving soil fertility through effects on physical and chemical soil properties. When added to soil FYM increase its organic matter content and improve soil physical properties. It was also observed that farm yard manure improves the physical and chemical properties of soil *viz*., base saturation of cation exchange capacity, with added advantages of improving the soil structure, organic matter content, microbial environment, and water retention capacity (Smaling 1993).

Organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients get turnover and many other change related to physical, chemical and biological parameters of the soil (Albiach *et al*. 2000).

Bulky nature of FYM might have helped in improving physical properties of the soil such as water holding capacity, bulk density etc compared to other sources (Hazarika *et al*. 2006).

Manure effects on soil physical properties include increased infiltration (Risse *et al*. 2006), water holding capacity (Liang *et al*. 2011) and reduced compaction and erosion (Salahin *et al*. 2011).

Application of organic manures improves soil physico-chemical properties and sustains the soil quality. Soil quality comprises soil fertility including biological activity which are closely related because it is through the biomass that the mineralization of the important organic elements occurs (Efthimiadou *et al*. 2010)

The positive response of legumes to manure has also been attributed to the quantity of manure N already available for the plants, amount of N that becomes available after mineralization during the season, release and availability of phosphorus, potassium and microelements (Bocchi and Tano 1994).

Furthermore, improvement in soil organic matter (SOM) leads to slow release of crop nutrients –Nitrogen(N), Phosphorus(P) and Potassium (K), improves buffering capacity of the soil and cation exchange capacity (Gachene and Kimaru 2003).

Available P was higher with FYM application (Whalen *et al*. 2000). This indicates that the application of FYM enhanced the P content of the soil.

Manure contains high amount of organic matter which increases the moisture retention of soil and improves dissolution of nutrients particularly phosphorus (Olupot *et al*. 2004). It also improves soil structure and in turn porosity. This allows better root growth and hence better nutrient uptake.

Growth attributes *viz.* plant height, number of branch per plant and LAI at harvest of both pigeon pea and groundnut were significantly improved due to application of farmyard manure @ 5tons ha^{-1} over no farmyard manure. Significant response to the farmyard manure may be explained by the fact that most of the Indian soils are poor in organic matter and application of farmyard manure might have increased the supply of easily assimilated major as well as micronutrients to plants, besides mobilizing unavailable form of nutrients into available form into the soil (Rajat and Ahlawat 2009).

Javaid and Mahmood (2010) in Pakistan, found significant effect of farm yard manure on soybean pod number.

Elsewhere the application of poultry manure also increased dry matter per hectare and grain yield (Chiezey and Odunze 2009).

The increase of nutrient concentration and uptake with application of FYM might be due to increased availability of nutrients to plants and improving the physical condition of the soil. The gradual mineralization and availability of nutrients along with increased moisture holding capacity of soil by FYM might be the reason for higher yield (Jat *et al*. 2013). This may be due to favourable effect of physical and chemical environment of soil with FYM application which causes continuous supply of nutrients (Mandal and Sinha 2002).

The complimentary effect of manure and fertilizers improves soil properties and helps towards sustaining soil productivity. It increased significantly with regular dressings of N fertilizers. The highest improvement was observed by applying 100% N or NP and FYM. The available P status of soil decreased in the plot receiving only N and potash application, though it increased with addition of FYM and phosphate fertilizer. The application of FYM with inorganic and biofertilizers significantly increased the available phosphorous. The SSP in combination with FYM had beneficial effect on the availability of phosphorous (Bharadwaj *et al*. 1994).

Murugappan *et al*. (1999) reported the increase in soil available nitrogen status on rhizobium continuous application of fertilizer in conjunction of FYM.

Singh *et al*. (1999b) reported significantly higher amount of available sulphur after 10 years on conjunction use of 5 ton of FYM and optimum NPK.

Application of organic manure in general, improves the availability of micronutrients like zinc, iron, manganese and copper (Naidu *et al*. 2009).

2.2.2. Biofertilizer

Biofertilizers can form an important component of INM System. With the use of biofertilizers, the degraded soils can be reclaimed biologically due to the ameliorating properties of microbes. Further, biofertilizers offer wide scope to reclaim waste lands due to biological activities of polysaccharide and organic acids secretion, nitrogen fixation, phosphate solubilization, nutrient release, improvement of physicochemical characters of soil and increase of organic stock of soil. Legume plants improve nodulation, nitrogen fixation biologically in their root nodules but are known to benefit the subsequent crops (Thompson 1980).

Biofertilizers are low cost and eco friendly input having tremendous potential for supplying nutrients which can reduce the chemical dose by 25-50% (Vance 1997).

Biofertilizers improves carbon and nitrogen mineralization by promoting soil microbial activities and narrowed down C: N ratio. It also declines bulk density and increases in water holding capacity (Nisha *et al*. 2007).

Seed inoculation with effective Rhizobium inoculants is recommended to ensure adequate nodulation and nitrogen fixation for maximum growth and yield of pulse crop. Many of these rhizobacteria were found to be synergistic with rhizobium and their co-inoculation with rhizobium showed an improvement in nitrogen fixation, nutrient uptake and yield of pulse crop (Rana *et al*. 2006).

Pulse seed treated with specific strains of rhizobium increases the yield through better nodulation and maintenance of organic matter in the soil (Saxena and Tilak 1999).

Biofertilizers have the ability to mobilize the nutritionally important elements from non-usable to usable form through biological processes and known to increase yield in several vegetables (Kumar *et al*. 2001).

Rhizobium inoculation significantly increased the seed and straw yield of mungbean. Increase in the seed yield due to inoculation was 60-69 kg ha^{-1}, which was equivalent to 9-10% over uninoculated (Singh and Tarafdar 2002).

A study by Rabbani *et al*. (2005) on the effect of *Rhizobium* inoculation, N, P and Mn on nodulation, yield and seed protein in pea showed that inoculated plants added 80kg Nha^{-1} and the average dry matter yield increased in pea plants over uninoculated control.

Other studies have also reported that significant increases in pod yield, seed yield and protein content were obtained by *Rhizobium* inoculation (Fening *et al*. 2010).

The increase in growth and yield with the integration of chemical fertilizers, inoculation of *Rhizobium* and PSB were also reported by Afzal and Bano (2008).

Biofertilizers play a vital role in maintaining long term soil fertility and sustainability. It may increase yield of crops by 10-30 percent (Khandelwal *et al*. 2012)

2.2.3. Lime

Lime materials contain carbonates, oxides or hydroxides required to apply in acid soils to raise soil pH and in addition neutralize toxic elements in the soil. Soil pH is used to determine whether or not to lime a soil.

Liming material include $CaCO_3$, $CaMg(CO_3)_2$, $Ca(OH)_2$, CaO and others, which vary according to their neutralizing value and degree of fineness. Besides increasing soil pH, lime also supplies significant amount of Ca and Mg, depending on the type of liming material. Indirect effects of lime include increased availability of P, Mo and B and more favorable conditions for microbially mediated reactions such as nitrogen fixation and nitrification, and in some cases improved soil structure (Nekesa *et al*.

2005). For instance, application of lime increased root and shoot yields in Nigeria (Anetor and Akinrinde 2006), grain yields of soybean in Brazil (Caires *et al*. 2006).

When lime is applied to the soil, Ca^{2+} and Mg^{2+} ions displace H^{+}, Fe^{2+}, Al^{3+}, Mn^{4+} and Cu^{2+} ions from soil adsorption site resulting in increase in soil pH (Sultana *et al*. 2009).

Lime application along with integrated nutrient management is often recommended to increase the phytoavailability of essential nutrients and ameliorate the acidity induced fertility constraints of such soils (Kumar *et al.* 2012).

2.2.4. NPK fertilizer

Indiscriminate use of high analysis chemical fertilizers resulted in the deficiency of nutrients other than the applied and caused declined in organic carbon (Singh *et al*. 1999b).

Work done in various parts of the country reveals that continuous application of chemical fertilizer caused gradual deterioration in soil reaction, organic carbon and CEC of soil (Kumar and Yadav 1993).

Basumatary and Talukdar (1998) reported that continuous application of chemical fertilizer alone led to decrease in pH, organic carbon and CEC of the soil.

Tiwari *et al*. (2002) observed increasing levels of NPK (100 to 150%) enhanced the amounts of available N, P and K significantly over control. It was due to addition of adequate amounts of N, P and K through higher level of fertilizers

Yield attributes viz. pod length, pods/plants, grains/pod and 100 seed weight increased significantly with increased N levels up to 180 kg N ha^{-1} due to direct role of N to seed growth (Singh *et al.* 2006).

Increased levels of chemical fertilizers (100 to 150% NPK) increased grain straw yields significantly over control (Kumar *et al*. 2015).

2.2.4. Combined effect of FYM, biofertilizer, lime and NPK fertilizer

Integration of chemical and organic sources and their efficient management has shown promise in not only sustaining the productivity and soil health but also in meeting a part of chemical fertilizer requirement of the crops (Hegde and Dwivedi 1993). Neither organic manure nor crop residues alone nor chemical fertilizers can achieve the yield sustainability where nutrients turnover in soil plant is high or when crops are grown in soils that are poor in organic matter and fertility status. Integrated supply of nutrients had significant influence on the physico-chemical characteristics of the soil.

Integrated Nutrient management and nutrient cycling through organic manure and crop residue management can enhance soil fertility and crop productivity, guard against emergence of multiple nutrient deficiencies and deterioration of soil health.

Beneficial effects of integrated use of nutrients in association with biofertilizers on content and uptake of nutrients have also been reported by several researches (Sakal *et al*. 2000).

Integrated use of chemical fertilizers with farmyard manure or green manure or rice straw residue facilitates to curtail the use of chemical fertilizers up to 50% and is a better alternative to use of full dose of recommended fertilizers (Gupta *et al*. 2006).

The importance of applying fertilizers in organic or inorganic form has been proven in various researches. Use of manures alone has a slow but positive effect in releasing nutrients since they require microbial activity to decompose it. On the other hand, mineral fertilizers are of rapid nutrient availability but expensive and are easily leached from the soil. However, application of combined organic and inorganic fertilizers is a viable solution to restore, maintain soil fertility and increase crop yields (Sharief *et al*. 2010).

Hati *et al*. (2001) observed that increasing yield parameters in sorghum due to application of organics attributed to supply of essential nutrients by continuous mineralization of organic manures enhanced inherent nutrient supplying capacity of the soil and its favorable effect on soil physical and biological properties.

Kumaran (2001) reported the application of FYM + fertilizer produced higher number of matured pods per plant, pod weight per plant, number of kernels per pod, test weight, pod yield and haulm yield of groundnut.

Guu *et al*. (1995) reported increase in pod yield of common bean with fertilizer and manure application.

Maheshbabu *et al*. (2008) in India found that combination of FYM and mineral fertilizer had a significant effect not only on soybean grain yield but also on its growth parameters.

Combined application of NPK + lime resulted in 147% yield increase while application of FYM @ 5t ha^{-1} along with NPK + lime further boosted the yield improvement up to 291 % over control in rice (Kumar *et al*. 2012).

2.3. Effect of INM on soil properties.

Soil properties include bulk density, particle density, porosity, water holding capacity, pH, EC, CEC, percent base saturation, available NPK, exchangeable Ca, Mg and available S, and micronutrients (Fe, Zn, Cu, Mn). These properties influence availability of nutrients to crop and therefore have potential to reduce or increase crop yields.

2.3.1. Soil physical and chemical properties

The use of chemical fertilizer continuously resulted in a gradual decline in crop productivity as well as nutrient imbalance in the soil and lead to an adverse effect on soil physico-chemical properties.

Long term applications of fertilizers for crop production significantly influence the soil properties. Continuous cropping and long term fertilization brought about a concomitant change in the soil properties depending upon the type of management practices (Yaduvanshi *et al*. 1985).

Integrated approach of plant nutrient management improves soil fertility and maintains soil health without affecting the yield of crops (Badanur *et al*. 1990).

Shankar *et al.* (2002) observed that application of farmyard manure along with inorganic fertilizers improved the physico-chemical properties of the soil.

Improved physicochemical properties of acid soils have been reported through combination of manure with N, P fertilizers and lime (Onwonga *et al*. 2010).

Gattani *et al*. (1976) observed an increase in bulk density of the soil where continuous cropping was done with the use of NPK fertilizers.

The soil remains fluffy and porous as a result of extensive root system and addition of organic matter through the plant residues (Lal and Mathur 1989) thereby reducing the bulk density.

Grewal *et al*. (1999) observed that continuous application of both potassic and phosphatic fertilizers lowered the bulk density.

Chaphale and Badole (1999) indicated that continuous application of nutrients NPK through fertilizers either alone or in combination recorded increase in bulk density of soil from 1.69 to 1.71 mg/m^3.

Singh *et al*. (2000) reported that application of organic manure as well as fertilizer improved the water retention capacity of the soil.

Long term application of FYM resulted in gradual and significant reduction in bulk density, increase in water holding capacity and water stable aggregates of red loam soil (Lal and Mathur 1989).

Santhy *et al.* (1999) observed a decrease in bulk density in plots receiving 100 per cent NPK + FYM, while the highest water holding capacity was observed in the plots receiving NPK + FYM.

Application of FYM either alone or in combination with NPK fertilizers did not affect the soil pH perhaps due to greater buffering action of organic matter (Singh 1991).

Prakash *et al*. (2002) also revealed an increase in pH due to application of manures.

Lal and Mathur (1988) observed that FYM treatment maintained the soil reaction showing thereby its buffering action.

On the other hand, Sarkar and Singh (1997) observed a decrease in soil pH from 6.5-6.0 because of the application of organic manure alone compared with the initial soil pH of 6.7.

Studies carried out by Bradchalam *et al.* (1996) in the alluvial soils of CRRI, Cuttack showed a decline in organic carbon content under NPK treatment.

Sharma *et al*. (1988) stated that continuous use of FYM either alone or in combination with fertilizers enriched the soil with total organic carbon, humic fraction and CEC of an acid soil.

Raju and Reddy (2000) observed that all organic added treatments enhanced inorganic carbon status of soil compared with its initial value.

Dubey and Verma (1999) reported an increase in the soil organic carbon with FYM application as compared to its initial value in rice-cowpea sequence under humid tropical Andaman Islands.

Raju and Reddy (2000) observed that after 5 years of continuous cropping, the fertilized plots with recommended fertilizer dose had higher organic carbon than that of unfertilized plots.

Yaduvanshi (2001) reported that continuous application of NPK with FYM or green manure significantly increased organic carbon from its initial value, while continuous use of inorganic fertilizer alone reduce organic carbon from its initial value.

Datt *et al.* (2003) while carrying out a study at Kukumseri (H.P.) on vegetable pea concluded that the organic carbon content increased with the addition of NPK and farmyard manure in comparison to control.

In general, there was increase in OC due to addition of organic manures *viz*., Pressmud cake (PMC), Farmyard manure (FYM), Vermicompost (VC), Fresh cow dung (FCD) and Post biomethanated spent wash (PBMSW) which were statistically at par with each other and it was due to creation of favorable conditions for growth of soil microorganisms, root biomass, *etc*. (Qureshi *et al*. 2005)

There was increase in OC due to addition of organic manures which was due to creation of favourable conditions for the growth of soil microorganisms, root biomass etc. (Laxminarayana 2005).

Basumatary (1995) also observed a decline in CEC and base saturation of the soil after 7 years of continuous cropping under chemical amendments.

Improvement in CEC and exchangeable bases with combined incorporation of chemical amendments and FYM was observed by Basumatary and Talukdar (1998).

Ndayegamiye and Cote (1988) reported significant increase of 7.6% and 15.2% in CEC at the rates of 4.0and 6.0 ton ha^{-1} of cattle manure.

Integrated treatments showed significant increase in exchangeable K over the chemical treated plots. Continuous application of organic matter improved the CEC of the soil and thus increased the retention of K in exchangeable form by a mass action effect (Bellakki *et al*. 1998).

Ayuba *et al*. (2005) found that available P increased significantly while total P was as high as 7.21 ppm following application of 15 ton ha^{-1}.

Combined application of Zn and organic matter along with recommended levels of N, P and K fertilizers have been reported to increase the status of major and micronutrients along with enhancement of organic carbon and other physical properties of soils (Vyas *et al*. 2003).

Application of lime +1/2 NPK + FYM increased pH of the soil rather than other organic sources, since organic matter has high cation exchange capacity (CEC) while it facilitated retention of exchangeable bases (Ossom and Rhykerd 2008).

Lime and P fertilizers improved soil pH and available P as reported by Anetor and Akinrinde (2006), who also attributed increase soil pH with lime which in turn reduced P fixation.

Kumar *et al*. (2005) while studying the response of rajmash (*Phaseolus vulgaris* L.) to integrated nutrient management in dry temperate region of Himachal Pradesh observed that pH, organic carbon (OC) and available NPK were maximum at recommended dose of NPK (40, 60 and 30 kg NPK ha^{-1}) along with *Rhizobium* + *Phosphate solubilizing* bacteria treatment.

Varalaxmi *et al*. (2005) conducted an experiment at farmer' s field on Alfisol of Bangalore to study the effect of integrated use of organic manure and inorganic fertilizers on change in organic carbon, available NPK status of the soil in groundnut-finger millet cropping system. The study indicated that application of recommended NPK along with 7.5 t FYM ha^{-1} not only improved the productivity of groundnut but also significantly improved the organic carbon, available N, P and K contents of soil.

In Nigeria, Ewulo (2005) found that application of 6 ton ha^{-1} of cattle manure increased total soil P, K, Ca, Mg and cations exchange capacity (CEC) and decreased exchangeable acidity.

Repsiene and Skuodiene (2010) found that lime and manure when applied sole or combined had a significant effect in reducing Al, increasing Ca, pH and Mg.

Ademba *et al*. (2010) reported significant increase in soil total P, K, Ca, and Mg with sole application of 10 ton ha^{-1} of manure, 60 kg P_2O_5 ha^{-1} and 250 kg ha^{-1} of lime. In addition, the same study revealed that lime and manure combined with DAP increased available P.

In a comparative study of organic manures and NPK fertilizer in acid soil, Adeniyan *et al.* (2011) found that 5 ton ha^{-1} of cattle manure significantly increased soil P, pH, organic C and cation exchange capacity.

The improvement was attributed to the integrated effect of the amendments by improving soil pH, microbial activity, nutrient release from organic matter decomposition and improved soil structure as well. In addition, Kisinyo *et al*. (2012) reported significant positive effects on soil pH and available P in acid soil of Western Kenya with application of lime and P fertilizer in sole or in combination.

2.3.2. Major nutrient status of soil

Prasad *et al*. (1986) reported that NH_4^+,NO_3^- and available N increased with increasing doses of fertilizers in an acid soil under multiple cropping system, with highest value under 100% NPK + FYM treated plots.

Acharya *et al*. (1988) observed that the treatment receiving FYM+100% of the recommended NPK improved the available N status of the soil after l3 years of continuous cropping.

Hedge and Dwivedi (1993) revealed that continuous addition of organic manures and inorganic fertilizers showed favourable effect in increasing the available soil N.

Bhandari *et al*. (1992) observed that application of NPK fertilizers alone or in combination with organic sources of N increase available N by 5-22 kg ha^{-1} as compared with its initial value.

Continuous application of NPK fertilizers alone or in combination with organic sources of N increased availability by 0.8-3.8kg ha^{-1} from its initial value (Yaduvanshi 2001).

Available N and K were increased significantly with organic sources of nutrient either alone or in combination with fertilizers over the fertilizers alone (Bellakki and Badanur 1997).

Basumatary and Talukdar (1999) stated that integrated use of chemical fertilizer with organic manures and bio-fertilizer were effective in improving available N in rice-rice cropping system. Also at the end of 7 years of cropping, a considerable build up of all fraction of P was observed for all the treatments except control, 50% chemical fertilizer and farmer's practice.

An increase in available N status on continuous application of fertilizer N in conjunction with FYM was also reported by Brar and Pasricha (1999).

Duraisami *et al*. (2001) observed that the N status increased progressively with increase in N levels possibly due to added N fertilizer.

Increasing the level of fertilizer application led to enrichment in available P status in the soil. Nambiar and Abrol (1989) indicated that the long term fertilizer experiments conducted with different crop sequences at various locations clearly indicated a decline of available P with application of N alone.

Long term experiments in rice-rice cropping system show that withholding P application continuously depleted the soil to the level of 6 kg P ha^{-1} from the initial level of 31 kg P ha^{-1} over a span of 14 years of cropping cycles in lateritic soils of Bhubaneswar (Nambiar 1994).

Hedge (1998) observed that continuous rice-wheat cropping led to increase in available P status in fertilized plots.

Thakur *et al*. (1999) reported that continuous application of varying levels of fertilizer maintained available P content of the soil at higher level over control.

Bradchalam *et al*. (1996) observed that in alluvial soils, there was drastic reduction in available P in the treatment receiving no P but the decrease was less pronounced in the treatments receiving P application.

Swarup and Wanjari (2000) observed that available P was improved marginally with NPK treatments.

Raju and Reddy (2000) observed a substantial build up of available P in all organic manured plots.

Enrichment of P in the soil with the application of balanced or higher dose of NPK and combined use of NPK along with FYM was evident under intensive rice cropping (Basumatary *et al*. 1996).

The results of the long term experiment revealed that available P decreased in absence of P application but increased wherever P was applied either alone or in combination with organic sources of manures (Bhardwaj and Omanwar 1994).

Rokima and Prasad (1991) reported that different inorganic fractions of P increased with increasing doses of fertilizers in a calcareous soil, but influence of FYM, blue green algae or both singly or in combination with fertilizers were generally small.

The improvement in the soil available P with FYM addition could also be attributed to many factors, such as the addition of P through FYM and retardation of soil P fixation by organic anions formed during FYM decomposition (Ali *et al*. 2009).

The increased availability of available P with organics could be ascribed to their solubilizing effect on the native insoluble P fractions through release of various organic acids, thus resulting into a significant improvement in available P status of the soil (Urkurkar *et al*. 2010).

Incorporation of FYM along with inorganic P might have increased the availability of P to crop and mineralization of organic P due to microbial action and enhanced mobility of P (Tiwari *et al*. 2010).

The favourable effect of Rhizobium +PSB inoculation in the buildup of P status could be because of solubilization of insoluble P reserve of the soil as well as the favourable condition created by *Rhizobium* by adding biomass in the soil (Basu *et al*. 2006).

Continuous cropping disturbs the natural equilibrium of K dynamics and in most cases depletion of all the forms of K was reported. Nath and Dey (1982) reported a considerable decrease in exchangeable K content as a result of continuous cropping.

Extensive rice cropping increase K in the soil with the application of balanced or higher dose of NPK and combined use of NPK along with FYM was observed (Palaniappan 1985).

Rao *et al.* (1999) observed that continuous application of K in amounts less than that removed by the crops led to a decline in available K as well as total K. It was also reported an increase in the release rate of K on application of FYM, which resulted larger decline in reserve pool i.e. total K.

Prasad and Rokima (1991) recorded an increase in water soluble, exchangeable and non-exchangeable K content with the application of FYM, blue green algae (BGA) or FYM+BGA over application of chemical fertilizers on clay loam soil.

A decline in available K status was observed in the plot receiving only N fertilizer but a significant increase in available K content had been noted in the plot which received either FYM or green manure along with N fertilizer. Balanced application of fertilizers alone or in combination with organic sources could check the extent of depletion, even it could register a buildup of non-exchangeable K pool on long term experimentation (Singh *et al*. 2001).

Yaduvanshi (2001) observed an increase in available K content with the continuous application of fertilizer K and organic manures over its initial level.

Integrated use of chemical fertilizer with organic manures and biofertilizers showed a negative balance in available K in rice-rice cropping sequence (Thakur *et al*. 1999).

Katyal *et al*. (1998) observed that integrated nutrient supply had a favourable effect on available K in rice-wheat cropping system.

Tripathi *et al*. (2009) reported that increase in available K in integration of chemical fertilizer along with the inoculation of *Rhizobium* + PSB might be because of release of exchangeable K from non-exchangeable K form by the action of organic acids released during biological N fixation, P solubilization and decomposition of organic biomass including crop residues. Similar results were also observed by Sawarkar *et al*. (2013).

Addition of lime in combination with reduced doses of NPK and organic manures increased the available K over that of inorganic and organic sources (Laxminarayana 2013).

Also the increase in the availability of K through addition of FYM in the INM treatment may be due to the decomposition of organic matter accompanied by the release of appreciable quantities of CO_2, which when dissolved in water, forms carbonic acid, which is capable of decomposing certain primary minerals and release of nutrients (Chesti *et al*. 2015).

2.3.3. Secondary nutrients

Sulphur (S), Ca and Mg are macronutrients required in relatively large amounts for good crop growth. Sulphur is considered as the fourth major limiting element after N, P and K. The other two essential plant nutrients i.e. Ca and Mg are often needed in acid soils and for some specific high Ca and Mg requiring crops.

A decline in available S due to continuous cropping and manuring was observed by Swarup and Ghosh (1980).

Intensive cultivation without sulphur addition resulted in a decrease in the sulphur fertility status. Nambiar (1988) observed that addition of FYM along with sulphur fertilizer resulted in a proportionate increase in available S content in the soil.

Results of a long-term fertilizers experiment under All India Co-ordinated Project revealed that NPK plots generally showed a fall in available S content to the extent of 40-60% while NPK + S plots showed either a buildup of S available or no depletion (Nambiar and Abrol 1989).

Nambiar (1994) reported that available soil S improves with the application of SSP as a P source but decline with application of DAP as P carrier in the lateritic soils of Bhubaneswar.

Basumatary (1995) indicated that both available and total S content of the soil showed an increasing trend with increasing addition of chemical fertilizer up to 100% NPK fertilizer.

The buildup of S content in the soil is due to FYM either alone or in combination with NPK was reported by Singh *et al*. (1999a). This improvement in soil fertility was attributed to addition of FYM and other organics which stimulated the growth and activity of microorganisms. They participate in the biological cycling of elements and transformation of the mineral compounds and thus increases the availability of nutrients in the soil.

Mohanty and Sharma (2000) reported that incorporation of FYM along with mineral NPK fertilizers enhances S availability in soil.

Singh *et al*. (2001) observed that continuous application of NPK, S and Zn with and without organic manure did not decline the available S but an increase was noted which was more pronounced on incorporation of FYM.

Bandyopadhya *et al*. (1969) reported that application of FYM decreased exchangeable Ca and Mg contents of soil of a long term manurial experiment on rice at Cuttack.

In an acid Ultisols, long term application of fertilizer and manures decreased exchangeable Ca and Mg contents of the soil (Kabeerathuma *et al*. 1993).

Bellakki and Badanur (1997) observed an increase in exchangeable Ca content of the soil due to incorporation of different organic sources of nutrients.

Kheyrodin and Antoun (2012) found that manure increased significantly soil P, Ca and Mg contents in the 15-30 cm depth.

Application of FYM 2 ton ha^{-1} decreased exchangeable Al and increased pH, available Ca and Mg in Cameroon (The *et al*. 2001).

2.3.4. Micronutrients

Sur *et al*. (2010) reported that amount of all cationic micronutrient (Fe, Mn, Cu and Zn) was progressively higher with the crop growth period suggesting a buildup of these micronutrients in soil resulting from the adoption of integrated nutrient management systems (INM). Such build up of cationic micronutrients in soil might be partly owing to release of native soil micronutrients resulting from the dissolution action of organic manures and also partly due to release from applied organic manures. The results corroborate with the findings of Singh *et al*. (1999b).

The available micronutrients were found to increase with increase in CEC of soils due to more availability of exchange sites on soil colloids. Similarly, the availability of micronutrients enhanced significantly with increase in organic matter because organic matter is helpful in improving soil structure and aeration. Organic matter protects the oxidation and precipitation of micronutrients into unavailable forms and supply soluble chelating agents which increase the solubility of micronutrients contents (Kumar and Babel 2011).

Shankar *et al*. (2012) reported significant influence of organic manures application on soil micronutrient status as compared to conventional fertilizers application.

2.4. Effect of INM on growth, yield attributes and yield

Combined application of manure and inorganic fertilizers (integrated nutrient management) may allow sustainable cropping with higher productivity and longer economic benefits than application of either one alone.

Long term experiments have shown that neither organic sources nor mineral fertilizers alone can achieve sustainability in crop production (Nambiar 1994).

Low soil fertility due to decades of land cultivation is a major factor in the decline of bean productivity. It is aggravated by high cost of fertilizers and their low use in smallholder farming systems. Integration of small amounts of inorganic fertilizer nitrogen along with nitrogen fixed by the legumes may offer a strategy to meet nitrogen needs of smallholder farmers (Mwangi 2010).

It is well established that combining mineral fertilizer with organic resources improves fertilizer use efficiency (Wangechi 2009).

It has been reported that rates of N_2 fixation of 1 to 2kg N ha^{-1} growing season day is possible in most legumes in tropical cropping systems (Giller 2001).

Rhizobium inoculation has favourable effect on legumes. Phosphate solubilizing bacteria improve nodulation through increased phosphate solubilization and hence increase symbiotic nitrogen fixation (Afzal and Bano 2008)

Research shows that application of combined organic and inorganic fertilizers at only half the recommended rates offers a more economical option resulting in optimum crop production compared to the use of single source. Application of inorganic fertilizers also provides a ready nutrient supply at the early growth phases of the young crop (Chemining'wa *et al.* 2007) coupled with the property of organic manure of moisture storage and slow release of nutrients, therefore sustain crop development cushioning against adverse conditions.

The growth attributes increased with the application of inorganic fertilizers might be due to rapid release and increased availability of N and P at the early stages of the growth of the crop. The soil application of biofertilizers might have helped to increase the biological nitrogen fixation and availability of phosphorus required for strong vegetative growth (Deshmukh *et al*. 2014).

Integration of nutrients increased yield and other yield attributes, indicating the enhancement of nutrients availability which resulted higher yield and yield attributes (Datt *et al*. 2013)**.**

According to the study conducted by Kanaujia *et al*. (1997) at Nauni (H.P) pea seed inoculation with *Rhizobium* culture attributed to higher number of nodules/plant at all the stages (45, 90 and 135 days after sowing) of plant growth and this increase in nodulation and nitrogen fixation due to the inoculation led to significantly more plant height, days taken to flowering, higher green pod and dry matter over uninoculated control.

Patel and Shelke (1998) while working with Indian mustard (*Brassica juncea*) at Parbhani (Maharashtra) observed that farmyard manure had a significant effect on the growth and yield components.

Parmar *et al*. (1998) while studying the effect of integrated nutrient supply system to 'DPP 68' vegetable pea (*Pisum sativum* var.arvense) in dry temperate zone of Himachal Pradesh during summer 1995 and 1996 reported that the green pea yield of pea, nodules/plant, plant height and pods per plant increased substantially and significantly with increasing level of NPK up to 100% of the recommended dose ($N_{20}P_{60}K_{30}$) both in presence and absence of FYM (10t ha^{-1}) compared with the control ($N_0P_0K_0$+ no FYM).

A field experiment conducted at Indore in Madhya Pradesh, Patel *et al*. (1998) showed that application of *rhizobium* culture and phosphate solubilizing bacteria in combination with 50% of N and P significantly increased plant height, pods per plant, grains per pod and ultimately pod yield over control and chemical fertilizers alone.

Chemining'wa *et* al. (2004) observed rhizobia inoculation increased number of nodules and nodule dry weight per plant for most species.

The pea plant inoculated with *Rhizobium leguminosarum* were superior in terms of plant height, number of pods per plant, number of grains per pod and yield than the non-inoculated plants (Asghar *et al*. 2003).

Datt *et al*. (2003) carried out a study in Kukumseri (H.P.) on vegetable pea and observed that successive addition of NPK in combination with FYM further increased the nodulation and other yield attributing parameters. The green pea yield increased significantly and substantially with increasing levels of NPK fertilizers up to 150% recommended dose in presence of FYM.

Similar results were reported by Kuldeep (2003) at Solan (H.P.). Maximum values with respect to green pod yield, plant height, number of green pods/plant, number of seeds/pod and 100-seed weight were recorded with the application of 20 t FYM ha^{-1} + 25 kg N + 65kg P_2O_5+ 97.5kg K_2O ha^{-1}.

Dass *et al*. (2005) conduced a field experiment at Koraput (Orissa) on pea crop with four levels of phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) and observed that increasing phosphorus level from 0 to 75 kg ha^{-1} consistently and significantly increased growth characters like plant height and yield attributes, *viz.* pod per plant, seeds per pod, green pod yield and straw yield.

In a field experiment conducted by Kumar *et al*. (2006) on the productivity of pea under Lahual valley conditions of Himachal Pradesh reported that an application of 20 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1} resulted in significantly higher seed yield, growth and yield contributing traits. This study corroborated with the study by Rana *et al*. (2006) as they also observed significantly highest straw yield at 100% of recommended fertility levels.

Negi *et al*. (2006) evaluated the effect of biofertilizers, nutrient sources and lime on growth and yield of garden pea var. Lincoln in acidic soils of Garhwal hills.

Rana *et al*. (2006) assessed the effect of *Rhizobium* culture in combination with organic and chemical fertilizers on rajmash (*Phaselous vulgaris*) under dry temperate conditions of Himachal Pradesh and observed taller plants, higher number of pods per plant, more grains per pod, more nodules per plant and higher straw yield in rajmash at 1t FYM ha^{-1} and it was statistically at par with 5t FYM ha^{-1}. They also indicated that Rhizobium inoculation resulted in taller plants, higher pods per plant, grains per pod, nodules per plant and straw yield over no inoculation. Also 100% of the recommended dose resulted in taller plants than 50% of the recommended dose.

The increased in growth, yield attributes and yield might be due to the beneficial effect of combined use of organics with balanced inorganic fertilization (Kumawat *et al*. 2013).

Benefits occurring from the integrated use of FYM with 100% NPK might be attributed to the positive impact of availability of individual plant nutrients and humic substances from manure. Improvement in yield due to combined application of inorganic fertilizer and organic manure might be attributed to control release of nutrients in the soil through mineralization of organic manure which might have facilitated better crop growth (Acharya *et al*. 2012).

Inoculation with an effective and persistent Rhizobium strain has numerous advantages, which include non-repeated application of nitrogen fertilizers and higher pod yield due to increased nodulation (Sanginga *et al*. 1994).

Bhattarai *et al*. (2003) while studying the effect of integrated nutrient management on yield attributes and economics of pea (*Pisum sativum*) in Imphal (Manipur) reported that the application of *rhizobium* or FYM in combination with full recommended nutrient dose increased the yield attributes but the best treatment found was poultry manure with full recommended nutrient dose.

Bahadur *et al*. (2006) observed a significant increase in number of nodule/plant in pea crop, when organic amendments and bio-fertilizers are applied in combination.

In a study by Sulieman and Hago (2009) investigating the effect of inoculation, N fertilizer and manure application on nodulation, dry matter accumulation, yield and yield components of beans, manure application and rhizobia inoculation significantly increased number of nodules per plant in all legumes species except one bean variety.

Otieno *et al*. (2009) reported that manure application and rhizobia inoculation significantly increased the number of nodules per plant in all legumes species except lima bean and rhizobia inoculation increased nodule dry weight of common bean.

Lal and Mathur (1989) observed that application of FYM along with fertilizers had a significant role in improving the yield attributes and quality of grains.

When manure was applied in conjunction with chemical fertilizers for efficient growth of crop, the gap between potential yield and the actual yield is bridged to a large extent. Jiyaram (1990) reported that with the application of 10 ton FYM in a rice based cropping system, 25 kg N could be replaced without any reduction in yield.

Bharadwaj *et al*. (1994) found that application of FYM along with 100 per cent NPK was more beneficial in relation to yield than that of 100 per cent and 150 per cent NPK alone.

Subbiah and Kumarswamy (2000) observed crop yield, quality parameters and soil fertility status increased and improved significantly when nutrients were applied through organic manures plus mineral fertilizer than through mineral fertilizers alone.

Dry matter production and seed yield of soybean were increased significantly by the application of farmyard manure (Ganeshamurthy and Sammi-Reddy 2000).

Yaduvanshi (2001) reported that application of NPK and its combination with green manuring and FYM increased the yield of rice and wheat significantly.

Singh *et al*. (2001) concluded that the use of FYM and green manure with fertilizer N has helped in sustaining the yield of rice and wheat as well.

Combining organic and inorganic sources of nutrients produced better crop yields on sustainable basis (Shah and Ahmad 2006).

Shankar *et al*. (2002) during a study at Faizabad (U.P.) on Indian mustard recorded the highest seed and stover yield under the treatment receiving 100% NPK along with 10t FYM/ha and *azotobacter* inoculation.

Higher uptake of nutrients by the crops will result in higher yield. As all the essential elements are released by the organic manures, the released essential elements play vital functional role in crops and thus ultimately increase yield with balanced nutrition.

2.5. Effect of INM on nutrient uptake

Integrated nutrient management practices recorded higher uptake of N, P and K and the response of crops is due to higher availability of these nutrients in soil reservoir besides additional quantity of nutrients supplied by FYM and inorganic fertilizers. This was ascribed to continuous supply of N, P and K throughout the crop growth periods as the nutrients supplied by inorganic sources were available to the crop in the early stages and in the later stages of the crop growth, the slow and continuous release of nutrients from the organic source made available (Vidyathi *et al*. 2011).

Integrated use of lime, organic manures and inorganic fertilizers not only enhanced sweet potato productivity but also increases nutrient use efficiency by countering the acidity and exchangeable Al content in the soil (Hartemink 2003).

Nitrogen is a macronutrient also known as vegetative nutrient and mostly used by the plants and therefore, an important nutrient for grain yield. However, availability of N is highly affected by soil acidity and leaching. Acidity tend to reduce microbial mediate processed that results in poor organic matter decomposition, mineralization of nitrogen and consequently low N availability. Application of soil acidity amendments may improve soil conditions for mineralization takes place and increase N availability in the soil, its uptake and finally positive influence of increasing crop yield (Sharma *et al*. 2013)

Son *et al*. (2001) in a farmer's field experiment under moderate acidic soil also reported that application of organic resources alone and combined with inorganic resources recorded 5.81% and 5.83% N content, respectively in soybean grain.

Tagoe *et al.* (2008) found increased in total N content in seed and plant as 10.1% and 40.6% respectively as affected by application of manure.

Application of lime increased soil pH and favored nitrogen fixation where N concentration in the plant was increased significantly by 3.1% as reported by Caires *et al*. (2006).

Phosphorus is an important plant macronutrient, making up to about 0.2 % of a plant's dry weight (Schachtman *et al*. 1998).

Phosphorus is present in seed and fruit in large quantities and is essential for seed formation. Phosphorus has also been reported to be root growth stimulant and it is associated with early crop maturity (Abbas *et al*. 2011).

In acidic soils, most plant nutrients tend to be unavailable but lack of P is said to be the one that largely affects crop growth, absorption of water and other nutrients hence low crop yields (Crawford *et al*. 2008).

Application of manure, lime and P fertilizers improve soil chemical, physical and biological properties. They reduce P fixation by Al and Fe oxides in the soil, and increase availability of P, which increases its uptake by crop (Kisinyo *et al*. 2012).

Total N uptake by rice crop was significantly higher in the straw incorporated treatments and chemical fertilizer. This might be due to decomposition of straw and release of N resulting in better growth and development of plant and thus more accumulation of N in grain and straw (Thakur and Singh 1987).

Total P uptake was significantly increased due to incorporation of straw and chemical fertilizer as compared to unincorporated treatments. This might be attributed to the fact that addition of organic matter might have decreased P fixation and increased availability of P by producing CO_2 which form carbonic acid with water and decompose some primary soil mineral (Iyer and Apte 1967). Increasing levels of P increased the P uptake.

Uptake of P is also synergistic to uptake of N and higher uptake could be due to solubilization effect of organic acids produced during decomposition of FYM, improved aeration and better root proliferation (Sharma *et al*. 2002).

Total K uptake was significantly higher in FYM and straw incorporated treatments and chemical fertilizers over unincorporated ones, increasing levels of K also increased the total K uptake (Hangarge *et al*. 2002).

Pagaria *et al*. (1995) reported that uptake of N, P and K was increased with full dose of NPK + 10t FYM compared to control.

Shankar *et al*. (2002) in an experiment at Faizabad (U.P.) on Indian mustard reported an increase in N, P and K uptake with 100% NPK along with 10t FYM ha^{-1} and *azotobacter* inoculation.

Datt *et al*. (2003) during their study on effect of supplementary use of farmyard manure along with chemical fertilizers on pea in Lahaul valley of Himachal Pradesh found that total N, P and K uptake increased significantly in different treatments in comparison to control. They also observed that successive increment of NPK fertilizers in the presence of FYM increased N, P and K uptake.

Rana *et al*. (2006) studied the effect of *rhizobium* culture in combination with organic and chemical fertilizers on rajmash (*Phaseolus vulgaris*) under dry temperate conditions of Himachal Pradesh and found significant increase in N, P and K uptake by grain and straw of rajmash with the increase in FYM levels from 0 to 10 tons ha^{-1}. Similarly, *Rhizobium* inoculation treatment was found better and recorded more N, P and K uptake than no inoculation. Among fertilizers levels, 100% of recommended fertilizer proved better than 50 % recommended fertilizer incase of N, P and K uptake in grain and straw of rajmash and observed that total uptake of N, P and K increased significantly with the application of graded levels of nitrogen from 40 to 100 kg ha^{-1}.

Rathod *et al*. (2012) reported higher uptake of NPK due to combined application of organic manures and fertilizers might have resulted in higher yields.

Increase in N uptake in integrated plot might be due to release of N as a result of decomposition of FYM. The increase in P may be ascribed to more availability of P from the added fertilizers and also to the solubilizing action of organic acids produced during decomposition of FYM. The increase in K uptake may be due to the release of K from the K bearing minerals by complexing agents. Similar observation was reported by Kumar *et al*. (2015).

CHAPTER- III

MATERIALS AND METHODS

The present investigation entitled "Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of Nagaland" was conducted at Porba village, Phek district, Nagaland during the year, starting from first week of April 2012 to first week of July 2012 and from first week of April 2013 to first week of July 2013. The details of location, weather condition and soil condition prevailing during the crop period and the experimental techniques are mentioned below:

3.1. General information

3.1.1. Experimental location

A field experiment was conducted during the *kharif* season of 2012 and 2013 at the demonstration farm of Krishi Vigyan Kendra at Porba Village, Phek District, Nagaland. The farm is located at latitude of 25°62'N and longitude of 95°33'E and at an elevation of 1842 m above the mean sea level.

3.1.2. Climatic condition

The climatic condition of Porba village is Sub- Alpine Temperate Zone (Singh *et al*. 2009). The data regarding weather conditions prevailing during the experiment period for Phek district was obtained from the meteorological observatory of ICAR Regional Research Centre, Jharnapani, Nagaland. The monthly meteorological data regarding distribution of total rainfall (mm), maximum and minimum temperature (^{o}C) maximum and minimum relative humidity (%), starting from April 2012 till the end of the investigation i.e. July 2012 and also for the second experiment starting from April 2013 to July 2013. Detailed weather reports are presented in Table 2 (a) and Table 2 (b) and are graphically illustrated in the Fig.1 (a) and Fig.1 (b).

3.1.3 Soil condition

The soil of experimental site was clay loam in texture, well drained and acidic in reaction. The fertility status of the soil was ascertained by taking soil samples from a

Table 2 (a) Meteorological data during the period of investigation of Phek district - 2012

Month	Average Temperature (°C)		Total Rainfall (mm)	Average Relative Humidity (%)	
	Maximum	Minimum		Maximum	Minimum
April	28.0	14.0	98.00	85	42
May	30.9	16.4	85.00	85	45
June	28.0	19.0	221.00	94	72
July	28.0	19.0	222.00	96	77

Source: ICAR Regional Research Centre, Jharnapani, Nagaland.

Table2 (b) Meteorological data during the period of investigation of Phek district - 2013

Month	Average Temperature (°C)		Total Rainfall (mm)	Average Relative Humidity (%)	
	Maximum	Minimum			Maximum
April	25.0	14.9	36.00	75	50
May	25.0	16.7	236.00	94	73
June	28.6	19.6	267.00	92	67
July	26.9	19.8	388.00	98	82

Source: ICAR Regional Research Centre, Jharnapani, Nagaland.

depth of 0-15cm from different locations of the experimental plots with the help of soil auger, which were processed and analyzed .The important characteristics of the initial soil of the experimental plot are given in Table 3.

3.2 Experimental details

3.2.1 Design and plan of layout

The present field experiment was laid out in randomized block design (RBD) with three replications and 18 treatments. The whole experimental field was divided into six equal blocks and each block was again divided into 9 equal sized plots measuring 3 x 2 meter in order to accommodate the treatments. Altogether there were a total of 54 plots. The treatments were allotted in each experimental plot randomly.

Experimental design: Randomised Block Design

Number of treatment combination	: 18
Number of replication	: 3
Total number of plots	: 54
Plot size	: 3 m X 2 m
Gross plot size	: 22.25x 22 m
Block border	: 0.75 m
Plot border	: 0.5 m
Variety	: French bean. Variety-Contender

The details of the experiment are given below and the plan of layout is presented in the Fig 2.

3.2.2 Treatment details

The experiment comprised of eighteen treatment combinations consisting of two levels of NPK, farm yard manure, biofertilizer and lime. The treatment details are as under:-

Symbols	Treatment Combinations
T_1	Control
T_2	50% NPK
T_3	100% NPK
T_4	Biofertilizer
T_5	Biofertilizer + 50% NPK
T_6	Biofertilizer + 100% NPK
T_7	Biofertilizer + Lime

T_8	Biofertilizer + Lime + 50% NPK
T_9	Biofertilizer + Lime + 100% NPK
T_{10}	5 ton FYM
T_{11}	5 ton FYM + 50% NPK
T_{12}	5 ton FYM + 100% NPK
T_{13}	5 ton FYM + Biofertilizer
T_{14}	5 ton FYM + Biofertilizer + 50% NPK
T_{15}	5 ton FYM + Biofertilizer + 100% NPK
T_{16}	5 ton FYM + Biofertilizer + Lime
T_{17}	5 ton FYM + Biofertilizer + Lime + 50% NPK
T_{18}	5 ton FYM + Biofertilizer + Lime + 100% NPK

FYM: Farm Yard Manure, 100% Recommended Dose of Fertilizer (RDF) of N (Urea), P (Single super phosphate) and K (Muriate of potash) are 100, 40 and 20 kg ha-1 respectively.

Farm Yard Manure (% on oven dried basis) - N-0.75%, P_2O_5- 0.3% and K_2O-0.5%.

Liming material used was $CaCO_3$- Lime- 56%, Magnesia-3.94%, Silica and insoluble material- 10.80%, Oxide of Fe and Al- 1.2%, moisture-8.07%, combined water and other matter by difference-19.99% (Jenkins and East 1909).

3.3. Cultivation details

3.3.1. Field preparation

A well drained field with uniform fertility status was selected for conducting the field trial. One deep ploughing and two harrowing were carried out to bring the soil to fine tilth. All the stubbles were then removed using manual labour. Before sowing, the fields were levelled and the plots were laid out according to the experimental plan and design.

3.3.2. Application of organic sources and fertilizer

Different doses of nutrients were applied through different sources as per the need of the treatments. The recommended level (100%) of N, P_2O_5 and K_2O based were 100, 40 and 20 kg ha^{-1} applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP) as per the treatments. Half of the nitrogen and full dose of P and K were applied in furrows below the seed at planting and remaining half amount of nitrogen was applied as top dressing at flowering time.

FYM @ 5t ha^{-1} and lime @ 200kg ha^{-1} were incorporated in the soil 10 days prior to planting of French bean. As per the treatment, seeds were treated with Rhizobium and Phosphotika biofertilizer @ 200gm each per 10 kg seeds. The seeds were soaked in the mixture of biofertilizer and kept for two hours in the shade before sowing.

3.3.3. Seed rate

Recommended seed rate used during the field experiment (2012 and 2013) is given below:

Seed rate: 50 kg ha^{-1}

3.3.4. Seed material and sowing

Good quality rajmash seeds cultivar Contender was sown. Seeds were hand dibbled to a depth of 5cm at a row spacing of 40cm and plant to plant spacing of 20 cm in small furrows opened with the help of a wooden marker. The first sowing was done on 05-04-2012 and in the second year sowing of rajmash was done on 09-04-2013.

3.3.5. Gap filling

To maintain the desired plant population gap filling was done within the first fortnight of sowing in both the experimental years.

3.3.6. After Care

The thinning operation was done seven (7) days after the crop germinated as 2-3 seeds were sown per hill. In order to keep the weeds under check, hand weeding twice at 20 and 40 days after sowing were taken up.

3.3.7. Harvesting and threshing

The crop was harvested on the second week of July 2012 i.e 90 days after sowing at physiological maturity plot wise. The harvested plants and pods were separated, labelled and transported to the cemented threshing floor. Seeds were sundried and seed yield was recorded as per the treatments. The seeds and stover were properly kept for laboratory analysis.

3.4. Sampling techniques and observation

3.4.1. Collection of soil samples

Soil samples were collected from surface soil i.e. 0-15cm randomly from each of the experimental plot before (initial) and after the harvest of the crop. Then, the soils

Table 3. Initial soil fertility status of the experimental field recorded in 2012.

Soil properties	Initial value 2012	Methods employed
Sand (%) Silt (%) Clay (%) Textural Class- Clay loam	20 47.1 32.9	Hydrometer method (Baruah and Barthakur, 1997)
Soil pH	5.12	Glass electrode pH meter (Jackson 1973).
Organic carbon (%)	0.58	Walkley and Black's method (Jackson 1973).
EC (dS m^{-1})	0.10	Electrode conductivity meter (Jackson, 1973).
Cation exchange capacity [cmol (p^+) kg^{-1}]	5.33	Ammonia distillation method (Jackson 1973).
Bulk density (Mg m^{-3})	1.42	Keen-Rackzowski box method (Baruah and Barthakur, 1997)
Particle density(Mg m^{-3})	2.72	Keen-Rackzowski box method (Baruah and Barthakur 1997)
Porosity (%)	48.22	Keen-Rackzowski box method (Baruah and Barthakur 1997)
Water holding capacity	49.85	Keen-Rackzowski box method (Baruah and Barthakur 1997)
Available nitrogen (kg ha^{-1})	242.89	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	8.20	Bray and Kurtz no. 1 method (Jackson 1973).
Available potassium (kg ha^{-1})	128.5	Neutral normal ammonium acetate extract of soil (Jackson 1973).
Exchangeable Ca [cmol(p^+)kg^{-1}]	1.22	Complexometric titration method (Jackson 1973).
Exchangeable Mg [cmol(p^+)kg^{-1}]	0.65	Complexometric titration method (Jackson 1973).
Available S (kg ha^{-1})	15.11	Mono-calcium phosphate extractable S method (Ensminger 1954)
Available Cu (ppm)	0.06	Atomic absorption spectrophotometer (Piper 1966)
Available Zn(ppm)	0.29	Atomic absorption spectrophotometer (Piper 1966)
Available Fe (ppm)	4.55	Atomic absorption spectrophotometer (Piper 1966)
Available Mn (ppm)	7.35	Atomic absorption spectrophotometer (Piper 1966)

were spread uniformly under shade for air drying. The soils were ground and passed through a 2 mm sieve and kept in polyethylene bags with proper labels for analysis.

3.4.2. Determination of soil physico-chemical properties of the soil

3.4.2.1. Bulk density (Mg m^{-3})

The bulk density of the soil was determined by Single value soil constants by Keen-Rackzowski Box method as described by Baruah and Barthakur (1997).

3.4.2.2. Particle density (Mg m^{-3})

The Particle density of the soil was determined by Single value soil constants by Keen-Rackzowski Box method as described by Baruah and Barthakur (1997).

3.4.2.3. Porosity (%)

The Porosity of the soil was determined by single value soil constants by Keen Rackzowski Box method as described by Baruah and Barthakur (1997).

$$\text{Total porosity (\%)} = \left[\left\{1 - \left(\frac{\text{Bulk density}}{\text{Particle density}}\right)\right\} \times 100\right]$$

3.4.2.4. Water holding capacity (%)

The Water holding capacity of the soil was determined by Single value soil constants by Keen-Rackzowski Box method as described by Baruah and Barthakur (1997).

3.4.2.5. Soil pH:

Soil pH was determined in soil water suspension (1:2.5) using glass electrode pH meter as described Jackson (1973).

3.4.2.6. Electrical conductivity (dS m^{-1})

Electrical conductivity of the soil was determined by taking the supernatant solution of soil water (1:2.5) suspension using electrode conductivity meter as described by Jackson (1973).

3.4.2.7. Organic carbon (%)

Organic carbon was estimated by rapid titration method of Walkley and Black as described by Jackson (1973).

3.4.2.8. Cation exchange capacity [cmol (p+) kg^{-1}]

Cation Exchange Capacity of the soil was determined by Ammonia Distillation method as described by Jackson (1973).

3.4.2.9. Per cent base saturation (%)

The percentage of the CEC occupied by basic cations is termed as per cent base saturation (%). It is calculated by

$$\% \text{ BS} = \frac{(\text{Ca} + \text{Mg} + \text{K} + \text{Na})}{\text{CEC}} \text{ x } 100$$

3.4.3. Determination of major, secondary and micronutrients status of the soil

3.4.3.1. Available nitrogen (kg ha^{-1})

Available nitrogen was estimated by alkaline potassium permanganate method given by Subbiah and Asija (1956).

3.4.3.2. Available phosphorus (kg ha^{-1})

Available phosphorus (P) was extracted with 0.03 N, NH_4F in 0.025 N HCl solution. The procedure is primarily meant for soil, which are moderate to strongly acidic acid with pH around 5.5 or less (Bray & Kurtz 1945) as described by Jackson (1973).

3.4.3.3. Available potassium (kg ha^{-1})

Available potassium (K) was extracted from soil with neutral ammonium acetate (pH 7) solution and potassium concentration in the extract was determined by flame photometer as described by Jackson (1973).

3.4.3.4. Exchangeable Ca and Mg [cmol(p+)kg^{-1}]

Exchangeable Ca and Mg were determined by complexometric titration method as described by Jackson (1973).

3.4.3.5. Available Sulphur (kg ha^{-1})

Available sulphur in soil was determined by Mono-calcium phosphate extractable S method as outlined by Ensminger (1954).

3.4.3.6. Available Zinc, Copper, Iron and Manganese (ppm)

Available Zinc, Copper, Iron and Manganese was determined by taking ten grams of soil which was extracted with 20ml of the extraction solution diethylene triamine penta-acetic acid (DTPA) and shaken thoroughly for 2 hours. The solution was filtered through Whatman No. 42 filter paper. The filtrate was red by using Atomic Absorption Spectrophotometer (Piper 1966).

3.5. Plant samples and observations recorded

A sample consisting of five plants selected randomly were tagged from the net plot area of each treatment for recording various biometric observations. The mean of the five plants was considered for further analysis. The observation on various growth parameters were recorded at 30, 60 and 90 days after sowing. Yield attributes and yield were recorded at harvest.

3.5.1. Growth attributes

3.5.1.1. Plant height (cm):

The plant height of the five tagged plants per plot was measured in centimeters from the base of the plant to the base of the fully opened youngest trifoliate leaf and expressed in cm at 30, 60 and 90 days after sowing.

3.5.1.2. Number of branches per plant

The number of branches on the tagged plants was counted at different stages and recorded.

3.5.1.3. Number of nodules per plant

The number of nodules per plant of the five tagged plants was recorded at flowering stage. The plants were uprooted along with soil around 7 cm radius and 15cm depth and the nodules were collected after washing of the soil in bucket of water and the number of nodules per plant was counted.

3.5.1.4. Fresh and dry weight of nodules (mg plant^{-1})

After the nodules were counted, the fresh weight of the nodules was recorded in mg per plant.

The nodules were kept in room temperature to bring its moisture to a constant. The nodules were taken out and dry weight was recorded after oven drying at 65^0C in mg per plant.

3.5.2. Yield attributes and yield.

3.5.2.1. Number of pods per plant

Number of pods per plant was counted from all the five tagged plant and average was recorded as number of pods per plant.

3.5.2.2. Pod length (cm)

The pod length of the five tagged plants per plot was counted and average was recorded in centimetre.

3.5.2.3. No. of seeds per pod

Well developed seeds from all the pods of the tagged plants were counted and average was recorded as number of seeds per pod.

3.5.2.4. Test weight (g)

Seed samples from the harvested yield were taken randomly and 100 grains were counted and weighted to get the test weight of grain. The test weight was recorded for both the trials.

3.5.2.5. Grain yield (q ha^{-1})

The grain yield of all the plots were collected treatment wise and the plot yield of each treatment was converted into q ha^{-1}.

3.5.2.6. Stover yield (q ha^{-1})

The stover yield of above ground matter from the net plot area at harvest, treatment wise was recorded after complete sun drying. The plot yield of each treatment was converted into q ha^{-1}.

3.6. Determination of nitrogen, phosphorus and potassium in grain and stover of rajmash and total N, P and K uptake.

Plant samples were collected plot-wise at the time of harvesting after 2012 and 2013. Grain and stover samples were washed with deionised water and dried in sun followed by oven dry at 70^0C and powered and packed in polythene bags with proper labelling.

3.6.1. Nitrogen (%)

Nitrogen content in grain and stover was determined by digestion and distillation procedure as described by Jackson (1973). The grain and stover sample were digested separately in conc.H_2SO_4 in presence of digested accelerators and then distilling the digested sample in Kjeldahl's flask. The distilled ammonia was collected in boric acid and nitrogen was estimated by back titrating with H_2SO_4.

3.6.2. Phosphorus (%)

Phosphorus content was determined by wet ashing method. The grain and stover sample were separately digested by nitro-perchloric digestion (Di-acid mixture) as described by Baruah and Barthakur (1997). Phosphorus estimation was done by calorimetrically using Vandomolypdophosphoric yellow color method given by Jackson (1973).

3.6.3. Potassium (%)

Potassium content in both grain and stover samples were determined separately by wet ashing method. The samples were digested by nitro-perchloric digestion (Di-acid mixture) as described by Baruah and Barthakur (1997). Potassium was determined flame photometrically as outlined by Jackson (1973).

3.6.4. Total nutrient uptake (kg ha^{-1})

The uptake of different nutrients (N, P and K) were separately carried out in grain and stover samples multiplying nutrient content (%) in grain and stover samples with their corresponding yield data.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Yield (kg ha}^{-1}) \text{ x Nutrient content(\%)}}{100}$$

3.7. Economics

Economics of different practices was worked out by comparison of treatments in respect of the following attributes:

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

Cost of cultivation for the sequences was calculated out separately by taking into account all investments.

3.7.2. Gross return (` ha^{-1})

For the sequence, the value of the main products and by-products in terms of money was calculated out separately on the basis of prevailing market price and was recorded on unit area basis.

3.7.3. Net return (` ha^{-1})

Net return for the sequence was worked out by subtracting the cost of cultivation for the sequence from the corresponding gross return.

3.7.4. Benefit cost ratio

Benefit-cost ratio was calculated by using the formula given below as:

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

3.8. Statistical analysis

Data obtained from various studies were statistically analysed in RBD by using the technique of Analysis of Variance given by Panse and Sukhatme (1989). The difference between the treatment means was tested as to their statistical significance with appropriate critical difference (C.D.) value at 5 per cent level of probability.

CHAPTER- IV

EXPERIMENTAL FINDINGS

The investigation entitled "Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of Nagaland" was conducted during the *kharif* season of 2012 and 2013 in the demonstration farm of Krishi Vigyan Kendra at Porba Village, Phek District, Nagaland. The experimental findings related to the present investigation are presented in this chapter under the following heads:

4.1. Soil physico-chemical properties

The analytical data on physico-chemical and physical properties of soil *viz.* bulk density, particle density, porosity, water holding capacity, pH, EC, organic carbon content, CEC and per cent base saturation of soils after the harvest of crop in 2012 and 2013 are as under:-

4.1.1. Bulk density (Mg m^{-3})

The effect of INM on the bulk density of soil depicted in Table 4 (a) showed significant effect with respect to treatments. In both 2012 and 2013, T_1 (1.41 and 1.42 respectively) recorded the highest value and was statistical at par with T_2 (1.40) and T_3 (1.39) in 2012 and only with T_2 in 2013 (1.40). The treatment T_4 to T_9 in 2012 and only T_4 to T_6 in 2013 were statistically at par with each other. T_{10} to T_{16} also did not show much difference among them. The lowest value (1.27 Mg m^{-3}) was observed in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in both years and it was at par with T_{18} (1.29 Mg m^{-3} in 2012 and 1.28 Mg m^{-3} in 2013).

The pooled data of 2012 and 2013 on bulk density of soil also revealed similar results. The highest bulk density in soil (1.41 Mg m^{-3}) was recorded from control while the lowest was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK as 1.27 Mg m^{-3}.

4.1.2. Particle density (Mg m^{-3})

The results pertaining to the effect of integrated nutrient management on particle density of soil in rajmash is presented in Table 4 (b). Variation in particle density of soil was observed to be significant and the highest particle density (2.71 Mg m^{-3}) was found

Table 4 (a): Effect of Integrated nutrient management on bulk density of soil after the harvest of rajmash.

Treatment	Bulk density (Mg m^{-3})		
	2012	2013	Pooled
T_1- Control	1.41	1.42	1.41
T_2- 50% NPK	1.40	1.40	1.40
T_3- 100% NPK	1.39	1.39	1.39
T_4- Biofertilizer	1.38	1.38	1.38
T_5 -Biofertilizer + 50% NPK	1.37	1.37	1.37
T_6- Biofertilizer + 100% NPK	1.37	1.37	1.37
T_7- Biofertilizer + Lime	1.36	1.36	1.36
T_8-Biofertilizer + Lime + 50% NPK	1.36	1.36	1.36
T_9- Biofertilizer + Lime + 100% NPK	1.36	1.36	1.36
T_{10} – 5 ton FYM	1.35	1.35	1.36
T_{11} –5 ton FYM + 50% NPK	1.34	1.34	1.34
T_{12} –5 ton FYM + 100% NPK	1.34	1.34	1.35
T_{13}- 5 ton FYM + Biofertilizer	1.32	1.32	1.32
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	1.33	1.34	1.34
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	1.31	1.31	1.31
T_{16}- 5 ton FYM + Biofertilizer + Lime	1.31	1.31	1.31
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	1.27	1.27	1.27
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	1.29	1.28	1.29
Initial value	1.42	-	-
SEm±	0.008	0.006	0.01
CD (P=0.05)	0.023	0.016	0.02
CV	1.042	0.673	0.86

Table 4 (b): Effect of Integrated nutrient management on particle density of soil after the harvest of rajmash.

Treatment	Particle density (Mg m^{-3})		
	2012	2013	Pooled
T_1- Control	2.71	2.71	2.72
T_2- 50% NPK	2.70	2.70	2.70
T_3- 100% NPK	2.69	2.69	2.69
T_4- Biofertilizer	2.68	2.68	2.68
T_5 –Biofertilizer + 50% NPK	2.67	2.67	2.67
T_6- Biofertilizer + 100% NPK	2.67	2.67	2.67
T_7- Biofertilizer + Lime	2.66	2.67	2.67
T_8-Biofertilizer + Lime + 50% NPK	2.65	2.66	2.66
T_9- Biofertilizer + Lime + 100% NPK	2.65	2.65	2.65
T_{10} – 5 ton FYM	2.66	2.65	2.66
T_{11} –5 ton FYM + 50% NPK	2.64	2.64	2.64
T_{12} –5 ton FYM + 100% NPK	2.63	2.64	2.64
T_{13}- 5 ton FYM + Biofertilizer	2.64	2.63	2.64
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	2.63	2.63	2.63
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	2.62	2.63	2.63
T_{16}- 5 ton FYM + Biofertilizer + Lime	2.62	2.62	2.62
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	2.61	2.61	2.61
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	2.62	2.62	2.62
Initial value	2.72	-	-
SEm±	0.010	0.013	0.008
CD (P=0.05)	0.028	0.04	0.02
CV	0.63	0.82	0.72

under control in both 2012 and 2013 and was statistically at par with the treatments T_2 (2.70 Mg m^{-3}), T_3 (2.69 Mg m^{-3}) and T_4 (2.68 Mg m^{-3}) in both the year. The lowest particle density (2.61 Mg m^{-3}) was found in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in both the experimental period- 2012 and 2013 respectively.

From the pooled data it was also apparent that control treatment obtained the highest particle density (2.71 Mg m^{-3}) in soil after harvest and the lowest from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 2.61 Mg m^{-3}.

4.1.3. Porosity (%)

Data pertaining to porosity of soil as influenced by INM have been presented in Table 4 ©. The data revealed that in both the years of experimentation, the maximum porosity was recorded from treatment in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) with 51.46 % in 2012 and 51.40 % in 2013 and was statistically at par with treatment T_{18} (50.57 % in 2012 and 50.96 in 2013). The lowest porosity of soil (48.16% and 47.79 % in 2012 and 2013 respectively) was found under control treatment (T_1) in both the years.

An analysis of the pooled data of 2012 and 2013 also showed the same trend where T_{17} receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK obtained the maximum porosity (51.44 %) while control treatment (T_1) obtained minimum porosity (47.98 %).

4.1.4. Water holding capacity (%)

Table 4 (d) also revealed that there was significant effect of treatments on the water holding capacity of the soil. In the 1st year (2012) of experimentation the values ranged from 49.29 to 56.89 per cent over the initial value of 49.85 per cent while in the 2nd year (2013) it ranged from 49.20 to 57.71 per cent.

The maximum water holding capacity of soil was recorded in the T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving 56.89 per cent which was followed by the treatments T_{18} (56.51%), T_{16} (56.15 %), T_{15} (55.79 %) and T_{14} (55.25 %). The minimum water holding capacity (49.29%) was found under the treatment T_1 (control).

Similarly in the second year (2013) also, the data showed that the water holding capacity was found to be highest (57.71 %) under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and it was statically at par with treatments T_{18} (57.48 %) and T_{16} (56.92 %). The minimum water holding capacity (49.20%) was found under

Table 4 (c): Effect of Integrated nutrient management on porosity of soil after the harvest of rajmash.

Treatment	Porosity (%)		
	2012	2013	Pooled
T_1- Control	48.16	47.79	47.98
T_2- 50% NPK	48.21	48.08	48.15
T_3- 100% NPK	48.39	48.26	48.33
T_4- Biofertilizer	48.38	48.45	48.42
T_5 –Biofertilizer + 50% NPK	48.75	48.56	48.66
T_6- Biofertilizer + 100% NPK	48.50	48.50	48.50
T_7- Biofertilizer + Lime	48.81	49.00	48.91
T_8-Biofertilizer + Lime + 50% NPK	48.81	48.87	48.84
T_9- Biofertilizer + Lime + 100% NPK	48.87	48.74	48.81
T_{10} – 5 ton FYM	49.06	48.93	49.00
T_{11} –5 ton FYM + 50% NPK	49.18	49.37	49.27
T_{12} –5 ton FYM + 100% NPK	49.11	49.14	49.13
T_{13}- 5 ton FYM + Biofertilizer	49.93	49.87	49.91
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	49.30	49.18	49.24
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	49.94	50.19	50.07
T_{16}- 5 ton FYM + Biofertilizer + Lime	50.05	50.13	50.09
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	51.46	51.40	51.44
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	50.57	50.96	50.77
Initial value	48.22	-	-
SEm±	0.37	0.36	0.28
CD (P=0.05)	1.05	1.03	0.80
CV	1.29	1.23	1.24

Table 4 (d): Effect of Integrated nutrient management on water holding capacity of soil after the harvest of rajmash.

Treatment	Water holding capacity (%)		
	2012	2013	Pooled
T_1- Control	49.29	49.20	49.25
T_2- 50% NPK	50.28	49.78	50.03
T_3- 100% NPK	50.88	50.55	50.72
T_4- Biofertilizer	51.23	51.63	51.44
T_5 –Biofertilizer + 50% NPK	51.40	52.75	52.08
T_6- Biofertilizer + 100% NPK	51.73	53.61	52.67
T_7- Biofertilizer + Lime	52.63	53.91	53.27
T_8-Biofertilizer + Lime + 50% NPK	52.82	54.63	53.73
T_9- Biofertilizer + Lime + 100% NPK	53.17	55.25	54.21
T_{10} – 5 ton FYM	53.79	55.67	54.73
T_{11} –5 ton FYM + 50% NPK	54.13	55.97	55.05
T_{12} –5 ton FYM + 100% NPK	54.54	56.16	55.35
T_{13}- 5 ton FYM + Biofertilizer	54.98	55.71	55.35
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	55.25	57.13	56.19
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	55.79	57.42	56.61
T_{16}- 5 ton FYM + Biofertilizer + Lime	56.15	56.92	56.53
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	56.89	57.71	57.31
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	56.51	57.48	57.00
Initial value	49.85	-	-
SEm±	0.15	0.28	0.16
CD (P=0.05)	0.43	0.82	0.47
CV	0.49	0.90	0.72

the treatment T_1 (control) and was at par with the treatment T_2 (50 % NPK) as 49.78 per cent.

Further the pool of two years also revealed maximum water holding capacity (57.31 %) in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and minimum (49.25 %) in control treatment.

4.1.5. Soil pH

Data on soil pH are presented in Table 4 (e). The initial soil pH recorded in 2012 was 5.12. After the harvest of the crop, the pH of the soil varied from 5.15 to 5.85 in 2012 and 5.11 to 5.83 in 2013. The highest pH (5.85) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in 2012 and was found to be statistically at par with the treatments T_{18} (5.83) and T_{16} (5.81). The lowest pH (5.15) was found under treatment T_1 (control).

Similarly, in 2013 the highest pH (5.83) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in 2012 and the lowest (5.11) under treatment T_1 (control) and the second lowest (5.23) under treatment T_2 receiving 50% NPK fertilizer.

Results from the pooled data of 2012 and 2013, showed that highest pH (5.84) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Minimum pH (5.13) was recorded from control.

4.1.6. Electrical conductivity (dS m^{-1})

The EC as a result of different treatments was found to be significant as it is evident from Table 4 (f). In 2012, the maximum EC (0.14 dS m^{-1}) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by the treatment T_{18} (0.13 dS m^{-1}) whereas the minimum EC was recorded under the treatment T_1 (Control) giving a value of 0.08 dS m^{-1}.

In 2013, the highest EC (0.13 dS m^{-1}) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by the treatment T_{18} (5 ton FYM +

Biofertilizer + Lime + 100% NPK) as 0.12 dS m^{-1}, while the minimum EC (0.08 dS m^{-1}) was observed under control treatment.

From the mean pooled data of 2012 and 2013 on EC of soil revealed that the highest EC in soil (0.14 dS m^{-1}) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). The minimum EC in soil was recorded from control plot as (0.08 dS m^{-1}).

Table 4 (e): Effect of Integrated nutrient management on soil pH after the harvest of rajmash.

Treatment	Soil pH		
	2012	2013	Pooled
T_1- Control	5.15	5.11	5.13
T_2- 50% NPK	5.22	5.23	5.23
T_3- 100% NPK	5.24	5.25	5.25
T_4- Biofertilizer	5.26	5.27	5.27
T_5 -Biofertilizer + 50% NPK	5.27	5.30	5.29
T_6- Biofertilizer + 100% NPK	5.30	5.32	5.31
T_7- Biofertilizer + Lime	5.70	5.72	5.71
T_8-Biofertilizer + Lime + 50% NPK	5.74	5.74	5.74
T_9- Biofertilizer + Lime + 100% NPK	5.73	5.76	5.75
T_{10} – 5 ton FYM	5.33	5.30	5.32
T_{11} –5 ton FYM + 50% NPK	5.34	5.31	5.33
T_{12} –5 ton FYM + 100% NPK	5.36	5.32	5.34
T_{13}- 5 ton FYM + Biofertilizer	5.36	5.33	5.34
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	5.34	5.31	5.33
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	5.35	5.33	5.34
T_{16}- 5 ton FYM + Biofertilizer + Lime	5.81	5.64	5.73
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	5.85	5.83	5.84
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	5.83	5.63	5.73
Initial value	5.12	-	-
SEm±	0.02	0.05	0.028
CD (P=0.05)	0.05	0.15	0.08
CV	0.54	1.64	1.20

Table 4 (f): Effect of Integrated nutrient management on EC of soil after the harvest of rajmash.

Treatment	EC (dS m^{-1})		
	2012	2013	Pooled
T_1- Control	0.08	0.08	0.08
T_2- 50% NPK	0.10	0.09	0.10
T_3- 100% NPK	0.10	0.09	0.10
T_4- Biofertilizer	0.10	0.10	0.10
T_5 -Biofertilizer + 50% NPK	0.12	0.12	0.12
T_6- Biofertilizer + 100% NPK	0.11	0.10	0.10
T_7- Biofertilizer + Lime	0.11	0.11	0.11
T_8-Biofertilizer + Lime + 50% NPK	0.12	0.11	0.12
T_9- Biofertilizer + Lime + 100% NPK	0.12	0.12	0.12
T_{10} – 5 ton FYM	0.10	0.10	0.10
T_{11} –5 ton FYM + 50% NPK	0.12	0.11	0.12
T_{12} –5 ton FYM + 100% NPK	0.11	0.12	0.12
T_{13}- 5 ton FYM + Biofertilizer	0.10	0.11	0.11
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.10	0.12	0.11
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.11	0.11	0.11
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.12	0.11	0.11
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.14	0.13	0.14
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.13	0.12	0.12
Initial value	0.10	-	-
SEm±	0.007	0.006	0.004
CD (P=0.05)	0.02	0.02	0.01
CV	11.10	9.29	10.10

4.1.7. Organic carbon (%)

Organic carbon content of the soils after harvesting of the crop as influenced by INM has been presented in Table 4 (g). The initial organic carbon content recorded in 2012 was 0.58 %. In the first year (2012), after the harvest of the crop, organic carbon varied from 0.60 to 0.98%. Maximum organic carbon (0. 98%) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK which was at par with treatments T_{18} (0.97%) receiving 5 ton FYM + Biofertilizer + Lime + 100% NPK and T_{16} (5 ton FYM + Biofertilizer + Lime) as 0.96 %, while the minimum organic carbon content (0.60%) was recorded in the control plot.

In the second year (2013), the highest organic carbon (0.99 %) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by T_{18} (0.97 %) and was found to be at par with the treatment T_{16} (0.95 %). While the lowest (0.60%) was recorded in the treatment T_1 (control) and at par with T_2 (0.61%), T_3 (0.63%) and T_5 (0.64%).

The mean pooled data also showed that the treatment receiving T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) recorded the highest organic carbon content (0.98 %) while the lowest was recorded with control treatment (0.60 %).

4.1.8. CEC [cmol (p^+) kg^{-1}]

It is evident from Table 4 (h), there was a significant effect of treatments on the CEC of the soil. In 2012, it varied from 5.24 to 6.22 cmol$(p^+)kg^{-1}$ as compared to initial value of 5.33 cmol$(p^+)kg^{-1}$. In the first year of experimentation (2012), the highest value was observed in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 6.22 cmol$(p^+)kg^{-1}$ followed by the treatment receiving T_{16} [6.19 cmol$(p^+)kg^{-1}$] and T_{18} [6.16 cmol$(p^+)kg^{-1}$]. The lowest CEC of 5.24 cmol$(p^+)kg^{-1}$ was recorded in the control treatment T_1 .

Similarly, in 2013 the maximum [5.81 cmol$(p^+)kg^{-1}$] was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) which was found to be statistically at par with the treatments T_{16} as 5.76 $cmol(p^+)kg^{-1}$, T_{18} and T_{14} as 5.75 $cmol(p^+)kg^{-1}$ and the minimum was recorded in T_1 (control) as 5.21 $cmol(p^+)kg^{-1}$ and it was at par with the treatments 50 % NPK [5.22 $cmol(p^+)kg^{-1}$] and 100 % NPK [5.23 $cmol(p^+)kg^{-1}$].

Table 4 (g): Effect of Integrated nutrient management on organic carbon of soil after the harvest of rajmash.

Treatment	Organic carbon (%)		
	2012	2013	Pooled
T_1- Control	0.60	0.60	0.60
T_2- 50% NPK	0.63	0.61	0.62
T_3- 100% NPK	0.66	0.63	0.65
T_4- Biofertilizer	0.69	0.65	0.67
T_5 -Biofertilizer + 50% NPK	0.72	0.64	0.68
T_6- Biofertilizer + 100% NPK	0.77	0.68	0.72
T_7- Biofertilizer + Lime	0.80	0.68	0.74
T_8-Biofertilizer + Lime + 50% NPK	0.84	0.70	0.77
T_9- Biofertilizer + Lime + 100% NPK	0.86	0.72	0.79
T_{10} – 5 ton FYM	0.88	0.74	0.81
T_{11} –5 ton FYM + 50% NPK	0.90	0.76	0.83
T_{12} –5 ton FYM + 100% NPK	0.91	0.82	0.87
T_{13}- 5 ton FYM + Biofertilizer	0.94	0.91	0.92
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.94	0.91	0.93
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.95	0.93	0.94
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.96	0.95	0.96
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.98	0.99	0.98
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.97	0.97	0.97
Initial value	0.58	-	-
SEm±	0.007	0.02	0.01
CD (P=0.05)	0.02	0.04	0.03
CV	1.51	3.50	2.59

Table 4 (h): Effect of Integrated nutrient management on CEC of soil after the harvest of rajmash.

Treatment	CEC [cmol $(p^+)kg^{-1}$]		
	2012	2013	Pooled
T_1- Control	5.24	5.21	5.22
T_{2}- 50% NPK	5.28	5.22	5.25
T_{3}- 100% NPK	5.31	5.23	5.27
T_{4}- Biofertilizer	5.35	5.28	5.32
T_5 -Biofertilizer + 50% NPK	5.42	5.33	5.38
T_{6}- Biofertilizer + 100% NPK	5.46	5.36	5.41
T_{7}- Biofertilizer + Lime	5.46	5.39	5.43
T_{8}-Biofertilizer + Lime + 50% NPK	5.52	5.46	5.49
T_{9}- Biofertilizer + Lime + 100% NPK	5.56	5.57	5.57
T_{10} – 5 ton FYM	5.60	5.61	5.61
T_{11} –5 ton FYM + 50% NPK	5.65	5.67	5.66
T_{12} –5 ton FYM + 100% NPK	5.67	5.70	5.68
T_{13}- 5 ton FYM + Biofertilizer	6.10	5.74	5.92
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	6.15	5.75	5.95
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	6.16	5.71	5.94
T_{16}- 5 ton FYM + Biofertilizer + Lime	6.19	5.76	5.97
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	6.22	5.81	6.02
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	6.18	5.75	5.97
Initial value	5.33	-	-
SEm±	0.01	0.02	0.01
CD (P=0.05)	0.03	0.06	0.03
CV	0.32	0.65	0.50

Results from the pooled data of 2012 and 2013, also showed that maximum CEC as 6.02 cmol(p^+)kg^{-1} was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Minimum CEC was recorded from control as 5.22 cmol(p^+)kg^{-1}.

4.1.9. Base saturation (%)

Data on per cent base saturation for both the experimentation years are presented in Table 4 (i). Base saturation percentage of the soil was significantly influenced by the treatments. Maximum per cent base saturation was observed under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 40.11% in 2012 and 40.41% in 2013. It was followed by T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) as 40.01 %, 40.03 % and T_{16} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 39.81 % and 39.74 % in 2012 and 2013 respectively.

Minimum per cent base saturation was recorded under the treatment T_1 (control) in both the experimental period as 37.56% in 2012 and 37.34% respectively. However, in all the cases, per cent base saturation decreased from initial (40.10 %).

Data from the pooled analysis showed that the highest per cent base saturation (40.26 %) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by T_{18} (40.02 %), while the lowest (37.45 %) was recorded in the treatment T_1 (control).

4.2. Major nutrient status of the soil

Results on status of available N, P and K of the soil at the end of the cropping sequence are presented in the Table 5 (a) and 5 (b) and graphically presented in Fig 3 (a), 3(b) and 3 (c). By and large, integrated treatments improved available nutrient status of soil as against chemical treatments.

4.2.1. Available N (kg ha^{-1})

Data on available N was significantly influenced by the treatments in both the experimental years and are presented in Table 5 (a) and Fig 3 (a). Initial available N recorded in 2012 was 242.89 kg ha^{-1}.

In 2012, the available N content due to different treatments varied from 240.56 to 331.26 kg ha^{-1} after the harvest of the crop. The highest available nitrogen was observed in the treatment T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) giving a value of 331.26 kg ha^{-1} followed by T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 309.13 kg ha^{-1}, T_{15} (302.29 kg ha^{-1}), T_{16} (300.81 kg ha^{-1}) and T_{12} (299.04 kg ha^{-1}),

Table 4 (i): Effect of Integrated nutrient management on per cent base saturation of soil after the harvest of rajmash.

Treatment	% Base saturation		
	2012	2013	Pooled
T_1- Control	37.56	37.34	37.45
T_2- 50% NPK	37.84	38.14	37.99
T_3- 100% NPK	38.12	38.40	38.26
T_4- Biofertilizer	38.43	38.28	38.36
T_5 -Biofertilizer + 50% NPK	38.26	38.26	38.26
T_6- Biofertilizer + 100% NPK	38.41	38.38	38.40
T_7- Biofertilizer + Lime	38.51	38.61	38.56
T_8-Biofertilizer + Lime + 50% NPK	38.67	38.88	38.78
T_9- Biofertilizer + Lime + 100% NPK	39.10	39.06	39.08
T_{10} – 5 ton FYM	38.91	39.25	39.08
T_{11} –5 ton FYM + 50% NPK	39.43	39.62	39.53
T_{12} –5 ton FYM + 100% NPK	39.48	39.22	39.35
T_{13}- 5 ton FYM + Biofertilizer	39.23	39.35	39.29
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	39.42	39.39	39.41
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	39.52	39.71	39.62
T_{16}- 5 ton FYM + Biofertilizer + Lime	39.81	39.74	39.77
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	40.11	40.41	40.26
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	40.01	40.03	40.02
Initial value	40.10	-	-
SEm±	0.16	0.13	0.12
CD (P=0.05)	0.45	0.38	0.34
CV	0.70	0.59	0.64

Table 5 (a): Effect of Integrated nutrient management on soil available N after the harvest of rajmash.

Treatment	Available N (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	240.56	228.53	234.55
T_2- 50% NPK	261.31	244.63	252.97
T_3- 100% NPK	271.77	262.42	267.10
T_4- Biofertilizer	276.96	269.40	273.18
T_5 -Biofertilizer + 50% NPK	278.17	275.32	276.75
T_6- Biofertilizer + 100% NPK	280.31	282.22	281.27
T_7- Biofertilizer + Lime	282.91	284.90	283.90
T_8-Biofertilizer + Lime + 50% NPK	287.40	287.68	287.55
T_9- Biofertilizer + Lime + 100% NPK	287.54	290.05	288.79
T_{10} – 5 ton FYM	288.71	292.83	290.77
T_{11} –5 ton FYM + 50% NPK	291.54	292.44	291.99
T_{12} –5 ton FYM + 100% NPK	299.04	301.97	300.51
T_{13}- 5 ton FYM + Biofertilizer	294.93	297.84	296.39
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	293.50	288.18	290.84
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	302.29	306.54	304.42
T_{16}- 5 ton FYM + Biofertilizer + Lime	300.81	301.94	301.38
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	309.13	316.95	313.04
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	331.26	324.11	327.69
Initial value	242.89	-	-
SEm±	3.80	3.18	2.99
CD (P=0.05)	10.91	9.18	8.59
CV	2.29	1.93	2.08

and while the lowest under the control giving 240.56 kg ha^{-1}. Similarly, during the second year (2013), the highest available nitrogen was recorded in T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) as 324.11 kg ha^{-1} which was at par with the treatment T_{17} (316.95 kg ha^{-1}) and the lowest in T_1 (control) as 228.53 kg ha^{-1}.

Further analysis from the pooled data revealed that the maximum available N (327.69 kg ha^{-1}) was also obtained from 5 ton FYM + Biofertilizer + Lime + 100% NPK while control recorded the minimum available N (234.55 kg ha^{-1}).

4.2.2. Available P (kg ha^{-1})

Available Phosphorus content in soil as affected by different treatments are presented in Table 5 (b) and Fig. 3 (b). Data on available P content of soil showed that different treatments significantly influenced the available P content of the soil. Initial available P content of the soil as recorded in 2012 was very low as (8.20 kg ha^{-1}). Available P content of the soil ranged from 10.90 to 21.46 kg ha^{-1}, with the highest value of 21.46 kg ha^{-1} recorded in the treatment T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) which was followed by T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 19.04 kg ha^{-1}. The lowest value 10.90 kg ha^{-1}was recorded under the control.

Similarly, in 2013 the maximum (21.33 kg ha^{-1}) was recorded in T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) followed by T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) with a value of 14.76 kg ha^{-1} and the minimum in T_1 (control) as 9.48 kg ha^{-1}.

Further analysis from the pooled data revealed that the maximum available P (21.39 kg ha^{-1}) was obtained from 5 ton FYM + Biofertilizer + Lime + 100% NPK while control recorded the minimum available P (10.19 kg ha^{-1}).

4.2.3. Available K (kg ha^{-1})

The result presented in the Table 5 (c) and Fig. 3 (c), showed that there was a significant influence of treatments on available K content of soil. Available K content of soil after the harvest of rajmash crop varied from 126.21 to 163.62 kg ha^{-1} (2012) and 120.98 to 160.51 kg ha^{-1} (2013) over the initial value of 128.5 kg ha^{-1}.

In 2012, the highest amount of available K was recorded in the treatment T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) with 163.62 kg ha^{-1} and was found to be at par with treatments T_{14} (157.46 kg ha^{-1}), T_{15} (158.43 kg ha^{-1}) and T_{17} (160.21 kg ha^{-1}),

Table 5 (b): Effect of Integrated nutrient management on soil available P after the harvest of rajmash.

Treatment	Available P (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	10.90	9.48	10.19
T_2- 50% NPK	13.20	10.97	12.09
T_3- 100% NPK	14.78	11.50	13.14
T_4- Biofertilizer	12.92	10.82	11.87
T_5 -Biofertilizer + 50% NPK	13.87	12.05	12.96
T_6- Biofertilizer + 100% NPK	14.27	12.62	13.44
T_7- Biofertilizer + Lime	13.34	11.96	12.65
T_8-Biofertilizer + Lime + 50% NPK	14.00	12.84	13.42
T_9- Biofertilizer + Lime + 100% NPK	14.68	12.93	13.81
T_{10} – 5 ton FYM	13.92	12.02	12.97
T_{11} –5 ton FYM + 50% NPK	15.53	13.28	14.41
T_{12} –5 ton FYM + 100% NPK	16.23	13.86	15.04
T_{13}- 5 ton FYM + Biofertilizer	16.02	12.75	14.38
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	16.08	13.85	14.97
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	17.04	14.07	15.55
T_{16}- 5 ton FYM + Biofertilizer + Lime	16.04	13.11	14.58
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	19.04	14.76	16.90
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	21.46	21.33	21.39
Initial value	8.20	-	-
SEm±	0.68	0.30	0.35
CD (P=0.05)	1.97	0.86	1.00
CV	7.81	4.00	6.40

Table 5 (c): Effect of Integrated nutrient management on soil available K after the harvest of rajmash.

Treatment	Available K (kg ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	126.21	120.98	123.59
T_{2-} 50% NPK	133.75	130.70	132.23
T_{3-} 100% NPK	149.50	146.38	147.94
T_{4-} Biofertilizer	129.05	127.55	128.30
T_5 -Biofertilizer + 50% NPK	134.92	132.72	133.82
T_{6-} Biofertilizer + 100% NPK	153.18	147.65	150.42
T_{7-} Biofertilizer + Lime	137.62	129.31	133.46
T_{8-}Biofertilizer + Lime + 50% NPK	140.95	135.35	138.15
T_{9-} Biofertilizer + Lime + 100% NPK	152.90	149.14	151.02
T_{10-} 5 ton FYM	138.07	130.88	134.48
T_{11} –5 ton FYM + 50% NPK	154.47	138.42	146.45
T_{12} –5 ton FYM + 100% NPK	156.27	150.91	153.59
T_{13-} 5 ton FYM + Biofertilizer	146.72	135.77	141.25
T_{14-} 5 ton FYM + Biofertilizer + 50% NPK	157.46	141.12	149.29
T_{15-} 5 ton FYM + Biofertilizer + 100% NPK	158.43	153.41	155.92
T_{16-} 5 ton FYM + Biofertilizer + Lime	147.24	136.39	141.82
T_{17-} 5 ton FYM + Biofertilizer + Lime+ 50% NPK	160.21	158.17	159.19
T_{18-} 5 ton FYM + Biofertilizer + Lime+ 100% NPK	163.62	160.51	162.06
Initial value	128.5	-	-
SEm±	2.77	1.49	1.64
CD (P=0.05)	7.96	4.29	4.70
CV	3.27	1.84	2.64

while, the lowest available K content of the soil was observed under control (126.21 kg ha^{-1}) and at par with treatments T_2 (133.75 kg ha^{-1}) and T_4 (149.50 kg ha^{-1}) . Similar trend was observed in 2013 as the highest was observed in T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) giving 160.51 kg ha^{-1} and was observed to be at par with the treatment T_{17} (158.17 kg ha^{-1}) while the lowest available K content of the soil was observed under control (120.98 kg ha^{-1}).

Data from the pooled analysis revealed that the highest available K (162.06 kg ha^{-1}) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) while the lowest (123.59 kg ha^{-1}) was recorded in the treatment T_1 (control).

4.3. Secondary nutrients:

Data on secondary nutrients of the soil *viz*. exchangeable Ca, Mg and available S at the end of the cropping sequence (2012 and 2013) are presented in the Table 6 (a), 6 (b) and 6 (c). Similar to primary nutrients, integrated treatments brought about a significant increase in secondary nutrients of soil over chemical treatments.

4.3.1. Exchangeable Ca and Mg [cmol(p^+)kg^{-1}]

Exchangeable Ca content of the soil varied significantly with respect to treatments. It is observed from the data (Table 6. a) that the exchangeable Ca content in the soil ranged from 1.13 to 1.33 cmol(p^+)kg^{-1} in 2012 and 1.13 to 1.34 cmol(p^+)kg^{-1} in 2013 from the initial value of 1.22 cmol(p^+)kg^{-1} recorded in 2012. Highest exchangeable Ca content of the soil was observed in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving value of 1.33 cmol(p^+)kg^{-1} and it was followed by T_{18}[1.31 cmol(p^+)kg^{-1}], T_{15} and T_{16} as 1.30 cmol(p^+)kg^{-1}. Minimum exchangeable Ca of the soil was observed under control and T_2 giving as low as 1.13 cmol (p^+) kg^{-1}. In 2013, the highest was observed under T_{17} giving a value of 1.34 cmol(p^+)kg^{-1}, followed by T_{16} and T_{18} as 1.32 cmol(p^+)kg^{-1} and T_{15}[1.30 cmol(p^+)kg^{-1}], while the lowest exchangeable Ca content of the soil was observed under the control treatment as1.13 cmol (p^+) kg^{-1} .

From the pooled data of 2012 and 2013, it revealed that the maximum exchangeable Ca as 1.34 cmol (p^+) kg^{-1} was obtained from 5 ton FYM + Biofertilizer + Lime + 100% NPK, while control recorded the minimum 1.13 cmol (p^+) kg^{-1}.

Data on exchangeable Mg showed significant effect with respect to the treatments (Table 6 b). Initial exchangeable Mg content of the soil recorded in 2012 was

Table 6 (a): Effect of Integrated nutrient management on exchangeable Ca of soil after the harvest of rajmash.

Treatment	Exchangeable Ca [cmol(p^+)kg^{-1}]		
	2012	2013	Pooled
T_1- Control	1.13	1.13	1.13
T_2- 50% NPK	1.13	1.14	1.14
T_3- 100% NPK	1.14	1.15	1.15
T_4- Biofertilizer	1.14	1.16	1.15
T_5 -Biofertilizer + 50% NPK	1.15	1.17	1.16
T_6- Biofertilizer + 100% NPK	1.16	1.19	1.18
T_7- Biofertilizer + Lime	1.18	1.20	1.19
T_8-Biofertilizer + Lime + 50% NPK	1.20	1.22	1.21
T_9- Biofertilizer + Lime + 100% NPK	1.21	1.23	1.22
T_{10} – 5 ton FYM	1.22	1.24	1.23
T_{11} –5 ton FYM + 50% NPK	1.24	1.25	1.24
T_{12} –5 ton FYM + 100% NPK	1.26	1.26	1.26
T_{13}- 5 ton FYM + Biofertilizer	1.27	1.28	1.28
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	1.29	1.29	1.29
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	1.30	1.30	1.30
T_{16}- 5 ton FYM + Biofertilizer + Lime	1.30	1.32	1.31
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	1.33	1.34	1.34
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	1.31	1.32	1.32
Initial value	1.22	-	-
SEm±	0.007	0.011	0.007
CD (P=0.05)	0.02	0.03	0.02
CV	0.99	1.59	1.31

0.65 cmol (p^+) kg^{-1}. In 2012, the highest exchangeable Mg 0.72 cmol (p^+) kg^{-1} was recorded under treatment T_{17} followed by T_{16} [0.69 cmol(p^+)kg^{-1}] and T_{12}, T_{13}, T_{14} and T_{15} [0.68 cmol(p^+)kg^{-1}] were at par with each other. The lowest exchangeable Mg was recorded under the control as 0.61 cmol (p^+) kg^{-1}. In 2013, the highest exchangeable Mg was recorded in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving a value of 0.73 cmol (p^+) kg^{-1} followed by T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) as 0.71 cmol (p^+) kg^{-1}, while the lowest exchangeable Mg was recorded in T_1, T_2, and T_3 as 0.61 cmol (p^+) kg^{-1}.

Data from the pooled analysis (2012 and 2013) revealed that the highest exchangeable Mg was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 0.72 cmol (p^+) kg^{-1}while the lowest exchangeable Mg was recorded in the treatment T_1 (control) as 0.61 cmol (p^+) kg^{-1}.

4.3.2. Available S (kg ha^{-1})

A critical examination of the data shows that all the treatments were significantly superior to the control. Data on available S for both the years of experimentation have been presented in Table 6 (c). Available S content of soil in 2012 varied from 14.65 to 22.04 kg ha^{-1} over the initial value of 15.11 kg ha^{-1}. Highest available S (22.04 kg ha^{-1}) was recorded under the treatment T_{17}, followed by T_{18} (22.04 kg ha^{-1}), T_{15} (18.27 kg ha^{-1}) and T_{16} (17.04 kg ha^{-1}), while the lowest (14.65 kg ha^{-1}) was recorded in the control in 2012.

Similarly in 2013, a significant increase was observed in all the treatments. The highest amount of available S was recorded in the treatment T_{17} giving 22.63 kg ha^{-1} followed by the treatments T_{18}, T_{15} and T_{14} (21.37, 20.93 and 20.35 kg ha^{-1} respectively) while the lowest available S content of the soil was observed under control (15.30 kg ha^{-1}) and was statistically at par with the treatments T_2 (15.75 kg ha^{-1}), T_3 (16.06 kg ha^{-1}), T_4 (15.37 kg ha^{-1}), T_5 (15.95 kg ha^{-1}), T_7 (15.65 kg ha^{-1}) and T_8 (16.14 kg ha^{-1}).

From the pooled data, it was apparent that the highest available S (22.34 kg ha^{-1}) in soil after harvest from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and the lowest as (14.98 kg ha^{-1}) in the control plot.

4.4. Micronutrients

Data on micronutrients of the soil *viz*., available Cu, Zn, Fe and Mn are being presented in the Table 7 (a), 7 (b), 7 (c) and 7 (d) and graphically presented in Fig. 4 (a), 4 (b), 4 (c) and 4 (d) respectively.

Table 6 (b): Effect of Integrated nutrient management on exchangeable Mg of soil after the harvest of rajmash.

Treatment	Exchangeable Mg [cmol(p^+)kg^{-1}]		
	2012	2013	Pooled
T_1- Control	0.61	0.61	0.61
T_2- 50% NPK	0.62	0.61	0.62
T_3- 100% NPK	0.62	0.61	0.62
T_4- Biofertilizer	0.63	0.62	0.63
T_5 -Biofertilizer + 50% NPK	0.64	0.63	0.64
T_6- Biofertilizer + 100% NPK	0.65	0.64	0.64
T_7- Biofertilizer + Lime	0.64	0.64	0.64
T_8-Biofertilizer + Lime + 50% NPK	0.66	0.65	0.66
T_9- Biofertilizer + Lime + 100% NPK	0.66	0.66	0.66
T_{10} – 5 ton FYM	0.67	0.67	0.67
T_{11} –5 ton FYM + 50% NPK	0.67	0.67	0.67
T_{12} –5 ton FYM + 100% NPK	0.68	0.68	0.68
T_{13}- 5 ton FYM + Biofertilizer	0.68	0.68	0.68
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.68	0.69	0.68
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.68	0.69	0.69
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.69	0.70	0.69
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.72	0.73	0.72
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.67	0.71	0.69
Initial value	0.65	-	-
SEm±	0.01	0.003	0.004
CD (P=0.05)	0.02	0.01	0.01
CV	1.52	1.06	2.05

Table 6 (c): Effect of integrated nutrient management on soil available S after the harvest of rajmash.

Treatment	Available S (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	14.65	15.30	14.98
T_2- 50% NPK	15.16	15.75	15.46
T_3- 100% NPK	15.72	16.06	15.89
T_4- Biofertilizer	15.39	15.37	15.38
T_5 -Biofertilizer + 50% NPK	15.97	15.95	15.96
T_6- Biofertilizer + 100% NPK	16.10	16.92	16.51
T_7- Biofertilizer + Lime	16.06	15.65	15.86
T_8-Biofertilizer + Lime + 50% NPK	16.43	16.14	16.29
T_9- Biofertilizer + Lime + 100% NPK	16.72	17.05	16.88
T_{10} – 5 ton FYM	16.19	16.89	16.54
T_{11} –5 ton FYM + 50% NPK	16.72	18.32	17.52
T_{12} –5 ton FYM + 100% NPK	16.91	18.81	17.86
T_{13}- 5 ton FYM + Biofertilizer	16.38	17.62	17.00
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	17.31	20.35	18.83
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	18.27	20.93	19.60
T_{16}- 5 ton FYM + Biofertilizer + Lime	17.04	19.66	18.35
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	22.04	22.63	22.34
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	21.52	21.37	21.44
Initial value	15.11	-	-
SEm±	0.24	0.37	0.23
CD (P=0.05)	0.68	1.05	0.67
CV	2.42	3.55	3.03

4.4.1. Available Cu (ppm)

The effect of INM on available Cu content of the soil was significantly influenced by the treatments and presented in Table 7 (a) and Fig. 4 (a). Highest available Cu content was observed under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 0.13 ppm and was found to be at par with 0.12 ppm in T_{18} and 0.11 ppm in T_{14} and T_{15} in 2012, while the lowest available Cu content was recorded under control with 0.05 ppm.

In 2013, the highest available Cu content was observed in the treatment receiving T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 0.12 ppm followed by T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) as 0.11 ppm. While, the lowest available Cu was recorded under T_1 (control) in the second year of experimentation as 0.03 ppm.

Data from the pooled analysis (2012 and 2013) showed that the highest available Cu (0.13 ppm) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK), while the lowest was recorded in the treatment T_1 (control) as 0.04 ppm.

4.4.2. Available Zn (ppm)

Table 7 (b) and Fig. 4 (b) depicted the effect of different treatments on the available Zn content of the soil after the harvest of rajmash crop. In 2012, maximum available Zn content of the soil was observed under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) with a value of 0.63 ppm and was found to be statistically at par with the treatments T_{14} (0.60 ppm), T_{15} and T_{16} (0.61ppm) and T_{18} (0.62 ppm) while the lowest available Zn content was recorded under control treatment (0.20 ppm).

In 2013, the maximum available Zn was recorded as 0.64 ppm under T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and was found to be at par with T_{14} (0.60 ppm), T_{15} (0.62 ppm), T_{16} (0.61 ppm) and T_{18} (0.63 ppm), whereas the lowest available Zn was observed in control treatment and at par with treatment T_2 (0.23ppm).

From the pooled data (2012 and 2013), it was apparent that T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) obtained the highest available Zn (0.64 ppm) in soil after harvest and the lowest as (0.20 ppm) in the control plot.

4.4.3 Available Fe (ppm)

Data presented in Table 7 (c) and Fig. 4 (c), indicated that the effect of different treatments on the available Fe had significant influence. Initial available Fe content of

Table 7 (a): Effect of integrated nutrient management on soil available Cu after the harvest of rajmash.

Treatment	Available Cu (ppm)		
	2012	2013	Pooled
T_1- Control	0.05	0.03	0.04
T_2- 50% NPK	0.06	0.05	0.06
T_3- 100% NPK	0.06	0.06	0.06
T_4- Biofertilizer	0.06	0.07	0.07
T_5 -Biofertilizer + 50% NPK	0.07	0.07	0.07
T_6- Biofertilizer + 100% NPK	0.07	0.08	0.08
T_7- Biofertilizer + Lime	0.08	0.09	0.09
T_8-Biofertilizer + Lime + 50% NPK	0.08	0.10	0.09
T_9- Biofertilizer + Lime + 100% NPK	0.09	0.08	0.09
T_{10} – 5 ton FYM	0.08	0.09	0.09
T_{11} –5 ton FYM + 50% NPK	0.09	0.10	0.09
T_{12} –5 ton FYM + 100% NPK	0.09	0.10	0.10
T_{13}- 5 ton FYM + Biofertilizer	0.09	0.09	0.09
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.10	0.10	0.10
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.11	0.10	0.10
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.11	0.09	0.10
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.13	0.12	0.13
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.12	0.11	0.12
Initial value	0.06	-	-
SEm±	0.01	0.005	0.004
CD (P=0.05)	0.02	0.01	0.01
CV	13.04	7.15	10.39

Table 7 (b): Effect of integrated nutrient management on soil available Zn after the harvest of rajmash.

Treatment	Available Zn (ppm)		
	2012	2013	Pooled
T_1- Control	0.20	0.20	0.20
T_2- 50% NPK	0.23	0.23	0.23
T_3- 100% NPK	0.26	0.29	0.28
T_4- Biofertilizer	0.30	0.37	0.34
T_5 -Biofertilizer + 50% NPK	0.34	0.40	0.37
T_6- Biofertilizer + 100% NPK	0.49	0.49	0.49
T_7- Biofertilizer + Lime	0.51	0.50	0.51
T_8-Biofertilizer + Lime + 50% NPK	0.52	0.51	0.52
T_9- Biofertilizer + Lime + 100% NPK	0.53	0.51	0.52
T_{10} – 5 ton FYM	0.54	0.52	0.53
T_{11} –5 ton FYM + 50% NPK	0.56	0.54	0.55
T_{12} –5 ton FYM + 100% NPK	0.58	0.56	0.57
T_{13}- 5 ton FYM + Biofertilizer	0.59	0.58	0.59
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.60	0.60	0.60
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.61	0.62	0.61
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.61	0.61	0.61
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.63	0.64	0.64
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.62	0.63	0.62
Initial value	0.29	-	-
SEm±	0.01	0.02	0.01
CD (P=0.05)	0.03	0.05	0.03
CV	4.09	6.41	5.31

the soil recorded in 2012 was 4.55 ppm.

In 2012, the highest available Fe content was recorded as 5.96 ppm in T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK) followed by T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) as 5.37 ppm and in 2013, the highest available Fe content was recorded as 6.25 ppm under treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by T_{18} (5.82 ppm). The lowest available Fe (4.20 ppm and 4.22 ppm) were recorded in 2012 and 2013 respectively in treatment T_1 (Control).

Further analysis from the pooled data also revealed that the maximum available Fe (6.11 ppm) was obtained from 5 ton FYM + Biofertilizer + Lime + 100% NPK while control recorded the minimum available Fe (4.21 ppm).

4.4.4. Available Mn (ppm)

The effect of INM on available Mn content of the soil was significantly influenced and are presented in Table 7 (d) and graphically presented in Fig. 4 (d).

The treatment receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK (T_{17}) recorded the highest available Mn content of the soil as 8.14 ppm in 2012 and was statistically found to be at par with the treatments T_{14}, T_{15}, T_{16} and T_{18} (8.09, 8.10, 8.11 and 8.12 ppm respectively), while the lowest available Mn was recorded in control treatment as 6.36 ppm.

In the second year of experimentation (2013), the treatment receiving T_{17} (5 ton FYM, Biofertilizer, Lime and 50% NPK) recorded the highest available Mn content of the soil as 8.13 ppm in 2012 and was statistically found to be at par with the treatments T_{15}, T_{16} and T_{18} (8.09, 8.10 and 8.11 ppm respectively), while the lowest available Mn was recorded in control treatment as 6.36 ppm.

From the pooled data (2012 and 2013), it was evident that the highest available Mn (8.14 ppm) in soil after harvest was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and the lowest as (6.36 ppm) in the control plot.

4.5. Growth, yield attributes and yield

4.5.1. Plant height (cm)

From the perusal of the result presented in Table 8 (a), it showed that the effect of INM had significant effect on the plant height of rajmash recorded at an interval of 30, 60 and 90 days after sowing.

Table 7 (c): Effect of integrated nutrient management on soil available Fe after the harvest of rajmash.

Treatment	Available Fe (ppm)		
	2012	2013	Pooled
T_1- Control	4.20	4.22	4.21
T_2- 50% NPK	4.29	4.30	4.30
T_3- 100% NPK	4.33	4.39	4.36
T_4- Biofertilizer	4.42	4.47	4.45
T_5 -Biofertilizer + 50% NPK	4.47	4.51	4.49
T_6- Biofertilizer + 100% NPK	4.52	4.56	4.54
T_7- Biofertilizer + Lime	4.59	4.59	4.59
T_8-Biofertilizer + Lime + 50% NPK	4.62	4.62	4.62
T_9- Biofertilizer + Lime + 100% NPK	4.66	4.67	4.67
T_{10} – 5 ton FYM	4.67	4.70	4.68
T_{11} –5 ton FYM + 50% NPK	4.73	4.75	4.74
T_{12} –5 ton FYM + 100% NPK	4.89	4.83	4.86
T_{13}- 5 ton FYM + Biofertilizer	5.10	5.34	5.05
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	5.24	5.21	5.39
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	5.41	5.39	5.40
T_{16}- 5 ton FYM + Biofertilizer + Lime	5.42	5.55	5.49
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	5.96	6.25	6.11
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	5.37	5.82	5.60
Initial value	4.55	-	-
SEm±	0.15	0.11	0.07
CD (P=0.05)	0.43	0.33	0.21
CV	5.33	4.06	4.66

Table 7 (d): Effect of Integrated nutrient management on soil available Mn after the harvest of rajmash.

Treatment	Available Mn (ppm)		
	2012	2013	Pooled
T_1- Control	6.36	6.36	6.36
T_{2-} 50% NPK	6.64	6.56	6.60
T_{3-} 100% NPK	6.84	6.71	6.78
T_{4-} Biofertilizer	7.09	7.05	7.07
T_5 -Biofertilizer + 50% NPK	7.13	7.11	7.12
T_{6-} Biofertilizer + 100% NPK	7.18	7.16	7.17
T_{7-} Biofertilizer + Lime	7.23	7.23	7.23
T_{8-}Biofertilizer + Lime + 50% NPK	7.30	7.28	7.29
T_{9-} Biofertilizer + Lime + 100% NPK	7.36	7.33	7.35
$T_{10\,-}$ 5 ton FYM	7.39	7.41	7.40
T_{11} –5 ton FYM + 50% NPK	7.60	7.55	7.57
T_{12} –5 ton FYM + 100% NPK	7.87	7.77	7.82
T_{13-} 5 ton FYM + Biofertilizer	8.06	7.91	7.99
T_{14-} 5 ton FYM + Biofertilizer + 50% NPK	8.09	8.06	8.08
T_{15-} 5 ton FYM + Biofertilizer + 100% NPK	8.10	8.09	8.10
T_{16-} 5 ton FYM + Biofertilizer + Lime	8.11	8.10	8.10
T_{17-} 5 ton FYM + Biofertilizer + Lime+ 50% NPK	8.14	8.13	8.14
T_{18-} 5 ton FYM + Biofertilizer + Lime+ 100% NPK	8.12	8.11	8.12
Initial value	7.35	-	-
SEm±	0.02	0.01	0.01
CD (P=0.05)	0.06	0.04	0.03
CV	0.52	0.31	0.42

At 30 DAS, it was apparent that the plant height increased at all stages of the growth with different treatments of INM. The maximum plant height was recorded from treatment T_{17} with 17.94cm (2012) followed by treatment T_{18} (17.23 cm) and the lowest being recorded under control as 9.69 cm. During the second year of experimentation, the highest plant height was found in the INM treated plot as 17.68 cm in T_{17} (5 ton FYM, Biofertilizer, Lime and 50% NPK) and the lowest being observed under control treatment as 9.68 cm. Results from the pooled data of 2012 and 2013, showed that highest plant height (17.81 cm) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Minimum plant height (9.69 cm) was recorded from control.

At 60 DAS, variations in plant height were observed to be significant with the control plot and the lowest plant height was recorded from control plot as 19.59cm (2012) and 16.93 cm (2013). It was found that the highest rate of increase in plant height in 2012 was recorded with the INM treated plot as 33.09 cm followed by treatment T_{18} (32.27 cm) and in 2013 as 32.18 cm under treatment T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK). From the pooled data of 2012 and 2013, highest plant height (32.64 cm) was observed in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Minimum plant height (18.26 cm) was recorded from control.

At 90 DAS, treatment T_{17} showed the highest plant height as 38.47cm in 2012 and 41.59 cm in 2013 while the control plot recorded the minimum i.e 25.33 cm (2012) and 24.24 cm (2013). From the pooled data (2012 and 2013), it was apparent that T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) obtained the highest plant height (40.03 cm) in soil after harvest and the lowest as (24.78 cm) in the control plot. Results from the pooled data of 2012 and 2013, showed that highest plant height (17.81 cm) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Minimum plant height (9.69 cm) was recorded from control.

4.5.2. Number of branches per plant

Results of the influence of INM on number of branches per plant at 30, 60 and 90 DAS are presented in Table 8 (b).

Highest number of branches per plant was recorded from treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) with 5.17 which was at par with the treatment

T_{18} as 4.93 and the lowest being recorded under control treatment as 3.00 in the first year of experimentation. In 2013, the highest number of branches per plant was recorded from treatment T_{18} with 5.77 which was at par with the treatment T_{17} as 5.30,

Table 8 (a): Effect of integrated nutrient management on plant height (cm) of rajmash.

Treatment	30 DAS			60 DAS			90 DAS		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1- Control	9.69	9.68	9.69	19.59	16.93	18.26	25.33	24.24	24.78
T_2- 50% NPK	11.28	10.05	10.66	20.10	19.12	19.61	26.50	25.27	25.89
T_3- 100% NPK	11.52	10.57	11.04	20.84	20.11	20.48	27.93	27.62	27.78
T_4- Biofertilizer	11.51	11.18	11.35	21.52	20.80	21.16	28.65	28.54	28.60
T_5 -Biofertilizer + 50% NPK	12.29	11.67	11.98	22.62	21.60	22.11	29.02	29.06	29.04
T_6- Biofertilizer + 100% NPK	12.63	12.51	12.57	23.55	22.56	23.05	30.31	30.14	30.23
T_7- Biofertilizer + Lime	12.94	13.12	13.03	23.45	22.79	23.12	30.75	30.90	30.83
T_8-Biofertilizer + Lime + 50% NPK	13.41	13.98	13.70	24.11	23.52	23.82	32.63	32.20	32.42
T_9- Biofertilizer + Lime + 100% NPK	13.41	14.58	14.00	24.57	24.48	24.53	33.04	33.70	33.37
T_{10} – 5 ton FYM	14.59	14.74	14.66	25.10	25.42	25.26	33.87	34.13	34.00
T_{11} –5 ton FYM + 50% NPK	15.25	15.12	15.19	25.74	25.46	25.60	34.27	35.34	34.81
T_{12} –5 ton FYM + 100% NPK	15.83	15.61	15.72	26.41	26.37	26.39	34.73	35.68	35.21
T_{13}- 5 ton FYM + Biofertilizer	15.95	16.05	16.00	27.43	26.61	27.02	35.48	36.49	35.99
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	16.53	15.99	16.26	28.72	27.48	28.10	36.35	37.66	37.00
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	16.37	16.40	16.38	29.24	28.27	28.76	36.60	39.09	37.85
T_{16}- 5 ton FYM + Biofertilizer + Lime	16.57	17.21	16.89	29.71	28.75	29.23	36.96	39.66	38.31
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	17.94	17.68	17.81	33.09	32.18	32.64	38.47	41.59	40.03

T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	17.23	17.40	17.31	32.27	30.07	31.17	37.43	40.08	38.76
SEm±	0.20	0.24	0.15	0.40	0.55	0.38	0.32	0.58	0.34
CD (P=0.05)	0.59	0.70	0.42	1.16	1.59	1.10	0.91	1.67	0.98
CV	2.50	2.98	2.71	2.75	3.89	3.30	1.68	3.01	2.41

while the lowest was recorded under control treatment as 2.73. An analysis of the pooled data of 2012 and 2013 showed treatment T_{17} receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK obtained the maximum number of branches per plant (5.35) while control treatment (T_1) obtained minimum branches per plant (2.87).

At 60 DAS, numbers of branches per plant were observed to be significant and the minimum number of branches per plant was recorded from control plot and T_3 as 3.27 in 2012 and in 2013 under control as 3.17. The maximum number of branches per plant was recorded in 2012 as 5.53 and in 2013 as 5.47 in T_{17}. From the pooled data of 2012 and 2013, highest number of branches per plant (5.50) was observed in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK), while minimum number of branches per plant (13.22) was recorded from control.

At 90 DAS, the maximum number of branches per plant was observed as 5.38 under the treatment T_{15} (5 ton FYM + Biofertilizer + 100% NPK) and was found to be statistically at par with the treatments $T_{14,}$ T_{16} and T_{17} (5.20, 5.10 and 5.10) respectively in 2012 and in 2013 maximum number of branches per plant recorded as 5.33 under treatment T_{13} followed by T_{16}. The lowest number of branches per plant was recorded as 3.17 in both the years of experimentation. Results from the pooled data, showed that highest number of branches per plant (5.17) was recorded in T_{15} (5 ton FYM + Biofertilizer + Lime). Minimum number of branches per plant (3.24) was recorded from control plot.

4.5.3. Number of nodules per plant

Number of nodules per plant at 45 days for both the years is presented in Table 8 (c). The data clearly indicated that there was a significant effect of different treatments of INM in the number of nodules per plant. It was observed that the maximum number of nodules per plant was recorded under treatment T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK) in 2012 as 70 followed by T_{16} (63.38) and in 2013 as 79.28. The minimum number of nodules per plant was recorded under control in 2012 was 28.13 and in 2013 as 30.45 and was at par with the treatments T_2 (33.56) and T_3 (33.62).

Data from the pooled analysis showed that the highest number of nodules per plant (74.64) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by T_{16} (65.96), while the lowest (29.29) was recorded in the treatment T_1 (control).

Table 8 (b): Effect of integrated nutrient management on number of branches per plant of rajmash.

Treatment	30 DAS			60 DAS			90 DAS		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1- Control	3.00	2.73	2.87	3.27	3.17	3.22	3.31	3.17	3.24
T_2- 50% NPK	3.07	2.87	2.97	3.33	3.23	3.28	3.41	3.23	3.32
T_3- 100% NPK	2.80	2.97	2.88	3.27	3.37	3.32	3.26	3.57	3.41
T_4- Biofertilizer	3.27	3.33	3.30	3.33	3.47	3.40	3.17	3.43	3.30
T_5 -Biofertilizer + 50% NPK	3.40	3.47	3.43	3.67	3.90	3.78	3.64	3.60	3.62
T_6- Biofertilizer + 100% NPK	3.53	3.57	3.55	4.17	4.23	4.20	4.19	4.13	4.16
T_7- Biofertilizer + Lime	3.60	3.63	3.62	4.10	4.53	4.32	4.37	4.10	4.23
T_8-Biofertilizer + Lime + 50% NPK	3.73	3.73	3.73	4.40	4.37	4.38	4.37	4.40	4.38
T_9- Biofertilizer + Lime + 100% NPK	3.80	3.87	3.83	4.23	4.77	4.50	4.47	4.23	4.35
T_{10} – 5 ton FYM	3.87	3.93	3.90	4.13	4.50	4.32	4.56	4.50	4.53
T_{11} –5 ton FYM + 50% NPK	4.07	4.23	4.15	4.27	4.67	4.47	4.40	4.20	4.30
T_{12} –5 ton FYM + 100% NPK	4.20	4.50	4.35	4.30	5.03	4.67	4.37	5.00	4.68
T_{13}- 5 ton FYM + Biofertilizer	4.33	4.47	4.40	4.67	4.97	4.82	4.67	5.33	5.00
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	4.53	4.67	4.60	4.67	4.77	4.72	5.20	5.10	5.15
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	4.73	4.77	4.75	5.13	5.27	5.20	5.38	4.97	5.17
T_{16}- 5 ton FYM + Biofertilizer + Lime	4.77	4.87	4.82	4.93	5.27	5.10	5.10	5.20	5.15
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	5.17	5.30	5.23	5.53	5.47	5.50	5.10	5.17	5.13

T_{18}- 5 ton FYM + Biofertilizer + Lme+ 100% NPK	4.93	5.77	5.35	5.20	4.87	5.03	4.57	4.63	4.60
SEm±	0.11	0.24	0.10	0.15	0.08	0.07	0.13	0.12	0.09
CD (P=0.05)	0.32	0.68	0.30	0.43	0.24	0.21	0.39	0.34	0.26
CV	4.95	10.17	7.94	6.03	3.22	4.71	5.43	4.75	5.02

Table 8 (c): Effect of integrated nutrient management on number of nodules per plant of rajmash.

Treatment	Number of nodules per plant		
	2012	2013	Pooled
T_1- Control	28.13	30.45	29.29
T_2- 50% NPK	29.80	33.56	31.68
T_3- 100% NPK	33.47	33.62	33.55
T_4- Biofertilizer	34.20	37.25	35.73
T_5 –Biofertilizer + 50% NPK	40.00	39.83	39.92
T_6- Biofertilizer + 100% NPK	42.73	40.45	41.59
T_7- Biofertilizer + Lime	43.07	44.19	43.63
T_8-Biofertilizer + Lime + 50% NPK	47.67	47.69	47.68
T_9- Biofertilizer + Lime + 100% NPK	44.80	46.34	45.57
T_{10} – 5 ton FYM	46.53	48.00	47.27
T_{11} –5 ton FYM + 50% NPK	51.13	53.24	52.19
T_{12} –5 ton FYM + 100% NPK	52.47	54.48	53.48
T_{13}- 5 ton FYM + Biofertilizer	51.60	56.61	54.10
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	51.67	61.50	56.58
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	53.60	65.29	59.45
T_{16}- 5 ton FYM + Biofertilizer + Lime	63.33	68.59	65.96
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	70.00	79.28	74.64
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	55.93	73.16	64.55
Sem±	1.29	1.11	0.80
CD (P=0.05)	3.72	3.18	2.31

CV	4.80	3.77	4.22

4.5.4. Fresh and dry weight of nodules (mg plant^{-1})

The result presented in the Table 8 (d) and 8 (e) depicted the results of fresh and dry weight of nodules at 45 DAS for both the years of experimentation (2012 and 2013). It was evident from the data that there was significant effect in all the treatments.

The highest fresh weight of nodules was observed in treatment T_{17} (99.87 mg plant^{-1}) and it was statistically found to be at par with the treatment T_{16} (96.60 mg plant^{-1}) in 2012 and in 2013 as 115.76 mg plant^{-1}. While, the lowest fresh weight of nodules was recorded under control treatment as 47.53 mg plant^{-1} (2012) and 47.72 mg plant^{-1} (2013). From the pool data, highest fresh weight of nodules was also recorded under treatment T_{17} with a value of 107.82 mg plant^{-1} and the lowest as 47.63 mg plant^{-1} under control (Table 8 d).

Similar trend was recorded in dry weight of nodules per plant (Table 8 d) as the highest was observed in T_{17} (74.13 mg plant^{-1} in 2012 and 77.61 mg plant^{-1} in 2013) for the years and the lowest under control as 32.07 mg plant^{-1} (2012) and 35.99 mg plant^{-1} (2013).

Results from the pooled data, showed that highest dry weight of nodules per plant (75.87 mg plant^{-1}) was recorded in T_{15} (5 ton FYM + Biofertilizer + Lime), while the minimum was recorded from control plot with 34.03 mg plant^{-1} (Table 8 e).

4.5.5 Number of pods per plant and pod length (cm)

Observations recorded on number of pods per plant have been presented in Table 9 (a). The data reveals that application of chemical and organic fertilizer had significant influence on the number of pods per plant. The highest was recorded in treatment T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK) giving a value of 8.40 (2012) followed by T_{16} (7.77) and in 2013, the highest number of pods per plant was observed as 8.67 under treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by T_{18} (8.13). The lowest number of pods per plant being found under the treatment T_1 (control) as 5.60 (2012) and 5.50 (2013) respectively. Data from the pooled analysis showed that the highest number of pods per plant (8.53) was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK), while the lowest (5.55) was recorded in the treatment T_1 (control).

From the Table 9 (b), it was observed that there was significant effect of INM on the length of pod. During the first year of experimentation (2012), the highest

Table 8 (d): Effect of integrated nutrient management on fresh weight of nodules per plant of rajmash.

Treatment	Fresh weight of nodules (mg plant^{-1})		
	2012	2013	Pooled
T_1- Control	47.53	47.72	47.63
T_2- 50% NPK	50.87	53.10	51.98
T_3- 100% NPK	56.40	57.52	56.96
T_4- Biofertilizer	54.73	60.38	57.56
T_5 –Biofertilizer + 50% NPK	63.20	61.67	62.43
T_6- Biofertilizer + 100% NPK	64.93	64.16	64.55
T_7- Biofertilizer + Lime	68.23	67.89	68.06
T_8-Biofertilizer + Lime + 50% NPK	77.07	73.21	75.14
T_9- Biofertilizer + Lime + 100% NPK	77.53	73.30	75.42
T_{10} – 5 ton FYM	76.10	84.25	80.17
T_{11} –5 ton FYM + 50% NPK	77.53	79.40	78.47
T_{12} –5 ton FYM + 100% NPK	77.67	93.35	85.51
T_{13}- 5 ton FYM + Biofertilizer	82.20	94.58	88.39
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	80.47	97.26	88.87
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	85.93	98.20	92.07
T_{16}- 5 ton FYM + Biofertilizer + Lime	96.60	98.99	97.80
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	99.87	115.76	107.82
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	89.20	107.16	98.18

Sem±	1.78	2.13	1.29
CD (P=0.05)	5.11	6.11	3.71
CV	4.18	4.64	4.37

Table 8 (e): Effect of integrated nutrient management on dry weight of nodules per plant of rajmash.

Treatment	Dry weight of nodules (mg plant^{-1})		
	2012	2013	Pooled
T_1- Control	32.07	35.99	34.03
T_2- 50% NPK	34.20	39.91	37.05
T_3- 100% NPK	35.33	45.32	40.33
T_4- Biofertilizer	43.67	49.80	46.73
T_5 -Biofertilizer + 50% NPK	37.60	49.33	43.47
T_6- Biofertilizer + 100% NPK	39.67	53.56	46.61
T_7- Biofertilizer + Lime	42.47	54.10	48.29
T_8-Biofertilizer + Lime + 50% NPK	48.00	55.86	51.93
T_9- Biofertilizer + Lime + 100% NPK	51.87	57.99	54.93
T_{10} – 5 ton FYM	53.33	59.85	56.59
T_{11} –5 ton FYM + 50% NPK	53.33	62.34	57.84
T_{12} –5 ton FYM + 100% NPK	51.47	63.33	57.40
T_{13}- 5 ton FYM + Biofertilizer	55.33	66.65	60.99
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	55.60	68.85	62.22
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	63.53	68.48	66.01
T_{16}- 5 ton FYM + Biofertilizer + Lime	64.90	71.54	68.22
T_{17}- 5 ton FYM + Biofertilizer + Lime+	74.13	77.61	75.87

50% NPK			
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	61.33	74.69	68.01
SEm±	1.16	1.24	0.78
CD (P=0.05)	3.33	3.56	2.25
CV	4.02	3.66	3.77

Table 9 (a): Effect of integrated nutrient management on number of pods per plant of rajmash.

Treatment	Number of pods per plant		
	2012	**2013**	**Pooled**
T_1- Control	5.60	5.50	5.55
T_2- 50% NPK	5.80	5.80	5.80
T_3- 100% NPK	5.87	5.80	5.83
T_4- Biofertilizer	6.13	6.00	6.07
T_5 –Biofertilizer + 50% NPK	6.27	6.43	6.35
T_6- Biofertilizer + 100% NPK	6.47	6.53	6.50
T_7- Biofertilizer + Lime	6.83	6.93	6.88
T_8-Biofertilizer + Lime + 50% NPK	7.27	7.43	7.35
T_9- Biofertilizer + Lime + 100% NPK	7.30	7.30	7.30
T_{10} – 5 ton FYM	7.27	7.30	7.28
T_{11} –5 ton FYM + 50% NPK	7.47	7.60	7.53
T_{12} –5 ton FYM + 100% NPK	7.33	7.37	7.35
T_{13}- 5 ton FYM + Biofertilizer	7.40	7.70	7.55
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	7.73	7.80	7.77
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	7.47	8.10	7.78
T_{16}- 5 ton FYM + Biofertilizer + Lime	7.77	8.00	7.88
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	8.40	8.67	8.53
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	7.67	8.13	7.90
SEm±	0.11	0.14	0.10

CD (P=0.05)	0.33	0.39	0.28
CV	2.82	3.29	3.03

Table 9 (b): Effect of integrated nutrient management on pod length of rajmash.

Treatment	Pod length (cm)		
	2012	2013	Pooled
T_1- Control	13.33	14.26	13.80
T_2- 50% NPK	13.72	14.49	14.10
T_3- 100% NPK	14.11	14.74	14.42
T_4- Biofertilizer	14.37	14.88	14.62
T_5 –Biofertilizer + 50% NPK	14.70	15.06	14.88
T_6- Biofertilizer + 100% NPK	15.15	15.35	15.25
T_7- Biofertilizer + Lime	15.45	15.49	15.47
T_8-Biofertilizer + Lime + 50% NPK	15.81	15.95	15.88
T_9- Biofertilizer + Lime + 100% NPK	16.78	16.20	16.49
T_{10} – 5 ton FYM	16.37	16.73	16.55
T_{11} –5 ton FYM + 50% NPK	16.85	16.57	16.71
T_{12} –5 ton FYM + 100% NPK	16.15	17.28	16.71
T_{13}- 5 ton FYM + Biofertilizer	17.44	17.12	17.28
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	16.73	18.53	17.63
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	17.39	16.22	16.81
T_{16}- 5 ton FYM + Biofertilizer + Lime	16.76	16.99	16.88
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	17.59	17.41	17.50
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	16.75	16.99	16.87
Sem±	0.20	0.18	0.15

CD (P=0.05)	0.58	0.52	0.43
CV	2.19	1.94	2.04

pod length was recorded as 17.59 cm in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by treatment T_{13} (17.44 cm) and T_{15} (17.39 cm) and the lowest was found in control (13.33 cm). Highest pod length for the second year (2013) was obtained in treatment T_{14} as 18.53 cm followed by T_{17} (17.41 cm) and T_{13} (17.28 cm), while the lowest being recorded under control as 14.26 cm. Data from the pooled analysis (2012 and 2013), showed that the maximum pod length (17.63 cm) was recorded in the treatment T_{14} (5 ton FYM + Biofertilizer + 50% NPK).

4.5.6. Number of seeds per pod

Observations recorded on number of seed per pods have been presented in Table 9 (c). The influence of different treatments of INM had significant effect on the number of seeds per pod. It was found that the highest number of seed per pod was recorded in T_{17} treatment giving the value of 6.85 and was at par with the treatments T_{16} (6.65) and T_{18} (6.84) in 2012 and in the second year of experimentation (2013), the highest was recorded in T_{17} treatment as 6.90 followed by T_{16} (6.70), while the lowest in both the years was found under control as 4.27 (2012) and 4.60 (2013) respectively.

From the pooled data, it was also apparent that T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) obtained the highest number of seeds per pod (6.88) after harvest and the lowest from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and the lowest under control plot as 4.43.

4.5.7. Test weight (g)

A critical examination of the data pertaining to the effect of different treatments of INM on test weight as shown in Table 9 (d) recorded that T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) recorded the highest test weight in rajmash in both the years of experimentation with a value of 47.92g (2012) and 48.75g (2013) and the lowest test weight (43.23g and 43.33g during 2012 and 2013 respectively) under control treatment.

Data from the pooled analysis showed that the maximum test weight (48.33g) was recorded in the treatment T_{17} and the lowest recorded as 43.28g in control.

4.5.8. Grain Yield (q ha^{-1})

It is evident from the data presented in Table 9 (e) and Fig. 5, that the grain yield of rajmash was found to be higher in 1st year as compared to 2nd year and affected significantly due to effect of different treatments of INM.

Table 9 (c): Effect of integrated nutrient management on number of seeds per pod of rajmash.

Treatment	Number of seeds per pod		
	2012	2013	Pooled
T_1- Control	4.27	4.60	4.43
T_{2}- 50% NPK	4.33	4.73	4.53
T_{3}- 100% NPK	4.60	4.70	4.65
T_{4}- Biofertilizer	4.73	4.87	4.80
T_5 -Biofertilizer + 50% NPK	4.93	5.13	5.03
T_{6}- Biofertilizer + 100% NPK	4.93	5.27	5.10
T_{7}- Biofertilizer + Lime	5.04	5.33	5.19
T_{8}-Biofertilizer + Lime + 50% NPK	5.20	5.57	5.38
T_{9}- Biofertilizer + Lime + 100% NPK	5.33	5.63	5.48
T_{10} – 5 ton FYM	5.40	5.73	5.57
T_{11} –5 ton FYM + 50% NPK	5.56	5.73	5.65
T_{12} –5 ton FYM + 100% NPK	5.82	5.83	5.83
T_{13}- 5 ton FYM + Biofertilizer	6.14	5.87	6.00
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	6.28	5.90	6.09
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	6.40	6.27	6.33
T_{16}- 5 ton FYM + Biofertilizer + Lime	6.65	6.70	6.67
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	6.85	6.90	6.88
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	6.84	6.63	6.74

SEm±	0.07	0.06	0.05
CD (P=0.05)	0.21	0.19	0.14
CV	2.31	1.99	2.12

Table 9 (d): Effect of integrated nutrient management on test weight of rajmash.

Treatment	Test weight(g)		
	2012	**2013**	**Pooled**
T_1- Control	43.23	43.33	43.28
T_{2}- 50% NPK	44.10	43.83	43.97
T_{3}- 100% NPK	44.74	44.50	44.62
T_{4}- Biofertilizer	45.26	45.33	45.30
T_5 –Biofertilizer + 50% NPK	45.45	46.08	45.77
T_{6}- Biofertilizer + 100% NPK	46.10	46.72	46.41
T_{7}- Biofertilizer + Lime	45.93	46.51	46.22
T_{8}-Biofertilizer + Lime + 50% NPK	46.42	46.35	46.39
T_{9}- Biofertilizer + Lime + 100% NPK	46.46	46.60	46.53
T_{10} – 5 ton FYM	46.69	47.15	46.92
T_{11} –5 ton FYM + 50% NPK	46.69	47.09	46.89
T_{12} –5 ton FYM + 100% NPK	46.83	47.54	47.19
T_{13}- 5 ton FYM + Biofertilizer	47.25	47.59	47.42
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	47.25	47.57	47.41
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	46.91	47.75	47.33
T_{16}- 5 ton FYM + Biofertilizer + Lime	47.45	47.96	47.71
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	47.92	48.75	48.33
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	46.37	47.78	47.08

SEm±	0.17	0.36	0.19
CD (P=0.05)	0.49	1.05	0.56
CV	0.64	1.36	1.05

In 2012, the grain yield of the system as a whole ranged from 5.15 to 9.65 q ha^{-1}. The highest grain yield (9.65 q ha^{-1}) was recorded in the treatment T_{17} followed by T_{14} (8.83 q ha$^{-1)}$ and T_{18} (8.45 q ha^{-1}) and the lowest (5.15 q ha^{-1}) under the control.

Whereas in the second year of experimentation (2013), it showed the highest grain yield with 9.58 q ha^{-1} (T_{17}) followed by T_{18} (8.76 q ha^{-1}) and T_{14} (8.68 q ha^{-1}). The lowest grain yield being found under control as 5.22 q ha^{-1}.

Further analysis of the mean pool data of 2012 and 2013 revealed that the maximum grain yield was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) (9.62 q ha^{-1}) which was significantly superior over the rest of the treatments.

4.5.9. Stover yield (q ha^{-1})

Results of the influence of INM on the stover yield are depicted in Table 9 (f) and Fig. 5. Data of both the years of experimentation showed significant influence of the different treatments on the stover yield.

In the first year (2012), 5 ton FYM + Biofertilizer + Lime + 50% NPK increased the stover yield with a maximum of 10.20 q ha^{-1} and was found to be statistically at par with the treatments T_{16} (9.99) and T_{18} (10.10) and the control plot recorded the lowest stover yield with 8.16 q ha^{-1}. A similar trend was recorded for the second year (2013) giving the stover yield as 10.46 q ha^{-1}, while the lowest (8.22 q ha^{-1}) was recorded under the control which was found to be at par with the treatments T_2 (8.28), T_3 (8.32) and T_4 (8.34).

Data from pooled analysis (2012 and 2013) of stover yield of rajmash recorded that the maximum stover yield was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 10.33 q ha^{-1}) and the lowest was recorded under control (8.19 q ha^{-1}).

4.6. Nutrient content in grain and stover of rajmash

Results on the analytical data on the nutrient content in grain and stover of rajmash are presented in the Table 10 (a) to 10 (o).

4.6.1. Nitrogen content and protein content in grain (%)

The results pertaining to the influence of INM on nitrogen content in grain and protein content in grain and stover are presented in Table 10 (a) and 10 (b).The highest nitrogen content in grain was recorded in T_{17} as 3.86% followed by T_{18} (3.77 %) in 2012, while the lowest nitrogen content was recorded under control (2.96 %).

Table 9 (e): Effect of Integrated nutrient management on grain yield of rajmash.

Treatment	Grain yield (q ha^{-1})		
	2012	2013	Pooled
T_1- Control	5.15	5.22	5.19
T_2- 50% NPK	6.64	6.97	6.81
T_3- 100% NPK	7.23	7.25	7.24
T_4- Biofertilizer	6.54	6.54	6.54
T_5 –Biofertilizer + 50% NPK	7.29	7.31	7.30
T_6- Biofertilizer + 100% NPK	7.26	7.61	7.44
T_7- Biofertilizer + Lime	7.09	7.17	7.13
T_8-Biofertilizer + Lime + 50% NPK	8.43	8.38	8.41
T_9- Biofertilizer + Lime + 100% NPK	7.98	7.96	7.97
T_{10} – 5 ton FYM	7.34	7.26	7.30
T_{11} –5 ton FYM + 50% NPK	7.82	7.96	7.89
T_{12} –5 ton FYM + 100% NPK	8.21	8.19	8.20
T_{13}- 5 ton FYM + Biofertilizer	7.34	7.44	7.39
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	8.83	8.68	8.76
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	8.47	8.43	8.45
T_{16}- 5 ton FYM + Biofertilizer + Lime	8.13	8.02	8.08
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	9.65	9.58	9.62
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	8.45	8.76	8.61

SEm±	0.20	0.20	0.09
CD (P=0.05)	0.58	0.56	0.27
CV	4.53	4.38	4.39

Table 9 (f): Effect of integrated nutrient management on stover yield of rajmash.

Treatment	Stover yield (q ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	8.16	8.22	8.19
T_{2}- 50% NPK	8.19	8.28	8.24
T_{3}- 100% NPK	8.23	8.32	8.27
T_{4}- Biofertilizer	8.28	8.34	8.31
T_5 -Biofertilizer + 50% NPK	8.41	8.44	8.42
T_{6}- Biofertilizer + 100% NPK	8.50	8.55	8.53
T_{7}- Biofertilizer + Lime	8.63	8.62	8.63
T_{8}-Biofertilizer + Lime + 50% NPK	8.72	8.76	8.74
T_{9}- Biofertilizer + Lime + 100% NPK	8.78	8.82	8.80
T_{10} – 5 ton FYM	8.90	8.90	8.90
T_{11} –5 ton FYM + 50% NPK	9.18	9.04	9.11
T_{12} –5 ton FYM + 100% NPK	9.37	9.18	9.28
T_{13}- 5 ton FYM + Biofertilizer	9.61	9.47	9.54
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	9.61	9.71	9.66
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	9.82	9.90	9.86
T_{16}- 5 ton FYM + Biofertilizer + Lime	9.99	10.09	10.04
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	10.20	10.46	10.33

T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	10.10	10.25	10.18
SEm±	0.09	0.05	0.05
CD (P=0.05)	0.26	0.16	0.14
CV	1.57	0.49	1.14

A similar trend was followed in the second year of experimentation (2013) as 3.94 % followed by T_{18} (3.82 %) and the lowest under control as 2.95 %. Analysis from the mean pool data of 2012 and 2013, revealed that the maximum nitrogen content in grain was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) with 3.90 % and the lowest as 2.95 % in control.

It was found that the highest nitrogen content in stover of rajmash was recorded in T_{17} treatment giving the value of 0.68 % and was at par with the treatments T_{16} (0.67 %) and T_{18} (0.67 %) in 2012 and in the second year of experimentation (2013), the highest was recorded in T_{17} treatment with 0.66 % and at par with the treatments $T_{15,}$ T_{16} and T_{18} (0.64, 0.64 and 0.65 % respectively). The lowest in both the years was found under control as 0.51 % (2012) and 0.53 % (2013).

Mean pooled data of 2012 and 2013 showed that the maximum nitrogen content in grain (3.90 %) and stover (0.67 %) was recorded from the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and the minimum was recorded from control as 2.95 % (nitrogen content in grain) and 0.52 % (nitrogen content in stover). Pooled data (2012 and 2013) revealed that the highest protein content in grain was recorded in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 24.38 % while the lowest protein content in grain was recorded in the treatment T_1 (control) as 18.45%.

4.6.2. Phosphorus content (%)

The data in Table 10 (c) and 10 (d) showed the effect of INM on phosphorus content in grain and stover for both the experimentation years. The maximum phosphorus content in grain was found under treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 0.36 % followed by T_{18} (0.34 %) in 2012 and the lowest under control (0.18 %). Similar trend followed in the second year (2013) in grain content with highest in T_{17} as 0.35 % and the lowest under control as 0.17 %. In regards to stover, it was found 0.24 % and 0.25 % during 2012 and 2013 respectively under treatment T_{17} while lowest phosphorus content in stover was found to be 0.10 % and 0.09 % in 2012 and 2013 respectively.

The pooled data of 2012 and 2013 on phosphorus content in grain also revealed similar results. The highest phosphorus content in grain (0.36 %) and stover (0.25 %) was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK and while the lowest phosphorus content in grain and stover was recorded from control plot as 0.18 % and 0.10 % respectively.

Table 10 (a): Effect of integrated nutrient management on N content and protein content in grain of rajmash.

Treatment	N content in grain (%)			Protein content in grain (%)
	2012	2013	Pooled	Pooled
T_1- Control	2.96	2.95	2.95	18.45
T_2- 50% NPK	3.07	3.08	3.07	19.21
T_3- 100% NPK	3.12	3.12	3.12	19.49
T_4- Biofertilizer	3.15	3.13	3.14	19.63
T_5 -Biofertilizer + 50% NPK	3.22	3.19	3.21	20.04
T_6- Biofertilizer + 100% NPK	3.26	3.24	3.25	20.32
T_7- Biofertilizer + Lime	3.34	3.27	3.31	20.66
T_8-Biofertilizer + Lime + 50% NPK	3.37	3.34	3.36	20.99
T_9- Biofertilizer + Lime + 100% NPK	3.43	3.44	3.44	21.48
T_{10} – 5 ton FYM	3.51	3.53	3.52	22.00
T_{11} –5 ton FYM + 50% NPK	3.54	3.61	3.58	22.34
T_{12} –5 ton FYM + 100% NPK	3.62	3.62	3.62	22.64
T_{13}- 5 ton FYM + Biofertilizer	3.67	3.70	3.68	23.01
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	3.73	3.75	3.74	23.38
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	3.75	3.77	3.76	23.50

T_{16}- 5 ton FYM + Biofertilizer + Lime	3.75	3.81	3.78	23.62
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	3.86	3.94	3.90	24.38
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	3.77	3.82	3.79	23.70
SEm±	0.02	0.03	0.017	0.09
CD (P=0.05)	0.05	0.08	0.049	0.27
CV	0.80	1.34	1.09	1.09

Table 10 (b): Effect of integrated nutrient management on N content in stover of rajmash.

Treatment	N content in stover (%)		
	2012	2013	Pooled
T_1- Control	0.51	0.53	0.52
T_2- 50% NPK	0.53	0.54	0.53
T_3- 100% NPK	0.54	0.54	0.54
T_4- Biofertilizer	0.55	0.55	0.55
T_5 -Biofertilizer + 50% NPK	0.56	0.55	0.55
T_6- Biofertilizer + 100% NPK	0.56	0.56	0.56
T_7- Biofertilizer + Lime	0.57	0.57	0.57
T_8-Biofertilizer + Lime + 50% NPK	0.58	0.57	0.58
T_9- Biofertilizer + Lime + 100% NPK	0.58	0.57	0.58
T_{10} – 5 ton FYM	0.59	0.58	0.59
T_{11} –5 ton FYM + 50% NPK	0.61	0.59	0.60
T_{12} –5 ton FYM + 100% NPK	0.62	0.61	0.61
T_{13}- 5 ton FYM + Biofertilizer	0.63	0.62	0.63
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.64	0.63	0.64
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.66	0.64	0.65
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.67	0.65	0.66
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.68	0.66	0.67
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.67	0.64	0.65

SEm±	0.004	0.01	0.004
CD (P=0.05)	0.01	0.02	0.012
CV	1.23	2.21	1.76

Table 10 (c): Effect of integrated nutrient management on P content in grain of rajmash.

Treatment	P content in grain (%)		
	2012	2013	Pooled
T_1- Control	0.18	0.17	0.18
T_{2}- 50% NPK	0.20	0.18	0.19
T_{3}- 100% NPK	0.20	0.19	0.20
T_{4}- Biofertilizer	0.21	0.20	0.21
T_5 -Biofertilizer + 50% NPK	0.22	0.21	0.22
T_{6}- Biofertilizer + 100% NPK	0.23	0.22	0.23
T_{7}- Biofertilizer + Lime	0.23	0.23	0.23
T_{8}-Biofertilizer + Lime + 50% NPK	0.24	0.23	0.24
T_{9}- Biofertilizer + Lime + 100% NPK	0.25	0.24	0.25
T_{10} – 5 ton FYM	0.25	0.25	0.25
T_{11} –5 ton FYM + 50% NPK	0.26	0.25	0.26
T_{12} –5 ton FYM + 100% NPK	0.27	0.27	0.27
T_{13}- 5 ton FYM + Biofertilizer	0.28	0.28	0.28
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.30	0.29	0.30
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.31	0.31	0.31
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.32	0.32	0.32
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.36	0.35	0.36
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.34	0.33	0.34

SEm±	0.01	0.004	0.004
CD (P=0.05)	0.02	0.01	0.011
CV	3.97	2.90	3.44

Table 10 (d): Effect of integrated nutrient management on P content in stover of rajmash.

Treatment	P content in stover (%)		
	2012	2013	Pooled
T_1- Control	0.10	0.09	0.10
T_2- 50% NPK	0.14	0.13	0.13
T_3- 100% NPK	0.14	0.14	0.14
T_4- Biofertilizer	0.15	0.14	0.15
T_5 -Biofertilizer + 50% NPK	0.16	0.16	0.16
T_6- Biofertilizer + 100% NPK	0.17	0.16	0.17
T_7- Biofertilizer + Lime	0.17	0.17	0.17
T_8-Biofertilizer + Lime + 50% NPK	0.17	0.17	0.18
T_9- Biofertilizer + Lime + 100% NPK	0.18	0.18	0.18
T_{10} – 5 ton FYM	0.19	0.18	0.19
T_{11} –5 ton FYM + 50% NPK	0.19	0.20	0.20
T_{12} –5 ton FYM + 100% NPK	0.20	0.20	0.21
T_{13}- 5 ton FYM + Biofertilizer	0.21	0.21	0.21
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	0.22	0.22	0.22
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	0.22	0.23	0.23
T_{16}- 5 ton FYM + Biofertilizer + Lime	0.23	0.23	0.24
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	0.24	0.25	0.25
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	0.22	0.24	0.23

SEm±	0.005	0.007	0.004
CD (P=0.05)	0.01	0.02	0.011
CV	4.44	6.56	5.52

4.6.3. Potassium content (%)

The data revealed that the different treatments of INM had significant effect on the potassium content in grain and stover of rajmash (Table 10 e and 10 f). The highest potassium content (1.27 % both in 2012 and 2013) in grain was recorded under treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) while the lowest was recorded under control as 1.00 % and 0.99 % during 2012 and 2013 respectively.

Potassium content in stover was recorded to be highest in T_{17} as 1.82 % and was found to be statistically at par with T_{16} (1.78 %) and T_{18} (1.80 %) in 2012. The lowest was recorded in control as 1.59 %. Similar trend was recorded in 2013, where the highest potassium content (1.83 %) was found under treatment T_{17} and at par with T_{16} (1.80 %) and T_{18} (1.81 %), while the lowest potassium content in stover was found in control as 1.58 %. Data of the pooled data of the experiment (2012 and 2013) showed that the maximum potassium content in grain (1.27 %) and stover (1.83 %) was recorded from the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and the minimum potassium content in grain and stover was recorded from control as 1.00 % and 1.59 % respectively.

4.7. N, P and K uptake by grain and stover of rajmash and total N, P and K uptake by rajmash

4.7.1 Nitrogen uptake by grain and stover of rajmash and total nitrogen uptake (kg ha^{-1})

Perusal of the data presented in Table 11 (a) and 11 (b), revealed the effect of different treatments of INM on nitrogen uptake by grain and stover of rajmash during both the experimental years.

Application of different treatments influenced nitrogen uptake by rajmash grain significantly with the highest (37.23 and 37.80 kg ha^{-1} during 2012 and 2013 respectively) from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Whereas the minimum nitrogen uptake (15.21 and 15.40 kg ha^{-1} in 2012 and 2013 respectively) was recorded from control. Similarly, the maximum nitrogen uptake by stover was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in both the years as 6.97 kg $ha^{-1}$and 6.94 kg $ha^{-1}$and minimum as 4.19 kg ha^{-1} and 4.33 kg ha^{-1} was recorded from the control plot in 2012 and 2013 respectively. From the pool data, it was also revealed that INM has a significant influence on nitrogen uptake by rajmash grain and stover. The maximum nitrogen uptake by grain (37.52 kg ha^{-1}) and stover (6.96 kg ha^{-1}) was recorded from $T_{17.}$

Table 10 (e): Effect of integrated nutrient management on K content in grain of rajmash.

Treatment	K content in grain (%)		
	2012	2013	Pooled
T_1- Control	1.00	0.99	1.00
T_{2-} 50% NPK	1.04	1.03	1.04
T_{3-} 100% NPK	1.07	1.05	1.06
T_{4-} Biofertilizer	1.09	1.08	1.09
T_5 -Biofertilizer + 50% NPK	1.11	1.10	1.11
T_{6-} Biofertilizer + 100% NPK	1.12	1.12	1.12
T_{7-} Biofertilizer + Lime	1.15	1.13	1.14
T_{8-}Biofertilizer + Lime + 50% NPK	1.16	1.14	1.15
T_{9-} Biofertilizer + Lime + 100% NPK	1.18	1.16	1.17
T_{10} – 5 ton FYM	1.19	1.17	1.18
T_{11} –5 ton FYM + 50% NPK	1.20	1.18	1.19
T_{12} –5 ton FYM + 100% NPK	1.21	1.20	1.21
T_{13-} 5 ton FYM + Biofertilizer	1.23	1.22	1.23
T_{14-} 5 ton FYM + Biofertilizer + 50% NPK	1.24	1.23	1.24
T_{15-} 5 ton FYM + Biofertilizer + 100% NPK	1.25	1.24	1.25
T_{16-} 5 ton FYM + Biofertilizer + Lime	1.24	1.25	1.25

T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	1.27	1.27	1.27
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	1.25	1.26	1.25
SEm±	0.01	0.01	0.008
CD (P=0.05)	0.04	0.02	0.024
CV	1.95	1.27	1.62

Table 10 (f): Effect of integrated nutrient management on K content in stover of rajmash.

Treatment	K content in stover (%)		
	2012	2013	Pooled
T_1- Control	1.59	1.58	1.59
T_2- 50% NPK	1.60	1.59	1.60
T_3- 100% NPK	1.61	1.60	1.60
T_4- Biofertilizer	1.62	1.62	1.62
T_5 -Biofertilizer + 50% NPK	1.63	1.63	1.63
T_6- Biofertilizer + 100% NPK	1.64	1.64	1.64
T_7- Biofertilizer + Lime	1.63	1.64	1.64
T_8-Biofertilizer + Lime + 50% NPK	1.65	1.65	1.65
T_9- Biofertilizer + Lime + 100% NPK	1.66	1.68	1.67
T_{10} – 5 ton FYM	1.68	1.70	1.69
T_{11} –5 ton FYM + 50% NPK	1.70	1.72	1.71
T_{12} –5 ton FYM + 100% NPK	1.71	1.73	1.73
T_{13}- 5 ton FYM + Biofertilizer	1.73	1.75	1.74
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	1.75	1.77	1.76
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	1.77	1.79	1.78
T_{16}- 5 ton FYM + Biofertilizer + Lime	1.78	1.80	1.79

T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	1.82	1.83	1.83
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	1.80	1.81	1.80
SEm±	0.01	0.01	0.011
CD (P=0.05)	0.04	0.02	0.031
CV	1.31	1.08	1.18

Table 11 (a): Effect of integrated nutrient management on N uptake by grain of rajmash.

Treatment	N uptake by grain (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	15.21	15.40	15.31
T_2- 50% NPK	20.37	21.47	20.92
T_3- 100% NPK	22.57	22.60	22.58
T_4- Biofertilizer	20.59	20.48	20.54
T_5 –Biofertilizer + 50% NPK	23.47	23.33	23.40
T_6- Biofertilizer + 100% NPK	23.69	24.67	24.18
T_7- Biofertilizer + Lime	23.69	23.44	23.56
T_8-Biofertilizer + Lime + 50% NPK	28.45	28.02	28.23
T_9- Biofertilizer + Lime + 100% NPK	27.41	27.37	27.39
T_{10} – 5 ton FYM	25.75	25.65	25.70
T_{11} –5 ton FYM + 50% NPK	27.71	28.72	28.22
T_{12} –5 ton FYM + 100% NPK	29.73	29.65	29.69
T_{13}- 5 ton FYM + Biofertilizer	26.91	27.51	27.21
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	32.91	32.59	32.75
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	31.78	31.74	31.76
T_{16}- 5 ton FYM + Biofertilizer + Lime	30.48	30.54	30.51

T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	37.23	37.80	37.52
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	31.81	33.43	32.62
SEm±	0.73	0.72	0.36
CD (P=0.05)	2.11	2.07	1.03
CV	4.76	4.64	4.63

Table 11 (b): Effect of integrated nutrient management on N uptake by stover of rajmash.

Treatment	N uptake by stover (kg ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	4.19	4.33	4.26
T_2- 50% NPK	4.34	4.45	4.39
T_3- 100% NPK	4.44	4.52	4.48
T_4- Biofertilizer	4.56	4.56	4.56
T_5 –Biofertilizer + 50% NPK	4.68	4.64	4.66
T_6- Biofertilizer + 100% NPK	4.76	4.76	4.76
T_7- Biofertilizer + Lime	4.95	4.88	4.92
T_8-Biofertilizer + Lime + 50% NPK	5.06	5.02	5.04
T_9- Biofertilizer + Lime + 100% NPK	5.09	5.03	5.06
T_{10} – 5 ton FYM	5.25	5.16	5.21
T_{11} –5 ton FYM + 50% NPK	5.57	5.34	5.45
T_{12} –5 ton FYM + 100% NPK	5.78	5.57	5.67
T_{13}- 5 ton FYM + Biofertilizer	6.06	5.87	5.96
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	6.18	6.12	6.15
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	6.48	6.37	6.43
T_{16}- 5 ton FYM + Biofertilizer + Lime	6.73	6.56	6.64

T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	6.97	6.94	6.96
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	6.74	6.53	6.63
SEm±	0.10	0.06	0.05
CD (P=0.05)	0.28	0.17	0.15
CV	3.14	1.87	2.57

Data on total N uptake by rajmash have been depicted in Table 11 © and Fig. 6 (a). Total nitrogen uptake at the end of the first year (2012) varied from 19.40 to 44.20 kg ha^{-1}. The highest total N uptake (44.20 kg ha^{-1}) was recorded in the treatment T_{17}. The treatments $T_{14,}$ T_{15}, T_{16} and T_{18} (39.09, 38.27. 37.21 and 38.54 kg ha^{-1}respectively) were found to be at par with each other. The lowest N uptake (19.40 kg ha^{-1}) was recorded under the control. A similar trend was recorded in 2013 in total nitrogen uptake where the highest N uptake (44.75 kg ha^{-1}) was recorded in the treatment T_{17} and the treatments $T_{14,}$ T_{15}, T_{16} and T_{18} (38.71, 38.11, 37.10 and 39.96 kg ha^{-1} respectively) were found to be at par with each other. The lowest N uptake (19.72 kg ha^{-1}) was recorded under the treatment control.

Mean pooled data of the experiment (2012 and 2013) also showed that the maximum total nitrogen uptake by rajmash was recorded as 44.48 kg ha^{-1} from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) and the minimum was recorded from control (19.56 kg ha^{-1}).

4.7.2. Phosphorus uptake by grain and stover of rajmash and total phosphorus uptake (kg ha^{-1})

Table 11(d) and 11 (e) depicted the effect of INM on P uptake by grain and stover of rajmash. Statistically, it was found that application of different level of INM treatments had significant effect on phosphorus uptake. The highest phosphorus uptake by rajmash grain (3.48 and 3.35 kg ha^{-1} in 2012 and 2013 respectively) and rajmash stover (2.48 and 2.62 kg ha^{-1} during 2012 and 2013 respectively) was recorded in the treatment receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK and the lowest under control as 0.93 and 0.87 kg ha^{-1} (N uptake by grain) and 0.79 and 0.77 kg ha^{-1} (N uptake by stover) in 2012 and 2013 respectively. Results from the pool data also revealed that the treatment 5 ton FYM + Biofertilizer + Lime + 50% NPK recorded the maximum phosphorus uptake by grain (3.4 kg ha^{-1}) and stover (2.5 kg ha^{-1}).

Treatment differences in respect of total uptake of P were found to be significant at 5 % level of probability and are being presented in Table 11 (f) and Fig.6 (b). In the first year, the total phosphorus uptake was found to vary from 1.71 to 5.96 kg ha^{-1}. Maximum total phosphorus uptake was observed under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving 5.96 kg ha^{-1} followed by T_{18} (5.11 kg ha^{-1}) and T_{14} (4.96 kg ha^{-1}), while the minimum uptake (1.71 kg ha^{-1}) was recorded under the control. The following year, followed the same trend with the maximum (5.97 kg).

Table 11 (c): Effect of integrated nutrient management on total N uptake by rajmash.

Treatment	Total N uptake (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	19.40	19.72	19.56
T_2- 50% NPK	24.71	25.91	25.31
T_3- 100% NPK	27.01	27.12	27.06
T_4- Biofertilizer	25.14	25.04	25.09
T_5 –Biofertilizer + 50% NPK	28.15	27.97	28.06
T_6- Biofertilizer + 100% NPK	28.45	29.43	28.94
T_7- Biofertilizer + Lime	28.64	28.32	28.48
T_8-Biofertilizer + Lime + 50% NPK	33.50	33.03	33.27
T_9- Biofertilizer + Lime + 100% NPK	32.50	32.40	32.45
T_{10} – 5 ton FYM	31.00	30.81	30.91
T_{11} –5 ton FYM + 50% NPK	33.28	34.05	33.67
T_{12} –5 ton FYM + 100% NPK	35.51	35.22	35.37
T_{13}- 5 ton FYM + Biofertilizer	32.97	33.38	33.18
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	39.09	38.71	38.90
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	38.27	38.11	38.19
T_{16}- 5 ton FYM + Biofertilizer + Lime	37.21	37.10	37.15
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	44.20	44.75	44.48

T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	38.54	39.96	39.25
Sem±	0.72	0.70	0.38
CD (P=0.05)	2.08	2.02	1.08
CV	3.90	3.78	3.78

Table 11 (d): Effect of integrated nutrient management on P uptake by grain of rajmash.

Treatment	P uptake by grain (kg ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	0.93	0.87	0.90
T_2- 50% NPK	1.31	1.23	1.27
T_3- 100% NPK	1.45	1.40	1.43
T_4- Biofertilizer	1.38	1.33	1.36
T_5 –Biofertilizer + 50% NPK	1.60	1.51	1.56
T_6- Biofertilizer + 100% NPK	1.67	1.65	1.66
T_7- Biofertilizer + Lime	1.66	1.62	1.64
T_8-Biofertilizer + Lime + 50% NPK	2.02	1.96	1.99
T_9- Biofertilizer + Lime + 100% NPK	2.00	1.88	1.94
T_{10} – 5 ton FYM	1.84	1.82	1.83
T_{11} –5 ton FYM + 50% NPK	2.06	2.02	2.04
T_{12} –5 ton FYM + 100% NPK	2.24	2.21	2.23
T_{13}- 5 ton FYM + Biofertilizer	2.08	2.06	2.07
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	2.65	2.52	2.58
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	2.62	2.61	2.62
T_{16}- 5 ton FYM + Biofertilizer + Lime	2.63	2.57	2.60
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	3.48	3.35	3.42

T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	2.85	2.89	2.87
Sem±	0.08	0.06	0.04
CD (P=0.05)	0.23	0.18	0.10
CV	6.95	5.51	6.18

Table 11 (e): Effect of integrated nutrient management P uptake by stover of rajmash.

Treatment	P uptake by stover (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	0.79	0.77	0.78
T_2- 50% NPK	1.15	1.05	1.10
T_3- 100% NPK	1.18	1.14	1.16
T_4- Biofertilizer	1.24	1.20	1.22
T_5 –Biofertilizer + 50% NPK	1.35	1.32	1.34
T_6- Biofertilizer + 100% NPK	1.42	1.40	1.41
T_7- Biofertilizer + Lime	1.47	1.44	1.45
T_8-Biofertilizer + Lime + 50% NPK	1.48	1.52	1.51
T_9- Biofertilizer + Lime + 100% NPK	1.58	1.56	1.57
T_{10} – 5 ton FYM	1.69	1.63	1.66
T_{11} –5 ton FYM + 50% NPK	1.77	1.81	1.80
T_{12} –5 ton FYM + 100% NPK	1.91	1.87	1.89
T_{13}- 5 ton FYM + Biofertilizer	2.02	2.02	2.02
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	2.08	2.10	2.10
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	2.19	2.24	2.22
T_{16}- 5 ton FYM + Biofertilizer + Lime	2.33	2.32	2.33
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	2.48	2.62	2.55

T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	2.26	2.43	2.35
Sem±	0.05	0.07	0.04
CD (P=0.05)	0.14	0.21	0.10
CV	5.15	7.39	6.26

Table 11 (f): Effect of integrated nutrient management on total P uptake by rajmash.

Treatment	Total P uptake (kg ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	1.71	1.63	1.68
T_2- 50% NPK	2.45	2.28	2.37
T_3- 100% NPK	2.63	2.54	2.59
T_4- Biofertilizer	2.62	2.53	2.57
T_5 –Biofertilizer + 50% NPK	2.95	2.83	2.89
T_6- Biofertilizer + 100% NPK	3.09	3.05	3.07
T_7- Biofertilizer + Lime	3.12	3.06	3.09
T_8-Biofertilizer + Lime + 50% NPK	3.51	3.48	3.50
T_9- Biofertilizer + Lime + 100% NPK	3.58	3.48	3.53
T_{10} – 5 ton FYM	3.53	3.45	3.49
T_{11} –5 ton FYM + 50% NPK	3.83	3.83	3.83
T_{12} –5 ton FYM + 100% NPK	4.14	4.08	4.12
T_{13}- 5 ton FYM + Biofertilizer	4.10	4.08	4.09
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	4.73	4.62	4.68
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	4.81	4.86	4.84
T_{16}- 5 ton FYM + Biofertilizer + Lime	4.96	4.89	4.93
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	5.96	5.97	5.97

T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	5.11	5.32	5.22
Sem±	0.09	0.07	0.05
CD (P=0.05)	0.25	0.19	0.15
CV	4.10	3.12	3.60

ha^{-1}) total phosphorus uptake under treatment T_{17} while the control treatment recorded the minimum (1.63 kg ha^{-1}).

The pooled data of 2012 and 2013 revealed that the maximum total phosphorus uptake was obtained from the treatment receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK (5.97 kg ha^{-1}), while control recorded the minimum total phosphorus uptake (1.68 kg ha^{-1}).

4.7.3. Potassium uptake by grain and stover of rajmash and total potassium uptake (kg ha^{-1})

The effect of INM on potassium uptake by grain and stover of rajmash for both the experimental years have been depicted in Table 11 (g) and 11 (h). Application of different treatments influenced potassium uptake by rajmash grain significantly with the highest (12.96 and 13.32 kg ha^{-1} during 2012 and 2013 respectively) from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK). Whereas, the minimum potassium uptake by grain (8.13 and 8.16 kg ha^{-1} in 2012 and 2013 respectively) was recorded from control. Similarly, the maximum nitrogen uptake by stover was recorded from T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in both the years with 17.57 kg ha^{-1}and 17.50 kg ha^{-1}and minimum as 8.20 kg ha^{-1} and 8.24 kg ha^{-1} was recorded under the control plot in 2012 and 2013 respectively. From the pool data, it was also observed that the highest potassium uptake by rajmash grain (13.14 kg ha^{-1}) and stover (17.54 kg ha^{-1}) was recorded from $T_{17.}$

Data on total potassium uptake have been depicted for both the experimental years in Table 11 (i) and Fig.6 ©. During the first year (2012), total potassium uptake varied from 16.33-30.53 kg ha^{-1}. Total uptake of potassium was found to be highest under the treatment T_{17} giving a value of 30.53 kg ha^{-1} followed T_{18} (27.80 kg ha^{-1}). The treatments T_{14}, T_{15}, T_{16} and T_{18} (27.40, 27.26, 26.83 and 27.80 kg ha^{-1}) were found to be at par with each other. K uptake was recorded to be lowest (16.33 kg ha^{-1}) under the control. Similar trend was recorded for the consecutive year (2013). In regard to total uptake of K, it was found to be maximum (30.83 kg ha^{-1}) under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by treatment T_{18} (28.76 kg ha^{-1}) while the minimum (16.41 kg ha^{-1}) total K uptake was recorded under the control.

Data of the mean pooled data of the experiment (2012 and 2013) showed that the highest total potassium uptake by rajmash was recorded as 29.49 kg ha^{-1} from T_{17} (5

Table 11 (g): Effect of integrated nutrient management on K uptake by grain of rajmash.

Treatment	K uptake by grain (kg ha^{-1})		
	2012	2013	Pooled
T_1- Control	8.13	8.16	8.15
T_2- 50% NPK	8.55	8.56	8.56
T_3- 100% NPK	8.83	8.73	8.78
T_4- Biofertilizer	9.03	8.98	9.01
T_5 –Biofertilizer + 50% NPK	9.30	9.25	9.28
T_6- Biofertilizer + 100% NPK	9.52	9.57	9.55
T_7- Biofertilizer + Lime	9.93	9.74	9.84
T_8-Biofertilizer + Lime + 50% NPK	10.15	9.98	10.07
T_9- Biofertilizer + Lime + 100% NPK	10.36	10.23	10.30
T_{10} – 5 ton FYM	10.56	10.41	10.48
T_{11} –5 ton FYM + 50% NPK	11.02	10.70	10.87
T_{12} –5 ton FYM + 100% NPK	11.33	11.02	11.18
T_{13}- 5 ton FYM + Biofertilizer	11.79	11.58	11.69
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	11.92	11.94	11.93
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	12.25	12.31	12.28
T_{16}- 5 ton FYM + Biofertilizer + Lime	12.39	12.61	12.50
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	12.96	13.32	13.14
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	12.60	12.92	12.76

Sem±	0.17	0.09	0.10
CD (P=0.05)	0.48	0.25	0.29
CV	2.73	1.42	2.14

Table 11 (h): Effect of integrated nutrient management on K uptake by stover of rajmash.

Treatment	K uptake by stover (kg ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	8.20	8.24	8.22
T_{2}- 50% NPK	10.61	11.11	10.86
T_{3}- 100% NPK	11.62	11.60	11.61
T_{4}- Biofertilizer	10.62	10.63	10.63
T_5 –Biofertilizer + 50% NPK	11.91	11.95	11.93
T_{6}- Biofertilizer + 100% NPK	11.93	12.51	12.22
T_{7}- Biofertilizer + Lime	11.59	11.77	11.68
T_{8}-Biofertilizer + Lime + 50% NPK	13.89	13.80	13.85
T_{9}- Biofertilizer + Lime + 100% NPK	13.24	13.34	13.29
T_{10} – 5 ton FYM	12.31	12.37	12.34
T_{11} –5 ton FYM + 50% NPK	13.30	13.67	13.48
T_{12} –5 ton FYM + 100% NPK	14.03	14.20	14.12
T_{13}- 5 ton FYM + Biofertilizer	12.72	13.01	12.87
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	15.48	15.34	15.41
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	15.01	15.06	15.04
T_{16}- 5 ton FYM + Biofertilizer + Lime	14.44	14.41	14.43
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	17.57	17.50	17.54
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	15.21	15.84	15.53

Sem±	0.36	0.37	0.19
CD (P=0.05)	1.03	1.08	0.55
CV	4.79	4.94	4.79

Table 11 (i): Effect of integrated nutrient management on total K uptake by rajmash.

Treatment	Total K uptake (kg ha^{-1})		
	2012	**2013**	**Pooled**
T_1- Control	16.33	16.41	15.91
T_{2}- 50% NPK	19.15	19.67	18.82
T_{3}- 100% NPK	20.45	20.33	19.77
T_{4}- Biofertilizer	19.65	19.61	18.93
T_5 –Biofertilizer + 50% NPK	21.21	21.20	20.44
T_{6}- Biofertilizer + 100% NPK	21.45	22.08	20.97
T_{7}- Biofertilizer + Lime	21.52	21.51	20.84
T_{8}-Biofertilizer + Lime + 50% NPK	24.04	23.78	23.17
T_{9}- Biofertilizer + Lime + 100% NPK	23.61	23.56	22.82
T_{10} – 5 ton FYM	22.87	22.77	22.00
T_{11} –5 ton FYM + 50% NPK	24.32	24.37	23.45
T_{12} –5 ton FYM + 100% NPK	25.37	25.21	24.36
T_{13}- 5 ton FYM + Biofertilizer	24.51	24.59	23.70
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	27.40	27.28	26.25
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	27.26	27.37	26.15
T_{16}- 5 ton FYM + Biofertilizer + Lime	26.83	27.02	25.88
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	30.53	30.83	29.49
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	27.80	28.76	27.15

Sem±	0.35	0.37	0.24
CD (P=0.05)	1.01	1.06	0.69
CV	2.59	2.71	2.61

Table 12 (a): Effect of integrated nutrient management on cost of cultivation and gross return of rajmash.

Treatment	Cost of cultivation (`ha1)		Gross return (` ha-1)	
	2012	2013	2012	2013
T_1- Control	24000.00	24000.00	53948.00	54666.00
T_{2}- 50% NPK	27564.11	27564.11	68857.00	72184.00
T_{3}- 100% NPK	31128.22	31128.22	74769.00	74996.00
T_{4}- Biofertilizer	24610.00	24610.00	67884.00	67902.00
T_5 -Biofertilizer + 50% NPK	28174.11	28174.11	75423.00	75632.00
T_{6}- Biofertilizer + 100% NPK	31738.22	31738.22	75150.00	78665.00
T_{7}- Biofertilizer + Lime	26970.00	26970.00	73489.00	74286.00
T_{8}-Biofertilizer + Lime + 50% NPK	30534.11	30534.11	86916.00	86428.00
T_{9}- Biofertilizer + Lime + 100% NPK	34098.22	34098.22	82434.00	82246.00
T_{10} – 5 ton FYM	27220.00	27220.00	76070.00	75270.00
T_{11} –5 ton FYM + 50% NPK	30784.11	30784.11	80954.00	82312.00
T_{12} –5 ton FYM + 100% NPK	34348.22	34348.22	84911.00	84654.00
T_{13}- 5 ton FYM + Biofertilizer	27830.00	27830.00	76283.00	77241.00
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	31394.11	31394.11	91183.00	89713.00

T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	34958.22	34958.22	87646.00	87270.00
T_{16}- 5 ton FYM + Biofertilizer + Lime	30190.00	30190.00	84297.00	83227.00
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	33754.11	33754.11	99560.00	98938.00
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	37318.22	37318.22	87530.00	90675.00

Table 12 (b) Effect of integrated nutrient management on net return and B: C ratio of rajmash.

Treatment	Net return (` ha^{-1})		B:C Ratio	
	2012	2013	2012	2013
T_1- Control	29948.00	30666.00	1.25	1.28
T_2- 50% NPK	41292.89	44619.89	1.50	1.62
T_3- 100% NPK	43640.78	43867.78	1.40	1.41
T_4- Biofertilizer	43274.00	43292.00	1.76	1.76
T_5 -Biofertilizer + 50% NPK	47248.89	47457.89	1.68	1.68
T_6- Biofertilizer + 100% NPK	43411.78	46926.78	1.37	1.48
T_7- Biofertilizer + Lime	46519.00	47316.00	1.72	1.75
T_8-Biofertilizer + Lime + 50% NPK	56381.89	55893.89	1.85	1.83
T_9- Biofertilizer + Lime + 100% NPK	48335.78	48147.78	1.42	1.41
T_{10} – 5 ton FYM	48850.00	48050.00	1.79	1.77
T_{11} –5 ton FYM + 50% NPK	50169.89	51527.89	1.63	1.67
T_{12} –5 ton FYM + 100% NPK	50562.78	50305.78	1.47	1.46
T_{13}- 5 ton FYM + Biofertilizer	48453.00	49411.00	1.74	1.78
T_{14}- 5 ton FYM + Biofertilizer + 50% NPK	59788.89	58318.89	1.90	1.86
T_{15}- 5 ton FYM + Biofertilizer + 100% NPK	52687.78	52311.78	1.51	1.50

T_{16}- 5 ton FYM + Biofertilizer + Lime	54107.00	53037.00	1.79	1.76
T_{17}- 5 ton FYM + Biofertilizer + Lime+ 50% NPK	65805.89	65183.89	1.95	1.93
T_{18}- 5 ton FYM + Biofertilizer + Lime+ 100% NPK	50211.78	53356.78	1.35	1.43

ton FYM + Biofertilizer + Lime + 50% NPK) and the minimum was recorded from control (15.91 kg ha^{-1}).

4.8. Economics

Data on productivity and economic of effect of different treatments of INM with regard to grain yield, stover yield, cost of cultivation, gross return, net return, benefit cost ratio are presented in the Table 12 (a) and 12 (b) and Appendix I and II.

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

In both the year, the cost of cultivation was found to vary from `. 24000.00 $ha^{-1}$ to `. 37318.22 ha^{-1}. Highest cost of cultivation was observed under the treatment T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) giving `. 37318.22 $ha^{-1}$ in 2012 and 2013 followed by $T_{15}$, $T_{12}$, and $T_9$ (34958.22, 34348.22 and 34098.22). Lowest cost of cultivation (`. 24000 ha^{-1}) was recorded under the treatment control (T_1).

4.8.2. Gross return (` ha^{-1})

Maximum gross return was obtained under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) for both the years amounting to `. 99560.00 ha^{-1} in

2012 and `. 98938.00 ha$^{-1}$ in 2013 and the least was recorded in $T_1$ treatment as `. 53948.00 ha^{-1} and `. 4666.00 ha^{-1} in 2012 and 2013, respectively.

4.8.3. Net return (` ha^{-1})

The highest net return for the system was obtained under treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving `. 65805.89 ha$^{-1}$ (2012) and `. 65183.89 ha^{-1} (2013), followed by treatment T_{14} giving `. 59788.89 ha$^{-1}$ and Rs. 58318.89 ha$^{-1}$ in 2012 and 2013 respectively. The lowest net return was recorded to be `. 29948.00 ha^{-1} (2012) and `. 30666.00 ha^{-1} (2013) in treatment T_1 (control).

4.8.4. Benefit cost ratio

Maximum benefit cost ratio for the sequence was recorded as `. 1.95 (2012) and `.1.93 (2013) in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by `. 1.90 (2012) and `. 1.86 (2013) under treatment T_{14}. Minimum benefit cost ratio `. 1.25 (2012) and `.1.28 (2013) was obtained under control treatment.

CHAPTER- V

DISCUSSION

Results on the changes in physico-chemical properties, nutrient status of the soil, uptake of nutrients and yield due to "Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of Nagaland" are discussed in this chapter with relevant literature under the following heads.

5.1. Soil physico-chemical properties

5.1.1 Bulk density (Mg m^{-3})

2012 and `. 98938.00 ha$^{-1}$ in 2013 and the least was recorded in $T_1$ treatment as `. 53948.00 ha^{-1} and `. 4666.00 ha^{-1} in 2012 and 2013, respectively.

4.8.3. Net return (` ha^{-1})

The highest net return for the system was obtained under treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving `. 65805.89 ha$^{-1}$ (2012) and `. 65183.89 ha^{-1} (2013), followed by treatment T_{14} giving `. 59788.89 ha$^{-1}$ and Rs. 58318.89 ha$^{-1}$ in 2012 and 2013 respectively. The lowest net return was recorded to be `. 29948.00 ha^{-1} (2012) and `. 30666.00 ha^{-1} (2013) in treatment T_1 (control).

4.8.4. Benefit cost ratio

Maximum benefit cost ratio for the sequence was recorded as `. 1.95 (2012) and `.1.93 (2013) in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) followed by `. 1.90 (2012) and `. 1.86 (2013) under treatment T_{14}. Minimum benefit cost ratio `. 1.25 (2012) and `.1.28 (2013) was obtained under control treatment.

CHAPTER- V

DISCUSSION

Results on the changes in physico-chemical properties, nutrient status of the soil, uptake of nutrients and yield due to "Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of Nagaland" are discussed in this chapter with relevant literature under the following heads.

5.1. Soil physico-chemical properties

5.1.1 Bulk density (Mg m^{-3})

In both the experimental period, bulk density was found to decrease in all the treatments over the initial value (1.42 Mg m^{-3}). Slight decrease in bulk density was found in the treatment receiving both organic and inorganic sources. This may be ascribed to better aggregation, more pore space and due to incorporation of root biomass in the soil as evident from accumulation of organic matter content of the soil and thus reduces bulk density. Similar findings were also observed by Ali *et al*. (1996), Sharma (2000), and Singh *et al*. (2000).

Highest value of 1.41 Mg m^{-3} in 2012 and 1.42 Mg m^{-3} in 2013 was recorded in the control. Bulk density was found to increase slightly in the treatment receiving chemical fertilizers as compared to the treatment receiving both chemical and organic sources. This may be attributed to the deterioration of soil structure by inorganic fertilizers. A similar trend was also observed by Bellaki *et al*. (1998) and Chaphale and Badole (1999).

5.1.2. Particle density (Mg m^{-3})

There was a significant effect of treatments on particle density of the soil. The particle density was found to be highest in control plot as 2.71 Mg m^{-3} in 2012 and 2013. The lowest particle density (2.61 Mg m^{-3}) was found in the treatment receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK in both the experimental period- 2012 and 2013. In all the treatments, the particle density of the soil was found to be in decreasing trend in both the experimental period. This might be due to the fact that with increase in organic matter of the soil, the particle density decreases (Salvi *et al*. 2015).

5.1.3. Porosity (%)

The data in Table 4 (c) showed that the maximum porosity was recorded from treatment receiving 5 ton FYM, Biofertilizer, Lime and 50% NPK in both the experimental period with 51.46 % in 2012 and 51.40 % in 2013. There was a slight increase in the porosity of the soil at the end of both the trial period over the initial value (48.22 % in 2012 and 48.03 % in 2013). Probably, this was due to the increase in organic matter content and better aggregates of the soil which increases the percentage of pore space (Agglides and Londra 2000).

5.1.4. Water holding capacity (%)

The highest water holding capacity (56.89 % in 2012 and 57.71 % in 2013) was observed in treatment receiving both organic and inorganic fertilizers in both the year; this might be due to increase in macro and micro pores by continuous accumulation of organic matter and also due to improvement in the structural condition of the soil which might have increased the available water content of the soil. This result corroborate with the findings of Bharadwaj (1992) and Sharma and Bali (2000) and Walia *et al*. (2010).

5.1.5. Soil pH

There was an increase in the pH of the soil in all treatments after the harvest of rajmash crop in comparison with the initial value (5.12) in both the experimental period. In the integrated treatment plots, pH value was found to be slightly increased over initial value as a result of continuous incorporation and decomposition of organic materials which release basic cations and thus increased the pH. Increase in pH value with application of both organic and inorganic fertilizers was also reported by Prakash *et al*. (2002) and Kisinyo *et al. (*2012). The pH of the control plot as well as in INM treated plots was found to be increased probably due to excretion of bicarbonate hydroxyl ions from the roots in return to the uptake of anions and hydrogen ion from the soil. This is in conformity with the findings of Sarkar *et al*. (2000).

5.1.6. Electrical conductivity (dS m^{-1})

Data presented in Table 4 (f) indicated that the highest EC (0.14 dS m^{-1} in 2012 and 0.13 dS m^{-1} in 2013) was recorded in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) in 2012. The EC of the soil did not show any significant variation compared to initial EC status of the soil before sowing. This might be due to slow chemical changes that occurs in the soil profile and affected by environmental and biological factors. Malewar *et al.* (2000) reported that application of fertilizers and fly ash alone or in combination did not influences electrical conductivity of soil under sunflower and cotton crop. The plots which had received only farmyard manure, recorded more decrease in electrical conductivity which is obviously due to decomposition of organic matter in soil. A similar finding was also observed by Urkurkar *et al*. (2010).

5.1.7. Organic carbon (%)

Integrated application of organics with chemical fertilizers recorded higher values of OC compared to application of chemical fertilizers alone. Integration of organic sources and their subsequent decomposition brought about a significant increase in organic carbon content of the soil. Thus, after the harvest of the crop, the treatments receiving both organic and inorganic fertilizers showed a marked increase in organic carbon content over the initial value (0.58 %) which might be due to direct addition of organic manure in the soil which stimulated the growth and activity of microorganisms and also due to better root growth, resulting in the higher production of biomass, crop stubbles and residues (Pathak *et al*. 2005, Bedi and Dubey 2009 and Moharana *et al.* 2012). The subsequent decomposition of these materials might have resulted in the enhanced carbon content of soil. These results are in agreement with findings of Majumdar *et al.* (2008) and Nayak *et al*. (2012).

Although, organic carbon content was found to decrease in the only chemical treatments which might be due to lesser amount of crop residue accumulation. A similar trend was observed by Bradchalam *et al*. (1996), Yaduvanshi (2001) and Prakash *et al*. (2002).

5.1.8. CEC [cmol (p^+) kg^{-1}]

The highest value was observed in the treatment receiving both organic and inorganic fertilizers in T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving a value of 6.22 cmol $(p^+)kg^{-1}$ in 2012 and 5.81 cmol $(p^+)kg^{-1}$ in 2013. The increase in CEC could be attributed to the improvement in the organic carbon content of soil and also due to formation of humus as a result of decomposition of organic matter which might increase the surface area and developed more negative charge due to dissociation of H ion from functional group. A similar finding was also reported by Bijan *et al*. (1992) and Yagi *et al*. (2003). On the other hand, the CEC of the soil declined in the treatment receiving only chemical fertilizer which might be due to depletion of organic matter content in soil. Such a decline was also reported by Kumar and Yadav (1993) and Basumatary (1995).

5.1.9. Base saturation (%)

The highest per cent base saturation was observed under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as 40.11% in 2012 and in 2013 as 40.41%. The maximum per cent base saturation was found in the treatment receiving both organic and inorganic fertilizers as these organic materials contain different proportion of Ca, Mg, Na and K. During decomposition of these organic sources, these cations get released to the exchange sites and thus contribute to the higher base saturation. These results are in conformity with the findings Basumatary (1995) and Longkumer (2003). There was a slight decrease in the per cent base saturation in the soil at the end of the cropping period in both the experimental years over the initial value. Probably, this was due to the removal of bases from the soil as a result of continuous cropping. Such a declining trend in per cent base saturation was also reported by Basumatary (1995).

5.2. Major nutrient status of soil

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

In general, the available N was found to be higher in the integrated treatments vis-à-vis chemical treatments after the harvest of rajmash crop in both the experimental period (331.26 kg ha^{-1}in 2012 and 324.11 kg ha^{-1}in 2013). This might be due to increase in organic matter content of the soil which undergoes mineralization coupled with hydrolysis of urea creating a favourable condition for residual N balance in soil. Such an increase in available N was also observed by Bhandari *et al*. (1992) and Duraisami *et al.* (2001). Among the different integrated treatments, 5ton FYM+ biofertilizer + lime+ 100% NPK followed by 5ton FYM+ biofertilizer + lime+ 50% NPK showed the highest available nitrogen content in the soil. Though combination of FYM, lime, biofertilizer and inorganic fertilizer revealed better N availability, but this is true in all the INM treatments than that of chemical fertilizer alone. The increase in available N under INM treatments would also be due to the multiplication of soil microbes leading to enhanced conversion of organically bound N into organic forms and rapid mineralization leading to higher available N (Walia *et al*. 2010). Thamaraiselvi *et al*. (2012) and Sharma *et al*. (2013) also observed that available N content in soil increased with the use of recommended dose of fertilizer in combination with manure.

The decreased in available N status in the absolute control treatment may be due to the continual removal of soil N in the absence of external supply of N through fertilizers and manures. These results are in conformity with the findings Chesti *et al*. (2015).

5.2.2. Available phosphorus (kg ha^{-1})

In the integrated treated plots available P content of soil was found to be increase over the initial value which might be due to additional P incorporation through organic sources which released P and thus increased its availability in soil. This result corroborates with the findings of Sharma *et al*. (2008) and Datt *et al*. (2003). During decomposition of organic manure, various organic acids will be produced which solubulize phosphate and other phosphate bearing minerals and thereby lowers the phosphate fixation and increase its availability. Such an increase in available P was also observed by Manna *et al.* (2006) and Vidyavathi *et al*. (2011).

Moreover, the control plot having no fertilizer showed higher available P (10.90 and 9.48 kg ha^{-1} in 2012 and 2013) as compared to initial (8.20 kg ha^{-1}). This is attributed to the fact that the control plot received shoot biomass and considerable amount of root biomass of the crop. During the decomposition of the biomass by microorganisms, unavailable form of native P might have become available to plants. These results are in conformity with the findings Basumatary (1995) and Longkumer (2003).

5.2.3. Available potassium (kg ha^{-1})

There was an increase in available K content of the soil with increasing dose of chemical fertilizers. This might be due to the fact that addition of potassic fertilizers resulted in the increase in the concentration of K in the soil solution which increase the water soluble K content of the soil and to maintain dynamics equilibrium, K in the solution phase proportionately saturated the exchange site of the clay minerals resulting in an increase in exchangeable K in the soil (Tandon and Sekhon 1988). However, the increase in available K under integrated treatments might be due to addition of organic matter that reduced K fixation and released K due to interaction of organic matter with clay, besides the direct K addition to the pool of soil (Urkurkar *et al*. 2010 and Subehia and Sepehya 2012).

5.3. Secondary nutrients

5.3.1. Exchangeable Ca and Mg [cmol(p^+)kg^{-1}]

Results on the status of exchangeable Ca and Mg revealed that the maximum increase was observed in the treatments receiving both organic and inorganic fertilizers. The integrated treatments recorded the highest content of exchangeable Ca (1.33 cmol (p^+)kg^{-1} in 2012 and 1.34 cmol(p^+)kg^{-1} in 2013) and Mg (0.72 cmol(p^+)kg^{-1} in 2012 and

0.73 $cmol(p^+)kg^{-1}$ in 2013).This might be attributed to the addition of lime in the integrated treatments and also might be due to high Ca and Mg content in FYM. Similar result was observed by Basumatary (1995) and Patiram and Singh (1993).

However, at the end of cropping period, there was slight decline in exchangeable Ca and exchangeable Mg content which might be attributed to removal of these cations by the crops due to continuous cropping might be the reason for low recovery of these cations.

5.3.2. Available Sulphur (kg ha^{-1})

Integrated treatments recorded further increase in available S content over the chemical treatments. This might be ascribed to the organic sources which contain S as a constituent element and mineralization of these sources release proportionate amount of sulphate that was adsorbed rapidly by colloidal complex and due to maximum left over of nutrients in the soil due to application of various treatments. Similar results were observed by Kumar *et al*. (2011), Rathod *et al*. (2012) and Kumar *et al*. (2015). Data on available S status of the soil showed an increasing trend with increasing incorporation of chemical fertilizers which could be justified as the result of residual effect of application of single super phosphate and organic matter (Nambiar 1988).

5.4. Micronutrients

The INM treatments with organic manures either increased or retained the critical fertility status of micronutrients. Organic manures on decomposition produce a variety of biochemical substances which stimulate the solubility, transport and availability of micronutrients**.** The increase in organically treated plots might be due to release of chelating agents from organic matter decomposition which might have prevented micronutrients from precipitation, oxidation and leaching (Naidu *et al*. 2009). The available micronutrients were found to increase with increase in CEC of soils due to more availability of exchange sites on soil colloids.

There was reduction in micronutrients contents receiving only inorganic fertilizers. It was attributed to non replenishment of micronutrients through chemical fertilizers. Similar result was observed by Naidu *et al*. (2009).

5.4.1. Available Cu (ppm)

Available Cu content of the soil was recorded highest in the integrated treated plots. It is observed that availability of Cu is influenced by pH, texture, organic carbon, cropping pattern, CEC etc (Patel and Singh, 1995).

Cu availability was decreases when lime is applied and increases when FYM is applied. These findings corroborates with the result of Tandon (2009).

5.4.2. Available Zn (ppm)

The highest available Zn content of the soil was observed in the treatment receiving T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) giving a value of 0.63 ppm in 2012 and 0.64 ppm in 2013. Zn availability increase due to integrated treatment might be due to the complexing agents produce by organic matter and soil high in organic matter temporarily binds Zn in unavailable form through bicarbonates, hydroxides and organic compounds produced by the decomposition of organic waste (Halim *et al*. 2014). The results are in agreement with the findings of Tandon (2009). Halim *et al*. (2014) also reported that availability of Zn was slightly high in the initial soil and also in soil that collected before liming which decreased slightly after lime and the trend of decreased and increased availability of Zn was possibly due to increased pH after liming and decreased pH after application of nitrogenous fertilizer when pH decreased. Similar observation was also reported by Mikkelsen and Camberto (1994).

5.4.3. Available Fe (ppm)

There was increase in Fe availability in integrated treatments, this may be because organic matter hastens soil reduction, forms soluble organic complexes, causes more CO_2 production and brings about faster and greater accumulation of available iron. A similar result was also observed by Tandon (2009).

5.4.4. Available Mn (ppm)

The treatment receiving 5 ton FYM, Biofertilizer, Lime and 50% NPK recorded the highest available Mn content of the soil as 8.14 ppm in 2012 and 8.13 ppm in 2013. The availability of Mn increased with the increased value of soil pH up to below neutrality of soil which might be due to application of lime as liming increases the soil pH which helped the release of non available Mn to available Mn. This finding coincided with the findings of Halim *et al*. (2014).

5.5. Growth attributes

Integration of organic and chemical fertilizer showed higher value of growth parameters which might be due to supply of all the essential mineral nutrients in a balanced amount resulting in better growth and developments of plants (Thirumelai *et al*. 1993 and Kumar *et al*. 2009).

Growth attributes were recorded to be increased in biofertilizer treated plots over the control which might be due to the beneficial effect of biofertilizer in enhancing the nutrient supply to the plant (Chandra *et al*. 1987 and Thakur *et al*. 1999).

5.5.1. Plant height (cm)

The plant height was observed to be highest in the INM treated plot in both the experimental years as compared to control which might be due to the improvement in soil physical condition provided for plant growth and also due to increased availability of nutrients especially N, P_2O_5 and K_2O from the early stages of crop. Phosphorus fertilization improved the root system in French bean which in turn helped more assimilation of nutrients resulting in increased growth. These findings corroborates with the findings of Harendra and Yadav (2006) and Ramana *et al.* (2011). Tripathi *et al.* (2009) also observed that treatment receiving 75% NPK + Rhizobium +PSB recorded the highest plant height (231cm). This favourable effect could be ascribed to beneficial role of Rhizobium in the N nutrition through nodulation and P nutrition through P solubilization by PSB and consequently a better growth or development (Basu *et al*. 2006 and Afzal and Bano 2008).

5.5.2. Number of branches per plant

The maximum number of branches per plant was observed in the integrated plot. The increase in number of branches per plant due to PSB inoculation in the treatment could be due to the conversion of unavailable phosphorus to the available form particularly during the early crop growth phase which would have helped in the absorption of all major and minor nutrients required for the plants to put forth early vigour in vegetative growth. These findings corroborates with the findings of Dubey (1999) in soybean.

5.5.3. Number of nodules per plant

There was a significant effect of different treatments of INM in the number of nodules per plant in both the years of experimentation. These results are in conformity with the findings of Ali (1991). Legume plants help improves nodulation, nitrogen fixation biologically in their root nodules but are known to benefit the subsequent crop (Thompson, 1980). Manure application slightly increased the number of nodules relative to control. This was probably due to the slow mineralization of manure hence slow nitrogen release. In addition, the additional phosphorus present in the manure perhaps resulted in the positive effect of manure on nodulation. Phosphorus and farmyard manure have been reported to improve both the total and active nodules and nodule dry weight (Ganeshamurthy and Sammi-Reddy 2000 and Oteino *et al*. (2009).

5.5.4. Fresh and dry weight of nodules (mg plant^{-1})

The maximum fresh and dry weight of nodules was found in the integrated plot in both the trial period. It is observed higher nodule weight of French bean in integration of organic and nitrogenous fertilizer which might be due to application of organics enhanced microbial activity and application of fertilizer enhanced nutrient mobility and availability and suppressed the microbial activity. These findings corroborates with the result of Datt *et al*. (2013).

5.6. Yield attributes and yield

The yield attributes, namely, pod length, pods per plant, seeds per pod and 100-grain weight increased with the integration of chemical fertilizers and organic sources which might be due to the direct role of nitrogen to seed growth and indirectly help in accommodating osmotic imbalances present during final stage of seed filling of french bean crop (Kushwaha 1994, Dahatonde and Nalawar 1996 and Kumar *et al*. 2009).

The beneficial response of FYM to yield might be attributed to the availability of sufficient amount of plant nutrients throughout the growth period and especially at critical growth periods of crops resulting in better uptake, plant vigour and superior yield attributes (Sunder and Sitarammayya 2000 and Sharma *et al*. 2002).

The co-inoculation of biofertilizers increased the yield parameters like pod yield per plant, pod yield per plot, pod yield per hectare. It is evident that due to better assimilation of photosythates and added biofertilizers might be resulted in the improvement of soil physical, chemical and biological properties, which in turn helped in better nutrient absorption by the plant, resulted in better yield (Deshmukh *et al*. 2014).

5.6.1. Number of pods per plant and pod length (cm)

The data reveals that application of organic and inorganic fertilizer had significant influence on the number of pods per plant and pod length. The controlled plant showed the significantly lowest number of pods plant^{-1} and it might be affected due to changes in soil properties in response to liming. The results are similar to findings of Mustary (2010) and Halim *et al*. (2014).

5.6.2. Number of seeds per pod

The effect of INM had significant influence on the number of seeds per pod. The highest number of seed per pod was in T_{17} treatment giving the value of 6.85 in 2012 and 6.90 in 2013 respectively. Halim *et al*. (2014) found that liming effect on number of seed pod^{-1} was statistically highly significant. The number of seed pod^{-1} of rajmash might be affected due to changes in soil properties in response to liming. The results are in agreement with Sharma *et al*. (2000).

5.6.3. Test weight (g)

Yield attributes viz. pod length, pods per plants, grains per pod and 100 seed weight increased significantly with increased N levels up to 180 kg N ha^{-1} due to direct role of N to seed growth (Singh *et al*. 2006). It was observed that the integrated treatment receiving 5 ton FYM + Biofertilizer + Lime + 50% NPK recorded the highest test weight 47.92g in 2012 and 48.75 g in 2013).This might be due to changes in soil properties because of liming. It appears liming increased soil pH and availability of nutrients which increased the yield components giving higher yields. A similar trend was also observed by Halim *et al.* (2014).

5.6.4. Grain yield (q ha^{-1})

The higher yield under integrated use of organics with NPK fertilizers as compared to the chemical fertilizers alone may be ascribed to balanced use of essential nutrients besides improvement in soil health coupled with higher assimilation of nutrients. This result is in conformity with the findings of Jayakrishnakumar *et al*. (1994) and Kumar *et al*. (2015). Pulse seed treated with specific strains of rhizobium increases the yield through better nodulation and maintenance of organic matter in the soil (Saxena and Tilak 1999). Increase in yield by PSB could be due to the greater availability of nutrients in the soil and better nodulation under the influence of inoculation which might be attributed to better mobilization of phosphorus and increased the allocation of photosynthates towards the economic parts and also due to hormonal balance on the plant system. This finding corroborate with the findings of Menaria and Singh (2004) in soybean and Ramana *et al*. (2011) in cluster bean.

When lime is applied with organic sources, it had profound influence in comparison to inorganic chemical fertilizers and this might have enhanced nutrient transformations and improvement in soil physical properties that attributed to higher crop yields (Ossom and Rhykerd 2008).

5.6.5. Stover yield (q ha^{-1})

Results on the straw yield indicated that there was slight increase in the integrated treated plots. This might be attributed to better utilization of nutrients from the soil that resulted in proper vegetative growth and increased straw yield. The plot receiving 100% NPK applied through inorganic sources of fertilizers also showed a high straw yield which might be due to more vegetative growth resulting from higher dose of applied nitrogenous fertilizers. This corroborates the findings of Arora *et al.* (1991).

It can be seen that the treatment T_{17} was the best for both grain and stover yield. The treatments with organic sources were all superior to the inorganic treatments and the control plot. It can be noticed from the results obtained that the yield attributes which were found to be statistically significant, were better in the treatments receiving both organic and inorganic sources.

5.7. Nutrient content and N, P and K uptake of rajmash

The relationship between total amount of nutrients added through chemical fertilizer and organic sources and the total nutrients removed from these sources was significant with respect to N, P and K. The present investigation had shown a significant increase in the uptake of nutrients (N, P and K) in all the treatments than that of the control. This might be attributed to higher dry matter production as well as nutrient concentration in the treatments, where combine use of organic and inorganic fertilizers was applied. Thus, it appears that organic substitution directly or indirectly influences uptake of nutrients and in greater quantities than found in cases where the nutrient requirements were wholly supplied from inorganic sources. High grain yield along with substantial stover yield is associated with nutrient content in rajmash crop and high nutrient uptake.

The integration of chemical fertilizer, Rhizobium and PSB inoculation has not only influenced the N uptake but improved the P and K uptake also. Inoculation of PSB also increases N and K uptake along with P uptake by solubilization of insoluble organic phosphates, decomposition of phosphate rich organic compounds and production of plant growth promoting substances (Afzal and Bano 2008). The higher nutrient uptake with Rhizobium and PSB was also reported by Laxminarayana (2005) and Basu *et al*. (2006). The combined effect of organic and mineral fertilizers improved the nutrient uptake due to better growth and dry matter accumulation. The balanced nutrition also enhanced the synergistic effect on uptake of other plant nutrients. This result confirms the findings of Ahmad *et al*. (2007).

5.7.1. Nitrogen content (%), total nitrogen uptake (kg ha^{-1}) and protein content in grain.

The highest nitrogen content in grain was observed under treatment 5 ton FYM + Biofertilizer + Lime + 50% NPK giving a value of 3.86% in 2012 and 3.94 % in 2013 whereas in stover it was found as 0.68 % and 0.66 % in 2012 and 2013 respectively. The highest total N uptake (44.20 kg ha^{-1} in 2012 and 44.75 kg ha^{-1} in 2013) was recorded in the treatment T_{17}. It may be inferred that, when organics are applied along with inorganic fertilizers to soil, complex nitrogenous compounds slowly break down and make steady N supply throughout the growth period of crop, which might have attributed to more availability and its subsequent uptake by the crop. Addition of FYM reduced the loss of nitrates through leaching from the soil by providing a significant amount of plant nutrients created a balancing effect on the supply of nitrogen, phosphorus and potassium (Bijay-Singh *et al*. 1979 and Mallanagouda *et al*. 1995).The increased N uptake under full dose of fertilized treatment applied either through inorganic sources or in combination of organic and inorganic is associated with their increased soil availability and thereby uptake through increased biomass and yield of the crops in the respective treatments (Murmu *et al*. 2013). Higher protein content of grain was recorded under integrated treated plot which might be due to higher vegetative growth and yield attributing character resulting in increase uptake of nitrogen and protein content. The results are in conformity with the finding of Bunker *et al*. (2013).

5.7.2. Phosphorus content (%) and total phosphorus uptake (kg ha^{-1})

It was observed that the maximum phosphorus content in grain (0.36 % and 0.35 % during 2012 and 2013) and stover (0.24% and 0.25 % during 2012 and 2013 respectively) were recorded under treatment T_{17}. Maximum total phosphorus uptake was observed under the treatment T_{17} giving 5.96 kg ha^{-1} in 2012 and 5.97 kg ha^{-1} in 2013 respectively. Total P uptake was significantly increased due to incorporation of organic and chemical fertilizers as compared to unincorporated treatments. This might be attributed to the fact that addition of organic matter might have decreased P fixation and increased availability of P by producing CO_2 which form carbonic acid with water and decompose some primary soil mineral (Iyer and Apte 1967). The increase in P uptake with application of FYM and biofertilizers along with inorganic fertilizers may be attributed to a better availability of P in rhizosphere. This is in conformity with the findings of Shashidhara (2000).

5.7.3. Potassium content (%) and total potassium uptake (kg ha^{-1})

K content in grain, stover of French bean and K uptake was significantly affected by the INM treatments. The highest K content (1.27% in both 2012 and 2013) in grain was recorded under treatment $T_{17,}$ whereas in stover, it was recorded as 1.82 % in 2012 and 1.83% in 2013. Total Uptake of K was found to be maximum (30.53 and 30.83 kg ha^{-1} in 2012 and 2013) under the treatment $T_{17.}$ The reason for the increased uptake of K in the crop might be the result of increased availability of K in the soil due to the application of organics (Hangarge *et al*. 2002).

5.8. Economics

The economics of the INM treatments including cost of cultivation, gross return, net return and benefit cost ratio was worked out taking into consideration the grain and stover yield and the cost of inputs required for production of rajmash crop. The current market prices for grain and stover were used to calculate the net profit or loss in terms of rupees per hectare.

Highest cost of cultivation was observed under the treatment T_{18} giving `. 37318.22 ha$^{-1}$ in 2012 and 2013 and the lowest cost of cultivation (`. 24000.00 ha^{-1}) was recorded under the treatment control (T_1).The higher cost of cultivation associated in the treatment T_{18} (5 ton FYM + Biofertilizer + Lime + 100% NPK) could be attributed to higher seed cost, chemical and organic (FYM, biofertilizer and lime) fertilizers and labour cost.

The highest gross return was obtained under the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) for both the years as `. 99560.00 ha$^{-1}$ and `. 98938.00 ha^{-1} during 2012 and 2013 and the lowest was observed under control as `. 53948.00 ha$^{-1}$ in 2012 and `. 54666.00 ha^{-1} in 2013, respectively.

Maximum net return for the system was obtained under treatment T_{17} giving `. 65805.89 ha$^{-1}$ (2012) and `. 65183.89 ha^{-1} (2013), while the minimum net return was recorded to be `.29948.00 ha$^{-1}$ (2012) and `. 30666.00 ha^{-1} (2013) in control treatment.

The highest benefit cost ratio for the sequence was recorded as `. 1.95 (2012) and `.1.93 (2013) in treatment T_{17}. Lowest benefit cost ratio `. 1.25 (2012) and `.1.28 (2013) was obtained under control treatment.

From the data in the Table 12 (a) and 12 (b), it can be seen that treatment T_{17} where 5 ton FYM + biofertilizer + lime + 50% NPK were added gave the highest benefit cost ratio and the second highest was found in the treatment T_{14} (5 ton FYM + biofertilizer + 50% NPK).

CHAPTER –VI

SUMMARY AND CONCLUSION

The present investigation was aimed at studying the "Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of

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CHAPTER –VI

SUMMARY AND CONCLUSION

The present investigation was aimed at studying the “Effect of integrated nutrient management on soil properties, growth and yield of rajmash in acid soils of

Nagaland". Biofertilizer, FYM and Lime were the organic sources used as discussed in the preceding chapter and the crops were grown with recommended cultural practices.

Feasibility and effectiveness of eighteen treatments were evaluated in terms of physico-chemical properties, available nutrient status, grain and straw production, nutrient uptake and economic return under prevailing soil and climatic conditions of the experimental area of Phek district, Nagaland. The objective of the study was to assess the changes in physico-chemical characteristics of the soil under different INM treatments, to study the major, secondary and micronutrient status of the soil, to study the effect of different treatments of INM on the crop yield, to study the nutrient uptake pattern in Rajmash under different INM treatments and to study the best INM treatments for Rajmash in acid soils of Nagaland.

The important findings of this investigation are summarized below:

I. Both bulk density and particle density was found to decrease in all the treatments in both the experimental years over the initial value (1.42 Mg m^{-3} and 2.72 Mg m^{-3}) respectively. On the contrary, porosity and water holding capacity was found to be gradually increased. There was an increase in the pH of the soil at the end of the cropping sequence from the initial value. Organic carbon content, EC and CEC of the soil were found to be increased in all the treatment over the initial value and the highest value was recorded in treatments where T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK) were applied. Base saturation percentage of the soil showed a gradual decrease in both 2012 to 2013 irrespective of treatments.

II. Maximum increase in available N in soil (331.26 kg ha^{-1} in 2012 and 324.11 kg ha^{-1} in 2013) was found with T_{18} (5 ton FYM + Biofertilizer + Lime+ 100% NPK). Available P content of the soil showed significantly higher value in all treatments over the initial value. Among the treatments, the treatment T_{18} receiving 5 ton FYM + Biofertilizer + Lime + 100% NPK in both the experimental year showed the highest P content of the soil (10.90 to 21.46 kg ha^{-1} in 2012 and 9.48-21.33 kg ha^{-1} in 2013). For available K too, maximum K content in the soil was recorded in the treatment T_{18} receiving 5 ton FYM + Biofertilizer + Lime + 100% NPK in both the years. Among the integrated treatments, treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) recorded the highest exchangeable Ca and Mg content in the soil compared to the other treatments. Available S content of the soil was higher in integrated treatments than chemical fertilizer treatments. Among integrated treatments, treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) showed higher value as compared to the other treatments. On the other hand, available S content of the soil also increased in all the treatments over the control and initial in both the experimental years. The micronutrients content of the soil in both the year showed an increasing trend in all the treatments and giving the highest value under treatment T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK) over the control plot.

III. In respect of grain and stover yield for the year of experimentation (2012 and 2013), the application of 5 ton FYM + Biofertilizer + Lime + 50% NPK (T_{17}) gave the highest grain (9.65q ha^{-1}in 2012 and 9.58 q ha^{-1} in 2013) and stover yield (10.20 q ha^{-1} in 2012 and 10.46 q ha^{-1} in 2013) as compared to the other treatments.

IV. Organic substitution influenced the uptake of major nutrients in greater quantities than those supplied through chemical fertilizers. Among the treatments, treatment T_{17} (5 ton FYM + Biofertilizer + Lime+ 50% NPK) recorded the highest uptake of major nutrients in both the years.

V. From the view point of economic consideration, application of 5 ton FYM + Biofertilizer + Lime + 50% NPK T_{17} was found to be the best treatment in terms of gross return of `. 99560.00 (2012) and `. 98938.00 (2013), followed by 5 ton FYM + Biofertilizer + 50% NPK (T_5). In respect of B: C ratio, maximum value of `. 1.95 (2012) and `.1.93 (2013) was obtained again in the treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK), followed by `. 1.90 (2012) and `. 1.86 (2013) observed in the treatment T_{14} where 5 ton FYM + Biofertilizer + 50% NPK were applied.

Conclusion:

From the findings of the present investigation, it may be concluded that:

I. Almost all the soil physico-chemical properties, secondary nutrients and micronutrients content of the soil were found to be highest in the treatment receiving 5 ton FYM + Biofertilizer + Lime+ 50% NPK (T_{17}). While, among the integrated treated plots, treatment having 5 ton FYM + Biofertilizer + Lime + 100% NPK (T_{18}) had favorable impact on the major nutrient (NPK) of the soil. The grain, stover yield and NPK uptake by rajmash crop was also recorded to be maximum in treatment T_{17} (5 ton FYM + Biofertilizer + Lime + 50% NPK) as compared to other treatments.

II. Considering sustainability of soil health, crop yield, nutrient uptake and economic return, treatments involving use of 5 ton FYM + Biofertilizer + Lime + 50%

NPK $_{(T17)}$) may be recommended for growing rajmash in the acid soil of Nagaland under Sub Alpine Temperate agro-climatic condition.

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APPENDIX – I

Cost of cultivation of rajmash (per hectare)

Items	Unit	Rate (`)	Amount (`)
1. Preparatory tillage			
a. Ploughing	20	180.00	3600.00
b. Harrowing	4	180.00	720.00
2. Seeds and sowing			
a. Seed rate	50kg	300.00	15000.00
b. Sowing	5	180.00	900.00
3. Manures and fertilizer level 100:40:20			
a. Cost of fertilizer			
Urea	217.4kg	11.00	2391.40
SSP	250 kg	13.00	3250.00
MOP	33.34kg	23.00	766.82
Total			6408.22
b. Cost of organic sources			
FYM	5t	500.00	2500.00
Biofertilizer (Rhizobium + Phosphotika)	2kg	25.00	250.00
Lime	200kg	10.00	2000.00
c. Application of fertilizer			
T_2, T_4	2	180.00	360.00
T_3, T_5, T_7, T_{10}	4	180.00	720.00
T_6, T_8, T_{11}, T_{13}	6	180.00	1080.00
T_9, T_{12}, T_{14}, T_{16}	8	180.00	1440.00
T_{15}, T_{17}	10	180.00	1800.00
T_{18}	12	180.00	2160.00
4. Intercultural operation			
a. Weeding	6	180.00	1080.00
5. Harvesting and threshing	8	180.00	1440.00
6. Cleaning and bagging	5	180.00	900.00

Labour wages: `. 180.00 per day.

APPENDIX- II

Cost of cultivation of rajmash (per hectare) for the treatments.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	T_{18}
1.Preparatory tillage																		
a.Ploughing	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600
b.Harrowing	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
2.Seeds and sowing																		
a.Seed rate	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
b.Sowing	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
3.Manures and fertilizer																		
a.NPK fertilizer	-	3204.11	6408.22	-	3204.11	6408.22	-	3204.11	6408.22	-	3204.11	6408.22	-	3204.11	6408.22	-	3204.11	6408.22
b.Biofertilizer	-	-	-	200	200	200	200	200	200	-	-	-	200	200	200	200	200	200
c.FYM	-	-	-	-	-	-	-	-	-	2500	2500	2500	2500	2500	2500	2500	2500	2500
d.Lime	-		-	-	-	-	2000	2000	2000	-	-	-	-	-	-	2000	2000	2000
e.Application of fertilizer	-	360	540	540	900	1080	900	1260	1440	720	1080	1260	1260	1620	1800	1620	1980	2160
4.Intercultural operation																		
a.Weeding	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
5.Harvesting and threshing	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440
6.Cleaning and bagging	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
TOTAL OPERATIONAL COST	24000	27564.11	31128.22	24610	28174.11	31738.22	26970	30534.11	34098.22	27220	30784.11	34348.22	27830	31394.11	34958.22	30190	33754.11	37318.22

APPENDIX- III - Analysis of variance of INM on bulk density of soil.

Source of variation	d.f	Bulk density(Mg m^{-3})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00001	-	-	0.02
Replication	2	0.00029	0.0001	0.00043	1.47	1.69	-
Treatment	17	0.004*	0.004*	0.0072*	17.89*	45.66*	53.46*
Year x Treatment	17	-	-	0.00003	-	-	0.19
Error 1	34	0.00020	0.00008		-	-	-
Error 2	70	-	-	0.0014	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- IV- Analysis of variance of INM on particle density of soil.

Source of variation	d.f	Particle density(Mg m^{-3})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00021	-	-	0.22
Replication	2	0.0002	0.001	0.0009	0.87	1.50	-
Treatment	17	0.002*	0.003*	0.0042*	7.25*	5.16*	11.65*
Year x Treatment	17	-	-	0.0002	-	-	0.59
Error 1	34	0.00028	0.00048	-	-	-	-
Error 2	70	-	-	0.00036	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- V- Analysis of variance of INM on porosity of soil.

Source of variation	d.f	Porosity (%)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.148	-	-	0.12
Replication	2	0.904	0.183	1.206	2.18	0.89	
Treatment	17	2.356*	2.874*	4.426*	5.55*	6.18*	11.78*
Year x Treatment	17	-	-	0.100	-	-	0.27
Error 1	34	0.401	0.385		-	0.12	-
Error 2	70	-	-	0.375	-		-
Total 1	53	-	-	-	-	11.78	-
Total 2	107	-	-	-	-	0.27	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- VI - Analysis of variance of INM on water holding capacity of soil.

Source of variation	d.f	Water holding capacity (%)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	33.388*	-	-	43.72
Replication	2	0.110	0.110	0.763	1.61	2.70	-
Treatment	17	15.605*	15.605*	37.057*	228.54*	92.76*	245.83
Year x Treatment	17	-	-	1.001*	-	-	6.64
Error 1	34	0.068	0.068		-	-	-
Error 2	70	-	-	0.151	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- VII - Analysis of variance of INM on pH of soil.

Source of variation	d.f	Soil pH					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.020	-	-	0.96
Replication	2	0.001	0.020	0.021	1.15	2.55	-
Treatment	17	0.176*	0.147*	0.317*	204.91*	18.51*	74.20*
Year x Treatment	17	-	-	0.006	-	-	1.41
Error 1	34	0.001	0.008	-	-	-	-
Error 2	70	-	-	0.004	-	-	
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- VIII - Analysis of variance of INM on EC of soil.

Source of variation	d.f	EC ($dS\ m^{-1}$)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00005	-	-	0.21
Replication	2	0.00022	0.00022	0.00026	1.50	0.36	-
Treatment	17	0.001*	0.001*	0.00096*	4.39*	4.10*	7.97*
Year x Treatment	17	-	-	0.00010	-	-	0.83
Error 1	34	0.00015	0.00015	-	-	-	-
Error 2	70	-	-	0.00012	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- IX - Analysis of variance of INM on organic carbon of soil

Source of variation	d.f	OC (%)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.106*	-	-	78.81*
Replication	2	0.00030	0.001	0.0013	1.91	1.43	-
Treatment	17	0.047*	0.056*	0.099*	297.50*	76.84*	229.66*
Year x Treatment	17	-	-	0.0043*	-	-	10.05*
Error 1	34	0.00016	0.001	-	-	-	-
Error 2	70	-	-	0.00043	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- X - Analysis of variance of INM on CEC of soil

Source of variation	d.f	CEC [cmol $(p^{+})kg^{-1}$]					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.742*			320.86*
Replication	2	0.001	0.001	0.0023	1.87	1.30	-
Treatment	17	0.395*	0.395*	0.484*	1157.36*	110.13*	613.00*
Year x Treatment	17	-	-	0.051*	-	-	65.66*
Error 1	34	0.0003	0.0003	-	-	-	-
Error 2	70	-	-	0.0007	-	-	
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XI - Analysis of variance of INM on base saturation of soil

Source of variation	d.f	Base saturation (%)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.127	-	-	0.48
Replication	2	0.159	0.104	0.263	2.13	1.95	-
Treatment	17	1.683*	1.824*	3.455*	22.51*	34.05*	55.44*
Year x Treatment	17	-	-	0.0509	-	-	0.82
Error 1	34	0.075	0.054	-	-	-	-
Error 2	70	-	-	0.0623	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total =2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XII - Analysis of variance of INM on available N of soil

Source of variation	d.f	Available N (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	75.920	-	-	0.39
Replication	2	104.75	87.72	192.46	2.42	2.89	-
Treatment	17	1134.40*	1688.73*	2758.39*	26.23*	55.66*	77.17*
Year x Treatment	17	-	-	64.73*	-	-	1.81*
Error 1	34	43.246	30.342	-	-	-	-
Error 2	70			35.74	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-
Year	1	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1 =2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XIII - Analysis of variance of INM on available P of soil

Source of variation	d.f	Available P (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	127.44*	-	-	48.85*
Replication	2	2.494	2.494	2.61	1.77	0.42	-
Treatment	17	17.275*	17.275*	33.907*	12.28*	66.40*	41.61*
Year x Treatment	17	-	-	1.341	-	-	1.65
Error 1	34	1.407	1.407	-	-	-	-
Error 2	70	-	-	0.814	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XIV - Analysis of variance of INM on available K of soil

Source of variation	d.f	Available K (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	1105.85*	-	-	19.92*
Replication	2	44.166	11.340	55.50	1.92	1.70	-
Treatment	17	386.549*	377.765*	734.08*	16.82*	56.60*	50.96*
Year x Treatment	17	-	-	30.22*	-	-	2.10*
Error 1	34	22.984	6.674	-	-	-	-
Error 2	70	-	-	14.40	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XV - Analysis of variance of INM on exchangeable Ca of soil

Source of variation	d.f	Exchangeable Ca [cmol(p^+)kg^{-1}]					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.0054	-	-	5.01
Replication	2	0.00022	0.00088	0.0011	1.48	2.28	-
Treatment	17	0.014*	0.013*	0.0274*	98.90*	34.16*	106.43*
Year x Treatment	17	-	-	0.00013	-	-	0.52
Error 1	34	0.00015	0.00039	-	-	-	-
Error 2	70	-	-	0.00026	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XVI - Analysis of variance of INM on exchangeable Mg of soil

Source of variation	d.f	Exchangeable Mg [cmol(p^+)kg^{-1}]					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	614.04*	-	-	30127.45*
Replication	2	0.00014	0.00014	0.0203	1.35	2.17	-
Treatment	17	0.002*	0.002*	0.0846*	23.62*	76.37*	21.67*
Year x Treatment	17	-	-	0.064*	-	-	16.57*
Error 1	34	0.00010	0.00010	-	-	-	-
Error 2	70	-	-	0.0039	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XVII - Analysis of variance of INM on available S of soil

Source of variation	d.f	Available S (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	21.861*	-	-	933.49*
Replication	2	0.003	0.020	0.0234	0.02	0.05	-
Treatment	17	11.437*	15.802*	25.55*	68.34*	39.38*	92.53*
Year x Treatment	17	-	-	1.683*	-	-	6.10*
Error 1	34	0.167	0.401	-	-	-	-
Error 2	70	-	-	0.276	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XVIII - Analysis of variance of INM on available Cu of soil

Source of variation	d.f	Available Cu (ppm)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00001	-	-	0.06
Replication	2	0.00014	0.00011	0.00025	1.13	2.86	-
Treatment	17	0.001*	0.001*	0.0025*	10.44*	40.59*	32.81*
Year x Treatment	17	-	-	0.00022*	-	-	2.83*
Error 1	34	0.00013	0.00004	-	-	-	-
Error 2	70	-	-	0.00008	-	-	
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX-XIX - Analysis of variance of INM on available Zn of soil

Source of variation	d.f	Available Zn (ppm)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00083	-	-	0.19
Replication	2	0.001	0.004	0.00433	1.65	3.74	-
Treatment	17	0.063*	0.056*	0.117*	161.21*	56.71*	176.66*
Year x Treatment	17	-	-	0.00089	-	-	1.33
Error 1	34	0.00039	0.001	-	-	-	-
Error 2	70	-	-	0.00067	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XX - Analysis of variance of INM on available Fe of soil

Source of variation	d.f	Available Fe (ppm)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.1422	-	-	3.72
Replication	2	0.015	0.023	0.0382	0.23	0.59	-
Treatment	17	0.706*	0.965*	1.645*	10.68*	24.37*	32.05*
Year x Treatment	17	-	-	0.0254	-	-	0.49
Error 1	34	0.066	0.040	-	-	-	-
Error 2	70	-	-	0.05133	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXI - Analysis of variance of INM on available Mn of soil

Source of variation	d.f	Available Mn (ppm)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.03891*	-	-	169.46*
Replication	2	0.00006	0.00017	0.00023	0.04	0.32	-
Treatment	17	0.943*	0.953*	1.891*	624.13*	1767.89*	1900.84*
Year x Treatment	17	-	-	0.00335*	-	-	3.37*
Error 1	34	0.002	0.001	-	-	-	-
Error 2	70			0.0010	-	-	
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXII- Analysis of variance of INM on plant height at 30 DAS of rajmash

Source of variation	d.f	Plant height (cm) - 30 DAS					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.1672	-	-	0.32
Replication	2	0.205	0.319	0.523	1.64	1.80	-
Treatment	17	17.307*	20.545*	37.374*	138.28*	116.28*	254.92*
Year x Treatment	17	-	-	0.478*	-	-	3.26*
Error 1	34	0.125	0.177	-	-	-	-
Error 2	70	-	-	0.1466	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

DAS- Days after sowing. d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXIII- Analysis of variance of INM on plant height at 60 DAS of rajmash

Source of variation	d.f	Plant height (cm) - 60 DAS					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	20.167	-	-	6.41
Replication	2	1.333	1.816	3.148	2.72	1.98	-
Treatment	17	47.837*	48.722*	95.818*	97.67*	53.11*	140.19*
Year x Treatment	17	-	-	0.740	-	-	1.08
Error 1	34	0.490	0.917	-	-	-	-
Error 2	70	-	-	0.683	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

DAS- Days after sowing. d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXIV- Analysis of variance of INM on plant height at 90 DAS of rajmash

Source of variation	d.f	Plant height (cm) - 90 DAS					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	14.242	-	-	5.76
Replication	2	0.514	1.960	2.474	1.71	1.94	-
Treatment	17	48.202*	82.013*	127.64*	159.87*	81.26*	200.51*
Year x Treatment	17	-	-	2.565*	-	-	4.03*
Error 1	34	0.302	1.009	-	-	-	-
Error 2	70	-	-	0.63	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

DAS- Days after sowing. d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXV - Analysis of variance of INM on number of branches per plant at 30 DAS of rajmash.

Source of variation	d.f	Number of branches per plant - 30 DAS					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.290	-	-	0.82
Replication	2	0.036	0.320	0.3565	0.94	1.90	-
Treatment	17	1.488*	2.152*	3.565*	39.26*	12.78*	35.58*
Year x Treatment	17	-	-	0.074	-	-	0.74
Error 1	34	0.038	0.168	-	-	-	-
Error 2	70	-	-	0.1002	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

DAS- Days after sowing. d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXVI - Analysis of variance of INM on number of branches per plant at 60 DAS of rajmash.

Source of variation	d.f	Number of branches per plant - 60 DAS					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.871	-	-	6.55
Replication	2	0.087	0.046	0.1329	1.32	2.24	-
Treatment	17	1.441*	1.593*	2.930*	21.89*	77.90*	69.91*
Year x Treatment	17	-	-	0.1037*	-	-	2.48*
Error 1	34	0.066	0.020	-	-	-	-
Error 2	70	-	-	0.0419	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

DAS- Days after sowing. d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXVII- Analysis of variance of INM on number of branches per plant at 90 DAS of rajmash

Source of variation	d.f	Number of branches per plant (90 DAS)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.0618	-	-	0.10
Replication	2	0.101	0.075	0.1756	1.85	1.77	-
Treatment	17	1.441*	1.523*	2.838*	26.37*	36.02*	60.29*
Year x Treatment	17	-	-	0.126*	-	-	2.68*
Error 1	34	0.055	0.042	-	-	-	-
Error 2	70	-	-	0.0470	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

DAS- Days after sowing. d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXVIII - Analysis of variance of INM on number of nodules per plant of rajmash.

Source of variation	d.f	Number of nodules per plant					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	448.922*	-	-	33.63*
Replication	2	7.772	5.576	13.347	1.55	1.52	-
Treatment	17	369.546*	618.229*	950.902*	73.69*	168.50*	225.44*
Year x Treatment	17	-	-	36.872*			8.74*
Error 1	34	5.015	3.669	-	-	-	-
Error 2	70	-	-	4.217	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXIX - Analysis of variance of INM on fresh weight of nodules per plant of rajmash.

Source of variation	d.f	Fresh weight of nodules per plant (mg $plant^{-1}$)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	864.22*	-	-	32.52*
Replication	2	15.602	10.975	26.57	1.65	0.81	-
Treatment	17	681.409*	1215.574*	1810.46*	71.88*	89.59*	161.73*
Year x Treatment	17	-	-	86.515*	-	-	7.73*
Error 1	34	9.480	13.568	-	-	-	-
Error 2	70	-	-	11.19	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXX - Analysis of variance of INM on dry weight of nodules per plant of rajmash.

Source of variation	d.f	Dry weight of nodules per plant (mg plant^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	2063.07*	-	-	117.74*
Replication	2	6.791	10.731	17.52	1.69	2.33	-
Treatment	17	414.914*	414.152*	811.26*	103.22*	90.02*	193.76*
Year x Treatment	17	-	-	17.805*	-	-	4.25*
Error 1	34	4.020	4.601	-	-	-	-
Error 2	70	-	-	4.18	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXI - Analysis of variance of INM on number of pods per plant of rajmash

Source of variation	d.f	Number of pods per plant					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.466	-	-	2.81
Replication	2	0.041	0.125	0.166	1.06	2.26	-
Treatment	17	1.898*	2.580*	4.420*	48.73*	46.74*	96.67*
Year x Treatment	17	-	-	0.057	-	-	1.25
Error 1	34	0.039	0.055	-	-	-	-
Error 2	70	-	-	0.045	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXII - Analysis of variance of INM on length of pod of rajmash

Source of variation	d.f	Length of pod (cm)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	1.928	-	-	8.71
Replication	2	0.032	0.189	0.221	0.26	1.93	-
Treatment	17	5.405*	4.174*	8.899*	44.74*	42.57*	83.72*
Year x Treatment	17	-	-	0.679*	-	-	6.39*
Error 1	34	0.121	0.098	-	-	-	-
Error 2	70			0.106	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXIII - Analysis of variance of INM on number of seeds per pod of rajmash.

Source of variation	d.f	Number of seeds per pod					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.361	-	-	9.93
Replication	2	0.026	0.011	0.036	1.59	0.84	-
Treatment	17	2.144*	1.437*	3.497*	131.82*	114.83*	250.18*
Year x Treatment	17	-	-	0.083*	-	-	6.00*
Error 1	34	0.016	0.013	-	-	-	-
Error 2	70	-	-	0.013			
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXIV - Analysis of variance of INM on number of test weight of rajmash.

Source of variation	d.f	Test weight (g)					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	4.510	-	-	4.35
Replication	2	0.099	0.939	1.037	1.13	2.35	-
Treatment	17	4.431*	6.563*	10.732*	50.53*	16.42*	45.34*
Year x Treatment	17	-	-	0.262	-	-	1.11
Error 1	34	0.088	0.400	-	-	-	-
Error 2	70	-	-	0.236	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXV - Analysis of variance of INM on grain yield of rajmash.

Source of variation	d.f	Grain yield (q ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.065	-	-	0.29
Replication	2	0.128	0.100	0.228	1.06	0.88	-
Treatment	17	3.081*	2.830*	5.877*	25.62*	24.80*	51.63*
Year x Treatment	17	-	-	0.033	-	-	0.29
Error 1	34	0.120	0.114	-	-	-	-
Error 2	70	-	-	0.113	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-		-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXVI - Analysis of variance of INM on stover yield of rajmash.

Source of variation	d.f	Stover yield (q ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.021	-	-	0.07
Replication	2	0.170	0.127	0.296	8.47	64.59	-
Treatment	17	1.538*	1.614*	3.135*	76.70	822.21	293.18*
Year x Treatment	17	-	-	0.017	-	-	1.60
Error 1	34	0.020	0.002	-	-	-	-
Error 2	70	-	-	0.010	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX-XXXVII- Analysis of variance of INM on N content in grain and protein content (pooled) in grain of rajmash.

Source of variation	d.f	N content (%) in grain							
		Mean sum of square				F cal			
		2012	2013	Pooled	Protein in grain Pooled	2012	2013		Protein in grain Pooled
Year	1	-	-	0.0031	0.1226	-	-	1.26	1.25
Replication	2	0.001	0.002	0.0024	0.098	0.67	0.92	-	
Treatment	17	0.277*	0.231*	0.506*	19.780	362.13*	107.71*	357.90*	357.57*
Year x Treatment	17	-	-	0.0022	0.087	-	-	1.57	1.58
Error 1	34	0.001	0.002	-	-	-	-	-	-
Error 2	70			0.0041	0.055	-	-	-	-
Total 1	53	-	-	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXVIII - Analysis of variance of INM on N content in stover of rajmash.

Source of variation	d.f	N content (%) in stover					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.0022	-	-	4.69
Replication	2	0.0002	0.0003	0.0004	2.90	1.88	-
Treatment	17	0.006*	0.008*	0.013*	104.29*	48.88*	126.50*
Year x Treatment	17	-	-	0.00017	-	-	1.53
Error 1	34	0.00005	0.0002	-	-	-	-
Error 2	70	-	-	0.00011	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXIX- Analysis of variance of INM on P content in grain of rajmash.

Source of variation	d.f	P content (%) in grain						
		Mean sum of square			F cal			
		2012	2013	Pooled	2012	2013	Pooled	
Year	1	-	-	0.0018	-	-	17.76	
Replication	2	0.00004	0.0001	0.0001	0.37	1.26	-	
Treatment	17	0.008*	0.009*	0.0166*	75.27*	164.39*	215.74*	
Year x Treatment	17	-	-	0.00004	-	-	0.52	
Error 1	34	0.00011	0.00005	-	-	-	-	
Error 2	70	-	-	0.00008	-	-	-	
Total 1	53	-	-	-	-	-	-	
Total 2	107	-	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1-=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXX - Analysis of variance of INM on P content in stover of rajmash.

Source of variation	d.f	P content (%) in stover					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00002			0.10
Replication	2	0.0001	0.00015	0.0002	1.44	1.01	-
Treatment	17	0.0044*	0.005*	0.0097*	65.82*	37.48*	95.07*
Year x Treatment	17			0.00006			0.57
Error 1	34	0.0001	0.00014	-	-	-	-
Error 2	70			0.00010			
Total 1	53	-	-	-	-	-	-
Total 2	107						

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXI - Analysis of variance of INM on K content in grain of rajmash.

Source of variation	d.f	K content (%) in grain					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.0020	-	-	1.65
Replication	2	0.001	0.00040	0.0012	1.63	1.86	-
Treatment	17	0.019*	0.021*	0.0395*	36.35*	97.17*	111.28*
Year x Treatment	17	-	-	0.00017	-	-	0.49
Error 1	34	0.001	0.00022	-	-	-	-
Error 2	70	-	-	0.00036	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-		-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX-XXXXII - Analysis of variance of INM on K content in stover of rajmash.

Source of variation	d.f	K content (%) in stover					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.0016	-	-	1.00
Replication	2	0.001	0.00037	0.0016	2.60	1.11	-
Treatment	17	0.016*	0.019*	0.0350*	32.94*	57.25*	87.74*
Year x Treatment	17	-	-	0.00019	-	-	0.48
Error 1	34	0.00049	0.00033	-	-	-	-
Error 2	70	-	-	0.00040	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXIII - Analysis of variance of INM on N uptake by grain of rajmash

Source of variation	d.f	N uptake by grain (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	1.804	-	-	0.67
Replication	2	2.11	0.57	2.676	1.31	0.37	-
Treatment	17	85.60*	87.56*	172.67*	53.16*	56.27*	112.29*
Year x Treatment	17	-	-	0.508	-	-	0.33
Error 1	34	1.61	1.56	-	-	-	-
Error 2	70	-	-	1.53	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXIV - Analysis of variance of INM on N uptake by stover of rajmash

Source of variation	d.f	N uptake by stover (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.1220	-	-	3.37
Replication	2	0.02	0.01	0.036	0.78	1.32	-
Treatment	17	2.47*	2.08*	384.58*	84.87*	206.46*	235.82*
Year x Treatment	17	-	-	0.017	-	-	0.93
Error 1	34	0.03	0.01	-	-	-	-
Error 2	70	-	-	0.019	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-		-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXV - Analysis of variance of INM on total N uptake by rajmash.

Source of variation	d.f	Total N uptake (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.9880	-	-	0.41
Replication	2	1.70	0.72	2.417	1.09	0.48	-
Treatment	17	114.54*	114.41*	228.45*	73.12*	76.99*	154.10*
Year x Treatment	17	-	-	0.494	-	-	0.33
Error 1	34	1.57	1.49	-	-	-	-
Error 2	70	-	-	1.482	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXVI- Analysis of variance of INM on P uptake by grain of rajmash.

Source of variation	d.f	P uptake by grain (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.076	-	-	3.60
Replication	2	0.01	0.01	0.0211	0.41	1.14	-
Treatment	17	1.22*	1.21*	2.423*	61.34*	102.48*	158.64*
Year x Treatment	17	-	-	0.0028	-	-	0.19
Error 1	34	0.02	0.01	-	-	-	-
Error 2	70	-	-	0.0152	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-		-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXVII - Analysis of variance of INM on P uptake by stover of rajmash.

Source of variation	d.f	P uptake by stover (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.00009	-	-	0.0031
Replication	2	0.02	0.01	0.0300	2.19	0.81	-
Treatment	17	0.67*	0.81*	1.473*	88.72*	51.8*7	131.57*
Year x Treatment	17	-	-	0.0065	-	-	0.59
Error 1	34	0.01	0.02	-	-	-	-
Error 2	70	-	-	0.0112	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXVIII - Analysis of variance of INM on total P uptake by rajmash.

Source of variation	d.f	Total P uptake (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.0645	-	-	1.13
Replication	2	0.02	0.03	0.0492	0.86	2.24	-
Treatment	17	3.62*	3.96*	7.565*	155.81*	303.06*	429.31*
Year x Treatment	17	-	-	0.0104	-	-	0.59
Error 1	34	0.02	0.01	-	-	-	-
Error 2	70	-	-	0.0176	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXIX - Analysis of variance of INM on K uptake by grain by rajmash.

Source of variation	d.f	K uptake by grain (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.029	-	-	0.37
Replication	2	0.07	0.01	0.0810	0.87	0.38	-
Treatment	17	6.84*	7.59*	14.375*	81.73*	336.84*	280.05*
Year x Treatment	17	-	-	0.0565	-	-	1.10
Error 1	34	0.08	0.02	-	-	-	-
Error 2	70	-	-	0.0513	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXX - Analysis of variance of INM on K uptake by stover by rajmash.

Source of variation	d.f	K uptake by stover (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.583	-	-	1.24
Replication	2	0.16	0.31	0.470	0.41	0.75	-
Treatment	17	14.35*	14.02*	28.294*	37.17*	33.35*	72.22*
Year x Treatment	17	-	-	0.0812	-	-	0.21
Error 1	34	0.39	0.42	-	-	-	-
Error 2	70	-	-	0.391	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level
Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

APPENDIX- XXXXXI - Analysis of variance of INM on total K uptake by rajmash

Source of variation	d.f	Total K uptake (kg ha^{-1})					
		Mean sum of square			F cal		
		2012	2013	Pooled	2012	2013	Pooled
Year	1	-	-	0.350	-	-	0.86
Replication	2	0.07	0.34	0.406	0.19	0.81	-
Treatment	17	39.17*	40.46*	79.487*	105.38*	98.22*	208.83*
Year x Treatment	17	0.37	0.41	0.142	-	-	0.37
Error 1	34	-	-	-	-	-	-
Error 2	70	-	-	0.380	-	-	-
Total 1	53	-	-	-	-	-	-
Total 2	107	-	-	-	-	-	-

d.f- Degree of freedom. *= Significant at 5% probability level

Error 1 and Total 1=2012, 2013. Error 2 and Total 2= Pooled.

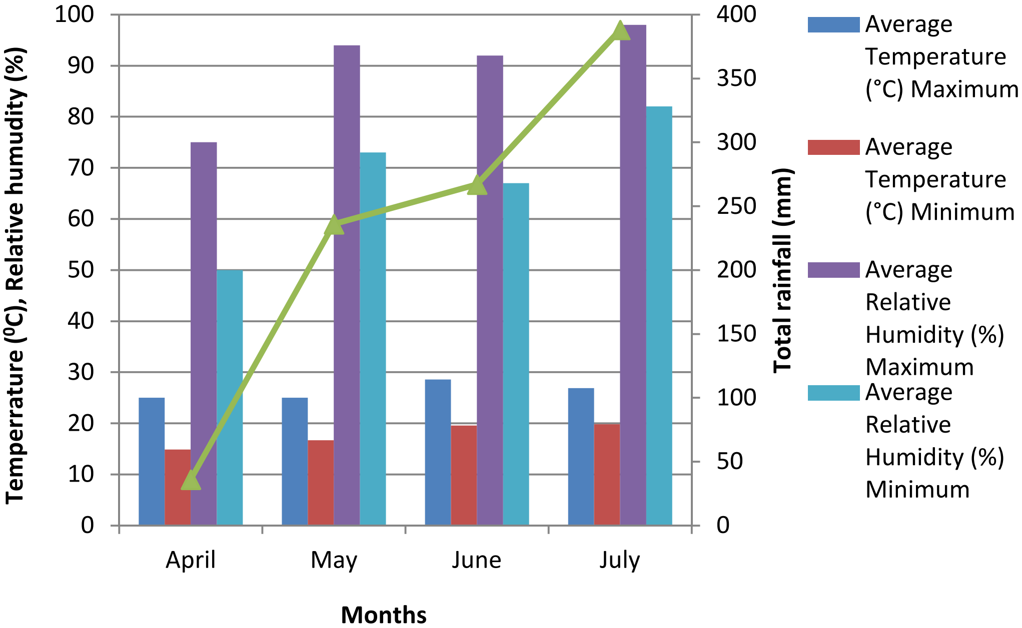

Fig 1(a): Meteorological data during the period of investigation (April to July, 2012)

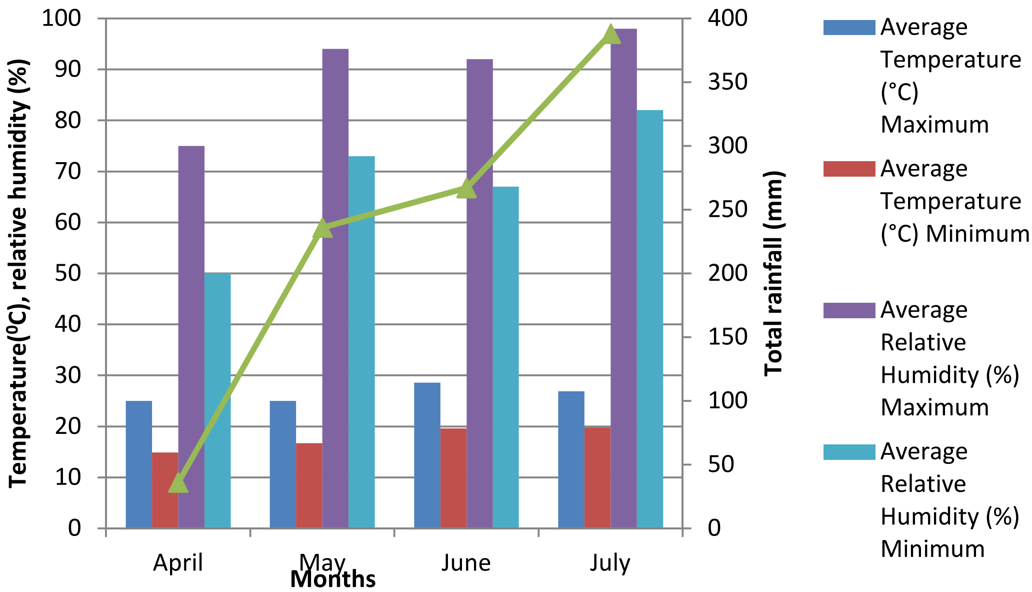

Fig 1 (b): Meteorological data during the period of investigation (April to July, 2013)

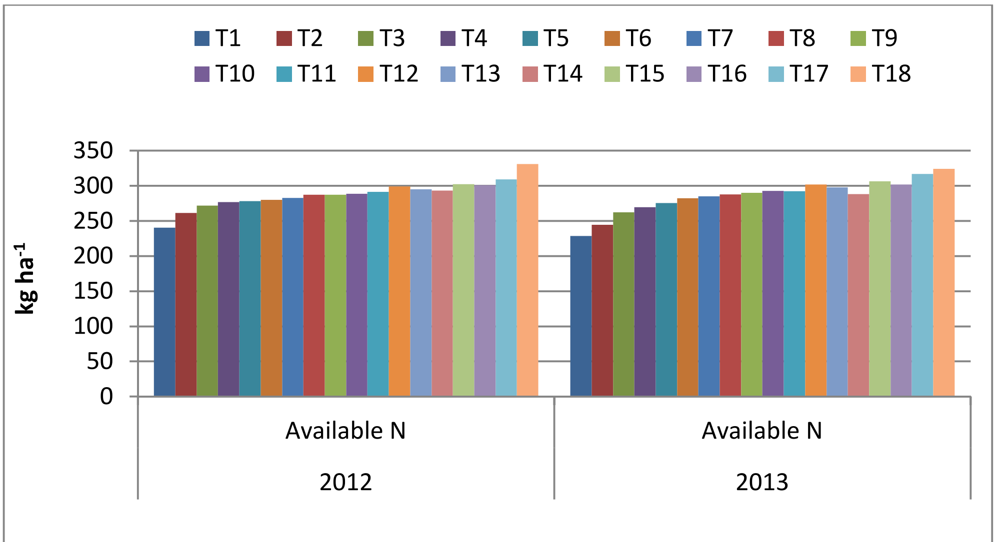

Fig. 3 (a) Effect of INM on available N of soil

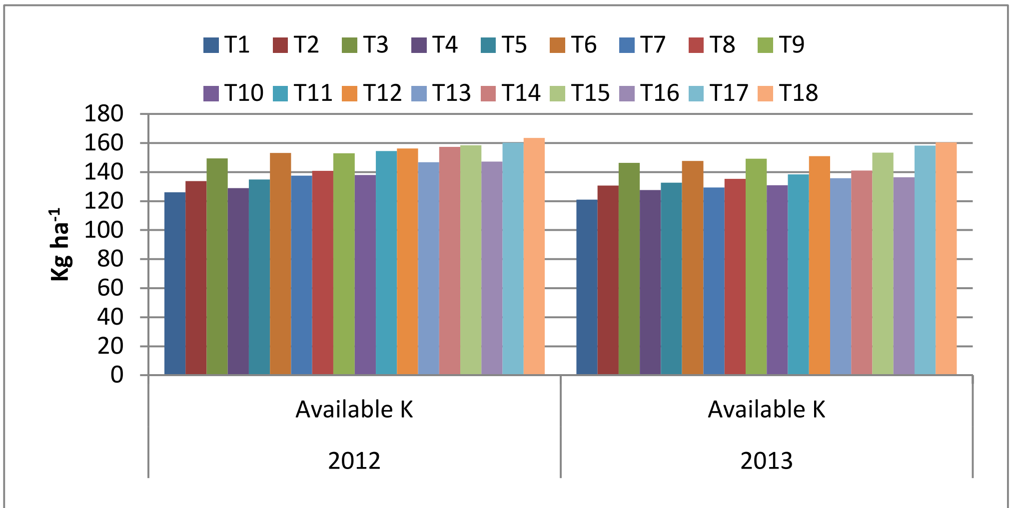

Fig. 3(c) Effect of INM on available K of soil

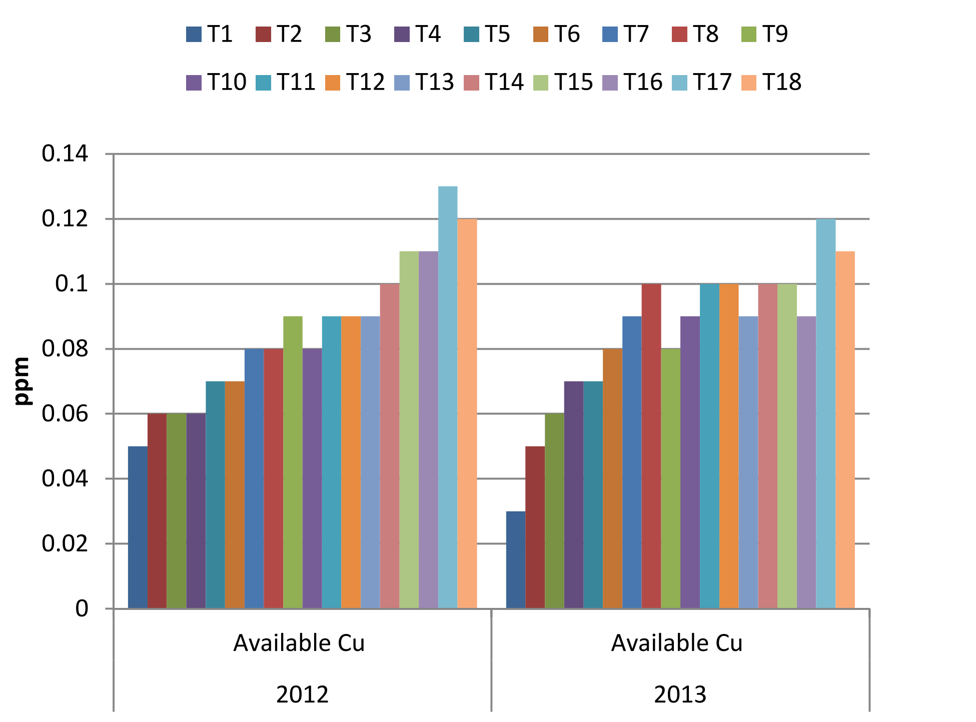

Fig.4 (a) Effect of INM on Available Cu of soil

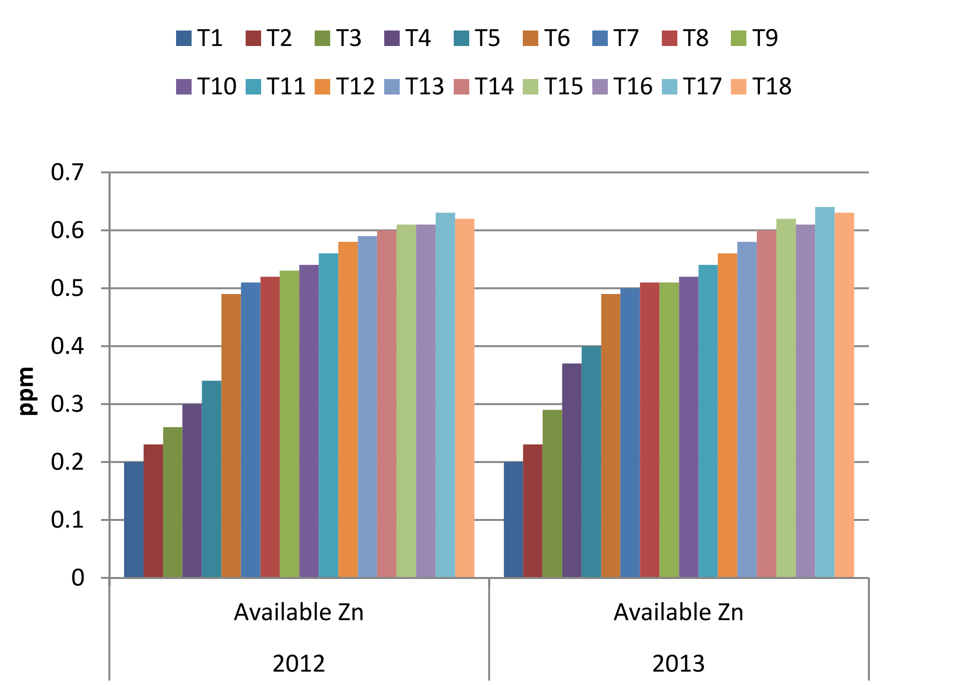

Fig.4 (b) Effect of INM on available Zn of soil

Fig. 4(c) Effect of INM on available Fe of soil

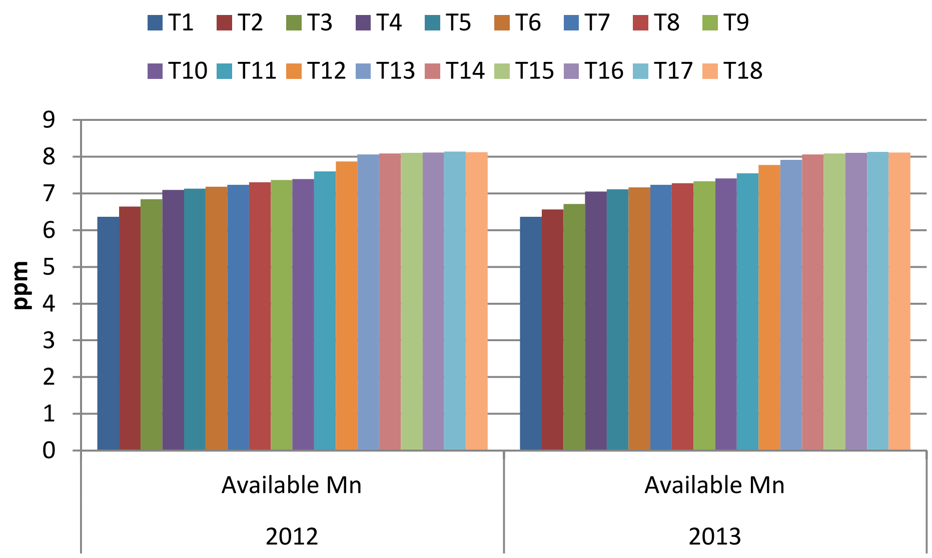

Fig. 4 (d) Effect of INM on available Mn of soil

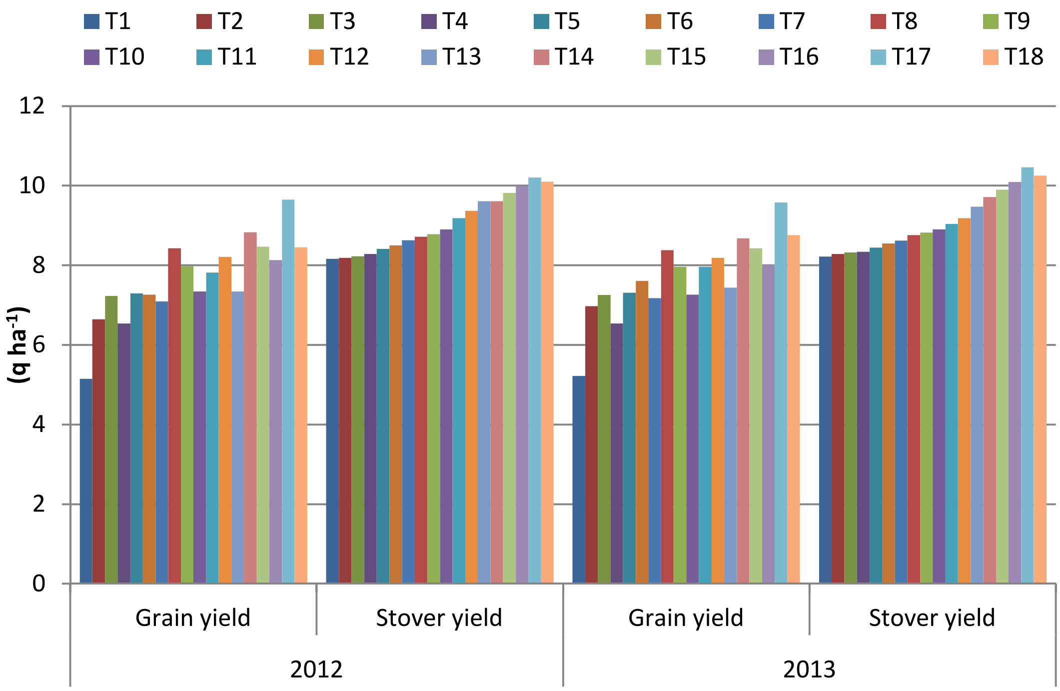

Fig. 5 Effect of INM on grain and stover yield of rajmash

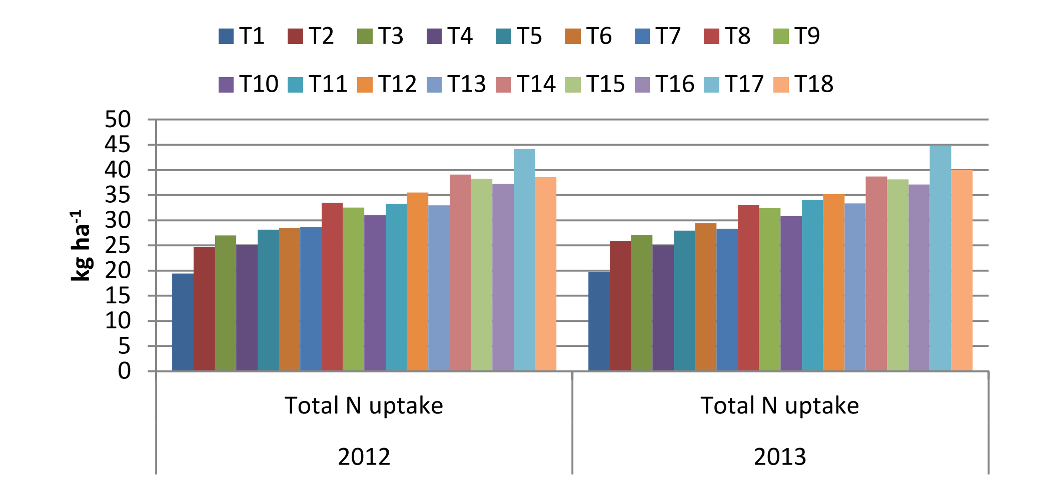

Fig. 6 (a) Effect of INM on total N uptake by rajmash

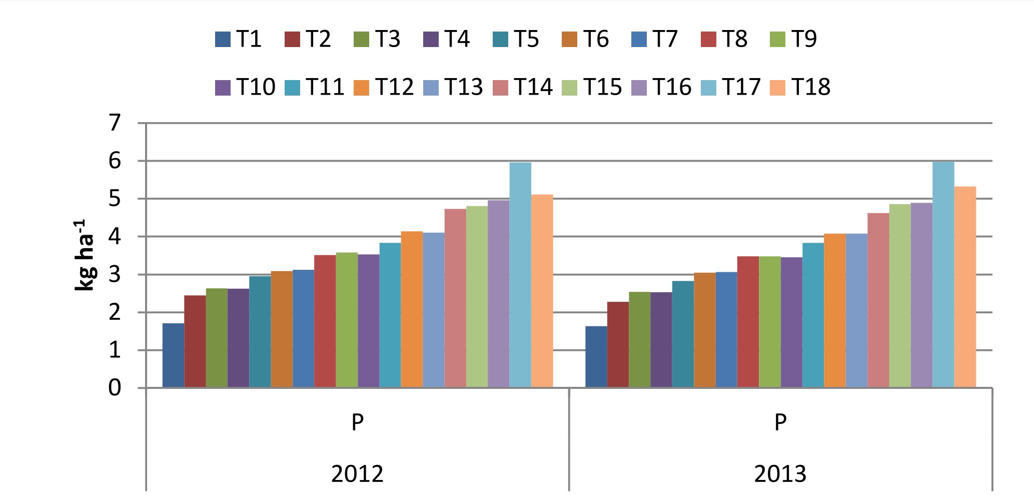

Fig. 6(b) Effect of INM on total P uptake by rajmash

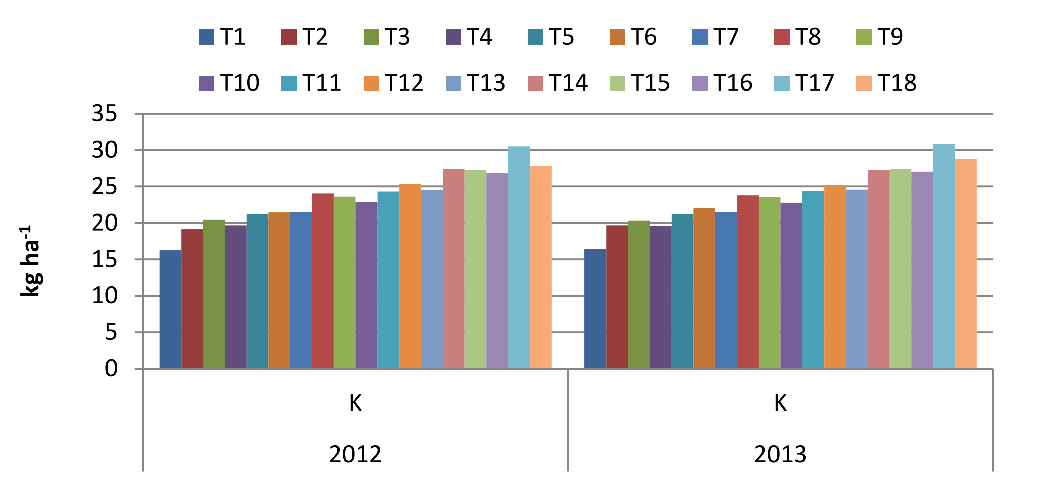

Fig. 6(c) Effect of INM on total K uptake by rajmash

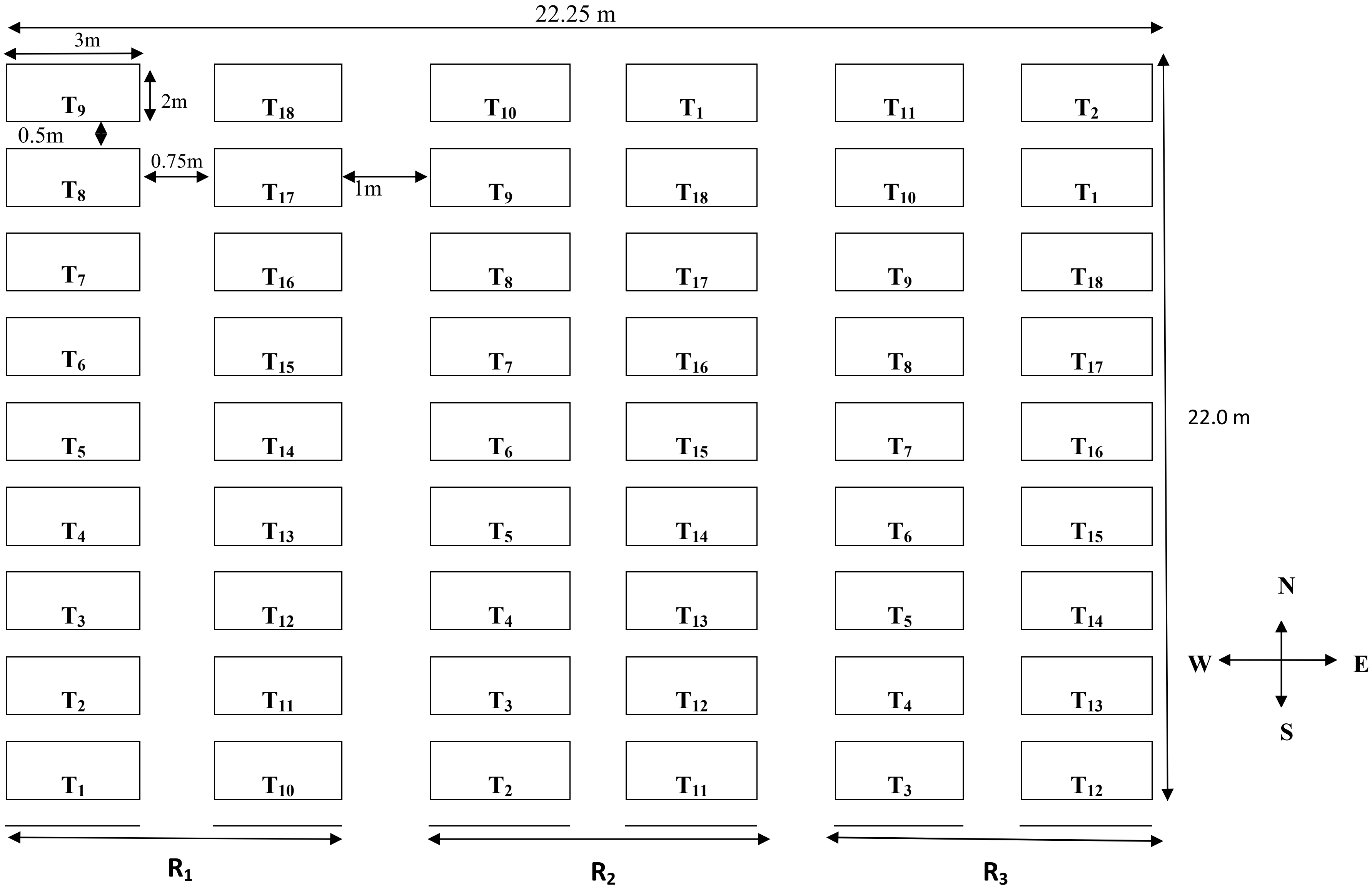

Fig 2: Layout of the experimental field

Plate 1. General view of the experimental field

Plate 2. Land preparation and seed treatment

Plate 3. Different stages of plant growth

Plate 4. Harvested Rajmash var. Contender