EFFECT OF PHOSPHOGYPSUM AND PAPERMILL SLUDGE ON GROUNDNUT IN A RICE–GROUNDNUT CROPPING SYSTEM OF ACID SOILS

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,
BHUBANESWAR
IN PARTIAL FULFILLMENT OF THE REQUIREMENT
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By

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CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF PHOSPHOGYPSUM AND PAPERMILL SLUDGE ON GROUNDNUT IN A RICE–GROUNDNUT CROPPING SYSTEM OF ACID SOILS**" submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)** of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of *bona fide* research work carried out by **N.L.V. Sivakumar** under my guidance and supervision. No part of the thesis has been submitted for the award of any other degree or diploma.

It is further certified that the assistance and help availed by his from various sources during the course of investigation has been duly acknowledged.

Bhubaneswar
Date: 30-08-2014

(B. B. Dash)

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ABSTRACT

Soil is the most vital resource for providing food for the ever- increasing population. Soil needs to be used rationally and conserved properly for realizing increased agricultural production on a sustainable basis In India, out of 328 mha of total geographical area 187.7 mha is subjected to degradation of various kinds, producing less than 20 of its potential capacity. Approximately 100 mha of land suffer from soil acidity out of which 51 mha is under forests and 49 mha under cultivation, of which 25.9 mha have P^H less than 5.6 and 23.07 mha P^H value between 5.6 and 6.5 (Motiramani, 1971, Sarkar , 2002). Orissa ranks third in country in total area under acid soil. In Orissa more than 70% of the total area is acidic and 25% have PH less than 5.5. These soils are formed mainly due to weathering under humid climate and heavy rainfall. Lateralization, Podzolization, intense leaching and accumulation of undecomposed organic matter under marshy conditions are the process contributing to acid soil development (Panda and Koshy, 1982). In addition, soil acidification due to prolonged application of acid forming fertilizers and leaching with acid precipitation (the result of industrial pollution) are also contributory factors (Haynes, 1984). Due to leaching of bases in high rainfall areas the PH falls below 7.0 because

increased active acidity. In these soils the concentration of H^+ ion exceeds that of OH ions. These soils may contain large amount of soluble Al, Fe, and Mn.

Soil acidity is characterized by low cation exchange capacity, sandy loam to loam textural class, low organic matter and low phosphorus availability while nitrogen content is variable. They are deficient in Ca and Mg, the degree of saturation of each being usually 20 to 25 %. Low productivity in acid soils due to various problems associated with soil acidity such as presence of Al, Fe and Mn in soil solution at a toxic level which affects plant growth. In addition to above affects, Mn toxicity inhibits Ca–uptake by plants, deficiency of many nutrients in soil, nutritional imbalance caused due to increase or decrease in concentration of ions in these soil solutions. Low phosphorus availability due to high P fixation and poor microbial activity leading to low nitrogen sulphur availability.

Liming is very much desirable where multi cropping is followed in acid soils with legumes as one of the crops in the sequence. Liming improves base saturation of soil, increases the soil PH to near neutrality, inactive Al, Fe and Mn, reduce P fixation (Panda and Koshy, 1982; Dwivedi, 1996), and stimulates microbial activity leading to mineralization of organic nitrogen and fixation atmospheric nitrogen. On liming exchange acidity is decreased by which varieties of crops sensitive to soil acidity could be grown on these lime amended soils. Application of a liming material which is cheaper than the pure lime is more economic and a viable option for the farmers of the acid soil zones of Orissa.

Groundnut (*Arachis hypogaea* L) is an annual legume crop grown in semi-arid regions of the world. It is the world's fourth most important source of edible oil and third most important source of vegetable protein. In India, groundnut is the principal oilseed crop, occupying an area of 6.4 million hectares with a production level of nearly 6.7 million tonnes of nuts-in-shell. It accounts for 33.5 per cent of the total area under oilseeds and 36.3 per cent of total oilseeds production. It is one of the important oilseed crops grown in the Orissa state of India, and accounts for 25 per cent of the total oilseed crop area of 0.77 lakh ha in the state (2003-04).

Groundnut response to gypsum, as with any other fertilizer, depends on the fertility status of the soil. The dissolution of gypsum is fairly rapid and therefore readily adds Ca to the podding zone.

Research works conducted on acid soils of Regional Research and Technology Transfer Stations of Orissa University of Agriculture and Technology (OUAT) at Bhubaneswar and Dhenkanal and farmers' fields of Dhenkanal districts in India, during rabi 2006-07 and kharif 2007, have revealed significant response of different crops to application of phosphogypsum (PG) a by product of phosphoric acid plants. Groundnut showed a yield increase of 20-58% over the recommended dose of fertilizer applied in seed rows at 250 kg/ha. Phosphogypsum applied in two splits, 50% at planting and 50% at peg initiation of groundnut during rabi and 75 and 25% during kharif was found to yield more than single application at planting.

Laboratory analysis of postharvest soil samples collected from different field trials and results of a laboratory incubation experiment revealed that phosphogypsum application at 125-375 kg/ha did not significantly decrease the soil pH within one year. It rather increases the calcium level of the soil. Phosphogypsum was found to increase the oil and protein content of groundnut. The seed weight and shelling percentage also increased with application of phosphogypsum up to the dose that allowed the crop for optimal growth and yield. A further study can only confirm these findings as it is the result of one year only.

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Chapter 1

Introduction

INTRODUCTION

Soil is the vital resource for providing food for the ever- increasing population. It need to be used rationally and conserved properly for realizing increased agricultural production per hectare on a sustainable basis In India, out of 328 mha of total geographical area 187.7 mha is subjected to degradation of various kinds, producing less than 20% of its potential capacity. Approximately 100 mha of land suffer from soil acidity out of which 51 mha is under forests and 49 mha under cultivation, of which 25.9 mha have P^H less than 5.6 and 23.07 mha between 5.6 and 6.5 (Motiramani, 1971, Sarkar , 2002). Odisha ranks third in the country in total area under acid soils. More than 70% of the total area is acidic and 25% have pH less than 5.5. These soils are formed mainly due to weathering under humid climate and heavy rainfall. Lateralization, Podzolization, intense leaching and accumulation of undecomposed organic matter under marshy conditions are the process contributing to acid soil development (Panda and Koshy, 1982). In addition, soil acidification due to prolonged application of acid forming fertilizers and leaching with acid precipitation (the result of industrial pollution) are also contributory factors (Haynes, 1984). Due to leaching of bases in high rainfall areas the pH falls below 7.0 because of increased active acidity. In these soils the concentration of H^+ ion exceeds that of OH ions. These soils may contain large amount of soluble Al, Fe, and Mn.

In order to overcome such problems some suggested approaches are: Selection of suitable crops for acid soils (Foy, 1984); and amelioration of soil acidity through liming (Kamprath, 1984). Liming is a widely accepted amelioration practice for efficient utilization of native soil nutrient and efficient use of added fertilizer, thereby increasing crop production.

Liming is very much desirable where multi cropping is followed in acid soils with legumes as one of the crops in the sequence. Liming improves base saturation of soil, increase the soil pH to near neutrality, inactive Al, Fe and Mn , reduce P fixation (Panda and Koshy, 1982; Dwivedi, 1996), stimulates microbial activity leading to mineralisation of organic nitrogen and fixation atmospheric nitrogen. On liming exchange acidity is decreased by which varieties of crops sensitive to soil acidity could be grown on these lime amended soils.

To obtain higher crop yields, it is therefore essential to lime the soil with suitable liming material. Materials like basic and blast furnace slag from steel industries, lime sludge from paper mills, press mud cake from sugar mills, cement kiln waste and precipitated $CaCO_3$ from fertilizer factories, which have been successfully used as soil amendments (Panda and Das, 1971). Lime sludge coming out from paper mills contains 35-45 % CaO & 1-2% Na2O, but has no adverse effect on crops. These materials are well compared with lime stone, dolomite and basic slag in raising the pH and increasing the available P content of acid soils

Amelioration of acid soils by liming though accepted for increasing crop productivity yet economically does not hold good because lime requirement of acid soils of India is very high. The amount of liming material required to raise the pH of the soils to a desired value under field conditions is known as lime requirement. It is expressed in Kg/ha. Moreover, the effect of liming does not stay long because of leaching loss of Ca. Hence split application is recommended to minimize the leaching loss (Pradhan and Mishra, 1985).Mathur (1985) working with acid soils of Bihar suggested that application of only 10% lime on the basis of lime requirement when applied every year like fertilizer in furrows would give as much crop yield of soybean, Groundnut etc. as from the application of full doses of lime. It is un economical and unaffordable by poor farmers of Orissa to lime as per the lime requirement to the extent of 100%. Therefore smaller doses such as 10%, 20%, and 30% of lime requirement need to be tried under different cropping systems commonly followed in the different agro climatic acid soil zones of the state for accessing their efficiency in supplying nutrient to different crops.

Groundnut (*Arachis hypogaea* L) is an annual legume crop grown in semi-arid regions of the world. It is the world's fourth most important source of edible oil and third most important source of vegetable protein. It accounts for 33.5 per cent of the total area under oilseeds and 36.3 per cent of total oilseeds production. It is one of the important oilseed crops grown in the Odisha state, and accounts for 25 per cent of the total oilseed crop area in the state (2003-04). Although India is a world leader in groundnut area, its productivity in India has remained low mainly because the crop is traditionally grown in the dry land belt of India characterized by poor soil fertility, erratic rainfall and low input levels. The physical condition of acid lateritic soils (Alfisol) is congenial for Groundnut cultivation but, low productivity of the crop with normal fertilization and cultural practices has been ascribed to the presence of exchangeable aluminium (Al), low level of calcium (Ca) and magnesium (Mg) as well as P due to fixation (Karmakar *et al.*, 1997; Raychaudhury *et al.*, 2003).

Gypsum is widely used as a source of Ca and Sulphur for groundnut worldwide. Groundnut response to gypsum, as with any other fertilizer, depends on the fertility status of the soil. The dissolution of gypsum is fairly rapid and therefore readily adds Ca and Sulphur to the podding zone. Positive responses have been observed on sandy soils with pH less than 5.0(0.01 M $CaCl_2$). Survey data from the smallholder farming sector has shown that the majority of the farmers do not apply gypsum or any other basal fertilizer to groundnut (Chikowo, 1998).

The use of lime provides not only Ca for the groundnut crop but also improves the availability of other plant nutrients. Proper incorporation of lime into the soil ensures availability of Ca in the podding zone (Cox *et al.* 1982). The crop following limed groundnut benefits from the residual effect of lime in addition to N contributed through fixation by the legume. Liming decreases the phytotoxic levels of Al and reduces nutrient imbalance (Belkacem and Nys, 1997).

Research works conducted on acid soils of Regional Research and Technology Transfer Stations of Orissa University of Agriculture and Technology (OUAT) at Bhubaneswar and Dhenkanal and farmers' fields of Dhenkanal districts in India, during rabi 2006-07 and kharif 2007, have revealed significant response of different crops to application of phosphogypsum (PG) a by product of phosphoric acid plants. However, the response varied with type of crops, cropping seasons and soil types. Groundnut showed a yield increase of 20-58% over the recommended dose of fertilizer applied in seed rows at 250 kg/ha. Phosphogypsum applied in two splits, 50% at planting and 50% at peg initiation of groundnut during rabi and 75 and 25% during kharif was found to yield more than single application at planting. Combined application of a moderate dose of phosphogypsum (125 kg/ha) and lime at 20% LR along with recommended dose of fertilizer in groundnut was however, either equal or more effective than a single and higher dose of phosphogypsum or lime. Laboratory analysis of postharvest soil samples revealed that phosphogypsum application at 125-375 kg/ha did not significantly decrease the soil pH within one year. It rather increases the calcium level of the soil. Phosphogypsum was found to increase the oil and protein content of groundnut. The seed weight and shelling percentage also increased with application of phosphogypsum up to the dose that allowed the crop for optimal growth and yield.

Keeping in view all these findings and results an attempt was made to note the effect of combined application of both PMS and Phosphogypsum to an acid alluvial soils of puri district, where in Rice Groundnut cropping system is a common practice.

The objectives of the present study were:

To study the influence of liming materials and phosphogypsum applied together on:-

1. Physico-chemical properties of the soil.
2. Crop growth and yield
3. Nutrient uptake and recovery by the crop
4. Post-harvest properties of soil

Chapter 2

Review of Literature

REVIEW OF LITERATURE

In India, acid soils occur in the Himalayan region, the Eastern and North-eastern plains, peninsular India and coastal plains under varying topography, geology, climate and vegetation. Most of these soils belong to the soil order, Ultisols, Alfisols, Mollisols, Spodosols, Entisols and Inceptisol. The acid soils are mostly distributed in Assam, Manipur, Tripura, Meghalaya, Mizoram, Nagaland, Sikkim, Arunachal Pradesh, West Bengal, Jharkhand, Orissa, Madhya Pradesh, Himachal Pradesh, Jammu & Kashmir, Andhra Pradesh, Karnataka, Kerala, Maharashtra and Tamilnadu. It is estimated that about 12 % soils are strongly acidic (pH < 5.0), 48 % moderately acidic (pH5.0-5.5) and 40 % mildly acidic (pH 5.6-6.5).

In acid soils, the concentration of H^+ ions exceeds that of OH ions. For the long time, it has been considered that the soil acidity is owing to exchangeable H^+ ions only. The dominance of Al in the soil acidity was reported in early thirties. Most of the clay particles interact with H^+ ions. Hydrogen saturated clay undergoes a spontaneous decomposition. In the octahedral layer, hydrogen ions replace the Al ions. The Al^{3+} released is then absorbed by the clay complex and a H-Al-Clay complex is formed rapidly. The trivalent aluminium hydrolyses to monomeric and polymeric hydroxyl-aluminium complexes and contributes to soil acidity.

Exchangeable H^+ and exchangeable Al^{3+} in major soil groups of India comprises 21 and 79 % of exchange acidity, where as pH dependant and exchange acidity accounted for 71 % of the total acidity. The unaccounted for acidity were probably due to hydrolysis of Fe and Mn on the exchange sites of the soil complex. The important soil factors that control the different kinds of soil acidity are pH, organic matter, exchangeable and extractable Al.

2.1 productivity constraints of acid soils

Acid soils pose many limitations to crop growth by way of toxic effects of acidity and of certain elements and restriction in the availability of certain other nutrients. Important nutrient elements as influenced by soil acidity are reviewed below.

2.1(a) Deficiency of major nutrients

The acid soils of India are generally poor in available nutrients owing to adverse effect of soil acidity, low base saturation, microbial and nutrient imbalances (Mandal, *et al*, 1975; Mandal 1976; Panda and Koshy, 1982; Tripathy *et al*, 1982; Singh *et al*, 1983; Mandal 1984)

Nitrogen (N)

The organic matter and N status of acid soils show extreme variation depending upon the nature of vegetation and intensity of organic matter decomposition. Except the Brown forest soils all other acid soils of Orissa are low in organic matter and total N status (Panda and Nanda, 1985). The total N content of broad acid soil groups of Orissa varied from 0.027 to 0.093% and ratio from 8:1 to 13.7:1(Patra, 1987)

Phosphorus (P)

Availability of both native and applied water soluble P is low, because high P fixation capacity of acid soils. Most of red lateritic acid soils of Orissa are low in available P (Bray's IP: 1.3 t0 5.9 ppm) although their total phosphorus is quite adequate ranging from 0.08 to 0.35 % (Panda and Mishra, 1969). High P fixation is observed in lateritic soils of Orissa (Sahoo, 1985), Sikkim (Gupta and Prasad, 1983), kerala (Madhu Soodhan and Padmaja, 1983), Bihar (Ghosh *et al.*, 1997) and Meghalaya (Majumdar *et al.*, 2003)

Potassium (K)

Potassium status of acid soil is characterized by extreme variation with differences in parent material composition and the degree of weathering of K beraing minerals .Mandal (1976) reported K fixing capacity to vary from o to 17%.The magnitude of K adsorption was higher in clayey soils rich in organic matter than others (Kumar, 1990). Roy (1987-88) indicated high percentage of upland soils of Bihar to be low in K. Most of the laterite soils of Orissa have low fixation capacity. Much of the K is lost owing to leaching (Mishra, 1979).

Secondary nutrients

Acid soils are deficient in Ca, Mg and S. Exchangeable calcium status was brought down from 2.9me to 1.00me/100gm of soil in an acid red loam ranchi after 21 years of wheat- maize cropping (Mathur, 1989). Continuous use of high dose of K, use of acidifying fertilizer and prolonged cropping with plants which remove considerable amount of Ca from soil results in Ca deficiency. Groundnut yield has been drastically reduced in acid course textured soils of Orissa due to Ca deficiency. Liming@ 10% of LR more a source of Ca rather than for correcting soil acidity has been found to significantly increase yield. Sulphur availability might be affected at low P^H owing to fixation of sulphate on hydrated oxides and reduced sulphur oxidation (Singh, 1993) .The total S content of all the soils in Orissa was in the range 25.7-925ppm. The light textured red and laterite soils and soils with low clay content contained less total S than other soils (Mishra *et al.*, 1990)

2.1(b) Micronutrient Toxicity Problems

All the soil groups of Orissa are adequately supplied with Fe, Mn and Cu and at some locations are present in toxic concentrations. Presence of Al, Fe and Mn in soil solution at a toxic level affects plant growth. Aluminium toxicity causes root injury (Foy, 1983), restricts cell division (Clarkson, 1965), restricts glucose phosphorylation (Siegel and Haug, 1983).Aluminium toxicity inhibits uptake of P, Ca, Mg, K, Fe, Zn, Cu and Mn by plants (Mugwira, 1980).

Tripathy *et al*, (1982) reported Mn toxicity in Bahal lands of Orissa and deficiency of poor Mo status in acid soils. Mn toxicity inhibits Ca uptake (Foy, 1984). Singh *et al*, (1992) described the occurrence of iron toxicity showing bronzing symptoms in rice. In Orissa, deficiency of B was found to be high among most of the soil groups except saline soils where it was found to be present in toxic concentrations. More than 80 % of the soils of different groups were found to be deficient in Mo (Sahu and Mitra, 1992).

2.1(c) Microbial activity

Soil acidity affects not only plant growth but also biological activity of soils. Poor microbial activity in acid soil leads to low nitrogen and sulphur availability. Absence or low counts of Azatobacter are recorded in acid soils and their nitrifying capacity was less but population of Beijrinckia proliferate in such soils (Subba Rao, 1983, Sharma *et al*, 1983). Rusell(1960) concluded that total microbial population is little affected by soil reaction in normal range but the activities of different groups of organisms are quite dependent on soil reaction Bacteria are not very active in soil with low PH. Patra (1974) working on acid soils of Orissa reported that bacterial population of soil increased on application of PMS. The increase was more pronounced with FYM.

2.2 Management of Acid soils

Considering the importance of acid soils in Eastern India, studies on their management were carried out by several workers. These results were well documented in several publications. Management of acid soils should aim at realization of production potential either by addition of amendments or by manipulation of agricultural practices to derive optimum crop yield under acidic conditions. Liming the acid soils, improved its physical, chemical and biological properties. There was significant improvement in yield with increased in availability of several plant nutrients. In addition to liming, the present thinking on acid soil management includes integration of nutrient management practices with in situ soil moisture conservation technology, agroforestry using a system approach of crop production to meet the food and nutritional security of the dominated tribal population in the rain fed regions of India. No doubt, liming technology is cost effective and can increase the crop yield by two-fold provided the liming materials are available to the farmers at sowing time.

Historically, lime and gypsum have been used to correct soil acidity, but their widespread use can be limited by availability and cost especially in many developing countries. Thus, low-input alternative or complementary methods need to be developed. Many industrial by products containing calcium and sulphate can act as a alternative amendments. However, their potential to correct soil acidity and their environmental risk need to be evaluated before large-scale use.

Basic slag

Basic slag is a by product of the basic open-hearth method of making steel. Basic slag contains 32 % total calcium and 3.5-8 % total phosphorus out of which 62-94 % is citrate soluble. Its performance compares well with superphosphate in acid soils with leguminous crops. Basic slag increases soil pH and mobile fraction of P, K, Ca and Mg during incubation period. Slag has been reported to increase pH, available P and decrease Al in South Nigeria acid soils. Also slag increased Ca, K uptake, promoted micronutrient uptake and increased dry matter yield. Studies from Brazil revealed that application of calcium silicate slag resulted in significant grain yield increase, tissue silicon content and silicon accumulation in straw and grain. Slag can also reduce soil acidity and increase available P, Si, exchangeable Ca and base saturation. In India, several studies in past indicated that the application of basic slag at 1-1 ½ times the lime requirement of acid soils resulted in higher yield of paddy. In a field experiment with clay-loam soil of pH 5.5 in CRRI, Cuttack, application of basic slag resulted in higher pH and higher total and extractable P. The rice yield was increased by2.93 q ha with basic slag. In a field trial at Palampur with soil pH 5.2, the yield of rice-wheat cropping system was significantly increased with use of basic slag from Bhilai. The favourable effect of basic slag in acid soils is due to its effect on the microbial population of the soil. This increases the water stable aggregates, improves the rate of mineralization and enhances soil fertility. Use of basic slag in agriculture hasbeen suggested as a P-carrier and as amendment for acid soils. The beneficial effect of basic slag on maize, wheat, gram and groundnut in Bihar has been well documented.

Tata Steel Industry, Jamshedpur generated about 6lakh tonnes of basic slag annually and that could be used in acid soils. Basic slag contains heavy metals (Cd, Cr, and Ni). High amount of Fe and Al present in red and laterite soils bind these toxic heavy metals tightly and thus prevent them to remain in available form in soil and plant.

There is hardly any possibility of contamination of underground aquifers through percolation. Results of field experiments with soil pH 4.8-5.5 in Jharkhand revealed that percent yield increase with basic slag @ 4 q ha over farmer's practice was from 11.2 to 23.8 in wheat, from 8.15 to 42.5 in gram, from 5.9 to 8.1in mustard and 6.42 to 8.56 in rai.

The management of acid soil should aim at realization of production potential either by addition of amendments to correct soil acidity and correct the soil abnormalities to or to manipulate the agricultural practices to obtain optimum crop yield under acid conditions. One of the practices is to grow acid tolerant crops/ verities (Foy, 1984) and other is amelioration of soil acidity through liming (Kamprath, 1984).

Liming is important for management of acid soils for it has considerable influence on crop yield and soil environment besides neutralizing soil acidity. The direct and residual beneficial effects of lime were reported by many workers (Prasad *et al.*, 1983; Mishra., 2002).

2.2.1 Lime as amendment and nutrient

Role of lime is dual, as soil amendment 9Foy, 1984) and plant nutrient supply (material. 1983; Prasad *et al.*, 1983). It improves base saturation, effective CEC (Patiram *et al.*, 1988), lime potential and increases availability of N, P, Ca and Mg in soil (Bishnoi *et al.*, 1988).

2.2.2 Counteracting effect of lime on toxic elements

Lime inactivates toxic elements like Al (Haynes, 1984; Patiram *et al.*, 1990; Verma *et al.*, 1996), Fe, and Mn in soil solution (Bishoni *et al.*, 1988; Panda and Koshy, 1982). The reduction in exchangeable Al and Mn probably occurs due to their precipitation as carbonates, oxides or hydroxides by liming (Prasad, 1962).

Different forms of soil aluminium, namely exchangeable, extractable and organically bound decreased with liming except amorphous Al which increased somewhat on liming (Singh *et al.*, 2000). The increase in amorphous form of Al may be attributed to the fact liming neutralized the Al^{3+} ions occupying exchange sites of the soil colloids by forming amorphous oxides or hydroxides i.e. the (Al- OH) Polymers which may interact with organic matter content of soil to form chelate/ complex with large area known for its high adsorptive power (Sanyal, 1995) thereby ensuring partial stabilization of former. According to Mongia *et al.* (1998), water soluble & exchangeable Al in soil could be brought down to trace by application for one half LR & ¼ th level of LR Gupta *et al.* (1990) observed lime application @ 20 q/ ha antagonized the toxic effects of Fe & Al. Dixit *et al.* (1993) found application of lime & K decreased different forms of Al & Fe and acidities. Similar studies were done by Muraldharan *et al.* (2001) to investigate the effects of lime and P application on extractable Al & Al potential in acid saline soils of kerala.

Maji *et al.* (1996) observed liming neutralized exchangeable Al^{3+} to a greater extent than exchangeable H^+ and reduced available Fe& Mn & exchangeable acidity in coastal acid saline soils of west Bengal. Iron and Mn contents decreased significantly due to application of zinc liming materials as $CaCO_3$ or Ca Mg $(CO_3)_2$ (Mukhopadhya *et al.*, 2001).

The results further indicated that such decrease in iron and Mn content has been found to be counteracted by application of higher levels of well decomposed FYM suggesting a favourable effect on release of Fe and Mn in soils.

2.2.3 Effect of liming on soil physical properties

Liming of acid soil is found to improve physical condition of soil. Barade *et al.* (1998) conducted a field experiment where liming improved soil aggregation, maximum water holding capacity and hydraulic conductivity of soil. Organic manuring along with lime resulted in still better aggregation of these soils. Prasad and Singh (1980) also observed beneficial effect of liming and FYM on soil aggregation. Water aggregates increased from 16.8% under control to 19.4% with 4 tonnes per hectare lime and 18.6% with 4 tonnes per hectare press mud which may be attributed to enhance flocculation of soil particles.

2.2.4 Effect of liming on soil chemical Properties

2.2.4 (a) Soil P^H

An increase in soil P^H is known under the many soil crops. Lime situations (Bishnoi *et al.*, 1988; 1989; Gupta *et al.*, 1990; Dixit *et al.*, 1993) and has been attributed to an increase in degree of base saturation and a decrease in exchangeable H^+ & Al^{3+} (Wikander, 1960; Bishnoi *et al.*, 1988). Sahu *et al*, (1990) observed that lime and organic matter addition S in highly weathered acid and laterite soils resulted in an increase in the CEC and pH values, which are essential for higher crop productivity. Studies made by Padhan % Mishra (1982) showed application for paper mill sludge and organic amendments caused a rise in soil pH of soil under lower dose or lime were comparable to that under full dose of lime which gradually decreased with time probably on account of uptake and down ward movements of lime due to leaching . Similar observations were made by Pradhan and Mishra (1985) and Gupta *et al.* (1989).

Chatterjee *et al.* (2001) reported that application of lime resulted significant decrease in exchangeable and total acidity, exchangeableAl^{3+}, H^+ and Fe^{3+}, total Fe and Al.

2.2.5 Effect of liming on Nutrient Availability

Lime application proved to be beneficial in increasing available nutrient status of acid soils.

Nitrogen (N)

Lime application increased the availability N status by 22.6% in acid soils Himachal Pradesh (Bishnoi *et al.*, 1988). It was also noticed that liming benefited soils, already low in native available N, more. Pal *et al.* (1985) conducted a laboratory incubation experiment in alluvial acid soils of West Bengal and found available N status of soil to increase within 20 days of incubation at ¼ th or ½ dose of lime application. Subsequent studies by Behura *et al.* (1996) found combined application of lime fertilizers increased the available N status of soil. Increase in available N in limed soil may be an indirect effect of enhanced pH and direct effect of accelerated decomposition and mineralisation of organic N.

Phosphorus (P)

The mechanism suggested for increased P availability due to action of lime is due to breaking of Aland Fe phosphorus vis-a-vis mineralization of organic P (Mandal *et al.*, 1975). Muralidhran *et al.* (2001) conducted an experiment in acid saline soils of Kerala to show the effect to different levels of lime and P application on the available P and phosphate potential. Liming and flooding of soil resulted in a decline in available P content of soil initially and later on increased up to 60 days after transplanting (DAT) of rice. Lime levels and application of P influenced the P availability in soil at 30 DAT but only the latter influenced P availability at 60 DAT.

The initial decline in available P on liming is attributed to increased P adsorption (Hayunes, 1982; Paliyal *et al.*, 2002) because of the formation of new adsorption surfaces in soils high in exchangeable Al caused by precipitation of exchangeable Al as amorphous hydroxyl-Al Polycations. A proportionate increase in available P up to 30th day, with increase in lime levels was observed by Mongia *et al.* (1998) in acid saline soils of Sunder bans (West Bengal).Application of lime / press mud @4 tonnes per hectare increased P availability in acid soils.

Potassium (K)

Liming acid soils may either increase or decrease the availability of K. Decreasing K availability can be explained by increased K fixation like NH_4^+ in acid soils. The increased CEC on liming retains more of fertilizers K and other cations against leaching (Mishra and Misra, 1979).The increase in available K status of acid soils by liming (bishnoi *et al.*, 1988; Behura *et al.*, 1996) can also be explained on the basis that release of K from non exchangeable fraction to available pool gets accelerated when acid soils are limed (Kamprath and Foy, 1987; Prasad *et al.*, 1987; Patiram *et al.*, 1988).

Calcium and Magnesium

Liming increases availability of Ca and Mg and their degree of saturation on soil colloids. (Boshnoi *et al.*, 1988; Behura *et al.*, 1996). Increasing the doses of lime resulted in an increase in exchangeable calcium of soil in Bihar (Mathur *et al.*, Prasad 1992). Similar studies were made by Gupta *et al.*, (1989) in acid soils of Sikkim, Pradhan and Misra (1982) in acid lateritic soils of Orissa and Chatterjee *et al.* (2001) in acids lateritic of Kokan.

Micronutrients

Generally availability of all micronutrients is reduced on liming acid soils except molybdenum but Lal and Mathur (1989) noted an increase in availability owing to high organic matter in soil.

Molybdenum

pH exerts a regulatory effect on the behaviour of molybdenum in soils. Singh (1987) noted higher availability of Mo in Ranchi soils due to organic manuring and liming, Pal *et al.*, (1985) noted higher availability of Mo in alluvial acid soils of West Bengal owing to liming. Molybdenum availability decreased in acid soils due to exchange of MoO_4^{2-} and $HMoO^{4-}$ ions on the colloids for OH^- in the solution. Verma and Jha (1970) observed that liming doubled the oxalate soluble molybdenum and increased its uptake by crops. Ebhin Masto *et al.*, (2000) reported higher availability of Mo in Srikakulam district due to application of lime.

Boron

Boron is an anion like molybdenum but unlike molybdenum its adsorption / precipitation increases with rise in pH. Sinha and Singh (1996) reported lowering of water soluble B upon liming as well as it s uptake by soybean and groundnut plants. More than 72% conversion of water soluble to insoluble form on liming acid soil was noted Singh and Sinha (1975).It appears that the major boron fixing inorganic compounds (hydroxides of Fe and Al) increase with a rise in pH and facilities boron adsorption in high pH soils.

Copper

An increase in concentration as well as uptake of copper has been found with increasing dose of liming materials.

Manganese and Iron

Application of lime caused a decrease in availability of iron (Behura *et al.*, 1996). Mukhaopadhyay *et al.* (2001) reported iron and Mn contents to decrease due to addition of lime.

Cobalt

Liming of acid soils of Singhbhum resulted in a significant increase of cobalt uptake by green gram and maize (Roy *et al.*, 1987).Organic matter and phosphorus augmented cobalt uptake significantly.

Zinc

Liming decreases zinc availability (Gupta *et al.*, 1989) and over liming may result in zinc fixation by encouraging strong adsorption of zinc ions on lime particles.

2.2.6 Effect of liming on Microbial population

Liming stimulates Microbial activity leading to mineralization of organic N and fixation of atmospheric nitrogen (Raychaudhuri *et al.*, 1998, Sahu & Mitra, 1996). Several process like ammonification, Organic matter decomposition and nitrogen fixation are stimulated by application of lime.

The population of bacteria, actinomycetes, Azotobacter, cellulose decomposers and phosphate solubilizers increase on liming or organic manuring, whereas Fungi and Beijerenckia proliferated in the absence of lime or FYM. Except fungi almost all other microorganism survived in neutral to alkaline pH (Sharma *et al.*, 1983). In acid soils, the BGA and symbiotic rhizobia could be improved by application of lime, phosphorus and molybdenum (Roy *et al.*, 1985). Oblisami (1973) observed that liming in the soil get in a drastic increase (0.7 to 20 times) in the bacterial population while the fungal flora showed a decrease from 5 to 25 % in the treated soil.

2.3 Dose of lime

The economic feasibility of liming has also to be looked into before recommending it as amendment. When applied in higher doses much of lime is lost by leaching from the top soil of light textured soils because of their low exchange capacity. Attempts were made to reduce the dose of lime to ¼ t0 ½ of lime requirement and apply in split doses (Tripathi *et al.*, 1983; Prasad *et al.*, 1983; Pradhan and Misra, 1985). Singh and Singh (1985); Sahu and Pal (1987) and Panda (1987) found lime dose of one-fourth of lime requirement to be optimum for getting a good crop yield. Pal and Mandal (1985) found one-fourth dose to be quite sufficient in alluvial acid soils of Islampur). Patiram *et al.* (1990) recommended lime application at the rate of 1to 2 times exchangeable aAl^{3+} to raise the pH above 5.5 Mathur *et al.* (1991) observed that the present net return due to liming increased with time at all levels of split doses of lime and 1/10 LR was found most profitable although 1/20 LR dose was sufficient to meet the Ca requirement of crops. sahu and Nanda (1988) recorded economic response to lime sludge applied at LR dose to a variety of crops in red loam soils of semiliguda.

2.4 Time and Method of Lime Application

The rate of reaction between soil and lime depends on moisture condition of soil. Under optimum moisture condition, neutralisation of soil acidity may be affected to a satisfactory level in the monsoon. But if irrigation facilities are available it can be applied in Rabi season also.

Deep placements of lime were in one way found superior to superior to surface application (Mandal *et al.*, 1966). An application of lower doses of lime (3 to 4 qha^{-1}) in furrows at the time of sowing of crops was advocated (Mathur, 1985) for poor and marginal farmers of Chotanagpur Plateau (Bihar).

Pradhan and Misra (1985) advocated that the paper mill sludge, a by product of paper mills should be applied in two splits, one - half mixed with the soil one week before sowing and the rest applied after 3 weeks time in bands

8cm deep into the soil and covered up before drilling other fertilizers used for top dressing .

2.5 Capacity of liming materials to neutralize soil Acidity

The capacity of liming materials to neutralize soil acidity depends upon

(i) Type of liming materials (ii) Fineness of liming mater materials.

2.5.1 Type of liming materials

Materials like carbonates, oxides, hydroxide of calcium and magnesium compounds are referred as “Agricultural limes” which neutralize soil acidity (Adams, 1984). Liming materials are classified as (a) neutrally occurring (b) Industrial wastes.

a. Naturally occurring liming materials

Naturally occurring lime sources such as calcite, limestone and dolomite limestone having industrial use have been acceptable as soil amendments because of poor economic viability. Stromatolitic limestone containing less calcium and high silica is quite acceptable. Deposits of about 40 million tones of stromatolyte are reported in Koraput districts of Odisha. It is a low grade lime stone commercially not exploited by steel industry. Attempt was made to evaluate its suitability as liming material. The rock was collected from Gupteswar area of Koraput district, ground to pass through different mesh sieves, *viz.* 22, 60, 100, and 350.

The neutralizing value of rock fragments was about 80 %. The fineness of soil particles had no effect on neutralizing value of the rock fragments. On an average, the Calcium content of rock fragment was about 17.3% and Mg content 10.5 %.

The efficiency of stromatolyte was compared with PMS or calcite through several studies carried out in OUAT, Bhubaneswar. In a pot culture experiment with maize, the pH was increased from 4.47 to 5.85 after 7 days of application of stromatolyte. Soil amelioration with $CaCo_3$ and PMS proved better during early stages of maize crop growth as compared to stromatolyte sources. Thereafter, the rock resources maintained higher pH than PMS and $CaCO_3$.The stromatolyte of different size particles had almost similar influence on reducing the exchange acidity, Al^{3+} and H^+.

Stromatolite deposits found in Orissa contain 28.32% CaO, 12% MgO & P_2O_5. Estimated reserve of such material in Orissa is about 40 mt (Panda & Misra, 1970).

b. Industrial wastes

Several industrial wastes such as steel mill slag (42% CaO), Blast furnace sludge from steel industries, lime sludge from paermills (40%CaO), press mud cake from sugar mills (33% CaO), cement klin wastes and precipitated calcium carbonate from fertilizer factories have high potential for use as soil amendments which are eco friendly (Panda and Das, 1971; Vithal rRao *et al.*, 1976).

PAPER MILL SLUDGE (PMS)

Paper mill sludge is a by-product of paper mill. It is estimated that about 2 lakh metric tonnes of PMS with 65-79 % neutralizing value and 22 to 35 % Ca content are dumped around four paper mills located in Cuttack, Rayagada, Brajarajnagar and Jeypore of Odisha. Efficiency of PMS was studied to find out the optimum dose of lime in reducing the soil acidity by neutralizing exchangeable Al^{3+}. With increase in levels of lime, there was significant rise in soil pH with decrease in exchange acidity, exchangeable H^+ and Al^{3+}. Application of lime @0.2 LR was adequate to bring the pH to a safe level for profitable crop production with neutralization of total exchangeable Al^{3+} within first week of application. The research results of OUAT, Bhubaneswar revealed that application of lime @ 0.2 LR raised the pH from 5.1 to 6.9 and decreased the exchangeable Al^{3+} from 0.62 to zero cmol (p^+) kg^{-1} within seven days of incubation.

Press mud (PM)

Pressmud is a by-product of sugar industry and can be utilized as an amendment to improve soil physical properties. Efforts were made at OUAT, Bhubaneswar to characterize press mud as a liming material for acid soils. The pH of the press mud varied between 6.5 to 6.92 and OC 16-18%. The neutralizing value of 22-24% indicated that it cannot be compared with $CaCO_3$ or PMS as a liming material. However, it can be used as an acid soil amendment because of high organic carbon content. The results of an incubation study with an acidic upland soil of Bhubaneswar (pH-4.8, exch. acidity-0.6cmol (P^+)kg^{-1}) showed that the pH increased significantly at all levels (0.2, 0.3, 0.4 LR) of PMS or PM. The exchange acidity decreased in all the lime treated soils and attained a value of zero on 7day of incubation. The study also indicated that application of PMS @ 0.2 LR or PM @ 0.3 LR was adequate to neutralize exchangeable Al^{3+}.

A Field study was conducted for three seasons on groundnut in an acidic upland site of OUAT Central Farm having pH 4.5, exchange acidity: 0.96 Cmol (p^+) kg^{-1}; O.C: 3.4 g kg^{-1} and LR: 6.3 t $CaCO_3$ ha^{-1}. PMS and PM were applied alone or in combination of 75:25, 50:50 and 25:75.

Application of PMS, PM and their combinations @ 0.2 LR increased the soil pH from 4.5 to 6.0-6.5. The peak pH was attained at 25 days of lime application and remained above 5.0 during the entire growth period. Exch.Al^{3+}decreased rapidly within 14 days of lime application and there after slowly, finally, it attained a negligible value between 73-103 days of application. Among the lime sources, the decrease in exchange acidity in PMS (100 %) was higher as compared to PM (100%).

The pod yield in lime control was 17.61q ha^{-1} and increased by 52-95 % in lime treatments. Highest yield of 36.4 q ha^{-1} was obtained when PMS and PM was applied in ratio of 75:25

LD slag

Linz-Donawitz (LD) slag, containing 29 % Ca, 21 % Fe and 5 % Mg, is a by-product of the iron and steel-making industry. The low P content of the LD slag discouraged its use in agriculture as a phosphatic fertilizer, but the total high Ca and Mg contents makes the LD slag a potential liming agent. Experiments in several European countries have demonstrated the ability of LD slag to raise the pH of acid soils, increasing the Ca and Mg contents of the soils' exchange complex. Application of LD slag @ 1.6 t ha^{-1} to soils with pH of 4-5 modified the physical and chemical properties of the soil and increased the dry matter yield by 15-40 %.

Several studies were conducted in OUAT, Bhubaneswar with LD slag from SAIL, Rourkela having pH 10.49, Ca content 16.82 %, Mg content 2.13 % and neutralizing value 58.8 %. Application of LD @ 0.1-0.4 LR to Alfisol with pH-4.53, exchange acidity 0.39 cmol (p^{+}) kg^{-1} and exchangeable $Al3^{+}$ 0.61 cmol(p^{+}) kg^{-1} increased the pH to 6.98. There was little difference in soil pH when LD slag was applied at sowing or at 5 and 10 days before sowing. Application of LD slag @ 0.3 LR recorded higher pH as compared to 0.1 or 0.2 LR. About 75% of exch. $Al3^{+}$ was neutralized within 14 days of LD Slag application. Application of LD slag @ 0.3 LR at 10 days before sowing resulted in highest ground nut pod yield of 31.8q ha^{-1} as against20.6q ha in control.

In another field study, the efficiency of LD slag was compared with PMS as sole or in combinations. Sole application of LD slag was inferior to PMS. However, combined application of LD slag and PMS (1:1 ratio) @0.3 LR increased the pod yield by 58 to 90 %.

2.5.2 Efficacy of different liming materials

Ananthanarayan *et al*., (1993) conducted an experiment in experiment in acidic soils of Shimago District, (Karnataka) to study the efficiency of different liming materials in neutralization soil acidity. It was concluded from their study that CaO , $Ca(OH)_2$ and $CaCO_3$ were effective in reducing soil activity at a rapid rate . The rate of reaction of these materials with acid soils was maximum during the first week of application. Mussoorie rock phosphate was not effective in ameliorating the soil acidity over a period of eight weeks while dolomite, paper mill sludge and basic slag neutralize the soil acidity fairly late i.e., after two months of their application in soil.

Relative efficiency of four sources of lime viz. limestone, dolomite, basic slag and lime sludge was compared in lateritic soil taking three successive crops of maize. When applied on equivalent basis the average relative efficiency were 100, 94, 111 and 108, respectively at 3 levels, viz. 1000, 2000, and 3000 $CaCO_3$ ha^{-1} and reported that lime sludge can profitably be use as amendment in light textured soils at low doses at low doses because of its faster solubility.

2.6 Crop response to liming

Crops have been classified according to their relative response to liming. Mandal *et al.* (1966) grouped upland crops into three categories (1) high response group (Pigeon pea, Soybean and Cotton) (2) Medium response group (maize, Groundnut, Gram, Lentil, and Pea) (3) Low response group (Paddy, potato, Small millets etc.). Under rained condition high responsive crops may be grown in the 1st year / season. Low responsive crops may be grown when effect of liming is furthered reduced.

Pradhan and Misra (1982) conducted field experiment to show the effect of application of paper mill sludge and organic amendments on yield of maize and horse gram.

The yield of crops increase significantly over control due to lime application particularly when applied with NPK fertilizers. 0.5 LR was significantly superior to control but at par with higher doses.

Application of lime, FYM and p fertilizer source individually and combination resulted in significant increase in grain yield and uptake of Ca and Mg by wheat in acid Alfisols of Himalayan region (Sharma *et al.*, 1994). The amelioration effect of acid soils following liming and K application increased significantly the yield of grain and straw in a what –soybean-linseed cropping system (Dixit *et al.*, 1993; dixit *et al.*, 1995).

Patiram *et al.* (1990) reported that application of dolomite limestone equivalent to two times the exchangeable Al completely eliminated the exchangeable Al and gave optimum yield of wheat and maize (Patiram *et al.*, 1989) in acid soils of Sikkim. Application of lime@20 and 25 q per ha caused significant increase in grain yield and uptake of P, K, Ca and Mg by wheat and maize in acid soils of Nagaland (Datta *et al.*, 1983) which corroborated with the finding of Gupta *et al.*, (1989).

Legumes are more responsive to lime in acid soil. Application of limestone powder@ 2500 kg per ha and lime sludge @ 1250kg per ha raised the yield of groundnut from 12.12 to 17.1 and 18.9 q per ha respectively in sandy loam lateritic soil of Dhenkanal District of Orissa. The shelling percentage was also improved by 12% due to liming (Hanson and Sahu, 1971). Dutta *et al* (1997-98) reported that liming up to 25% LR and 50% LR increased significantly the yield attribute characters, pod yield and oil content of groundnut. Chatterjee *et al* (2001) worked on effect of lime on yield, quality and nutrient uptake by 6 groundnut verities in an acid soils of konkan and reported that 10, 50, and 100% LR of soils in furrows increased the dry pod yield by 15.5, 23,4 and 32.6% over the treatment receiving recommended doses of NPK fertilizers (25:50:50) alone . They also reported the increase of protein content at 100% LR by 32 % over no application.

Productivity of rice-groundnut system was found to be higher in limed soils as compared to unlimed soils (Misra *et al.*, 1990). Singh and Singh (1983) reported that liming @10 to 16.5 tonnes per ha in acid soils of Kumaon hills increased the dry matter yield and nutrient content of French been under green house condition. Lime application decreased concentration Fe, Mn and Cu in shoots of mung grown in alluvial acid soils (pH 4.7) of North Bengal (Pal *et al.*, 1987).The concentration of Al and Mn in berseem decreased and that of Ca, Mg and P increased with increasing rate of liming (Tripathi *et al.*, 1983 and 1984). Liming the acid soils of Himachala Pradesh increased the dry matter yield of soybean crop and also uptake of N, P, K, Ca and Mg by the crop (Bishnoi *et al.*, 1988). It was found that graded dose of lime lime significantly increased the soybean yield in acid soils up to a certain level of liming, beyond which higher doses were not beneficial (Prasad *et al.*, 1985; Gupta *et al.*, 1989) Prasad *et al.*, 1992). The decrease in yield at higher level of liming might be due to imbalance of Ca, Mg and K ratios in plants brought about by the marked increase in Ca, and Mg concentration (Patiram, 1989). The yield of soybean was highest in acid soils of Sikkim when it was applied at the rate of 1 to 1.5 times the exchangeable Al content or 25% LR. Also liming increased the Ca uptake by plant (Patiram , (1990), Raychaudhury *et al.*, (1992) conducted an experiment in acid soils of Manipur to study the effect of liming and Rhizobium inoculation on the yield by 60 % . Inoculation also increased the grain yield. Lime and Rhizobium interaction was significant for grain yield, nodulation, N and P uptake. Liming improved the soil nutrient status and inoculation increased the Rhizodal population in soil. The study corroborated with the later finding of Raychoudhury *et al.* (1998) where rhizoidal was found to increase by both lime and P application resulting in increased nitrogen fixation, yield and nutrient uptake in soybean. Grain yield of urd soybean, lentil, and gram at 1/20 LR dose of lime were at par with full dose. Lime application @3.2 tonnes per ha increased the yield of black gram by 13.7% over no lime. Increase in lime dose from 3.2 to 6.4 t per ha was ineffective in increasing the yield (Shard *et al.*, 1991).

Remarkable response of green gram varieties like OBGG-40, OBGG-11, ONGG-52 OUM-6, OUM-7, Dhauli, pusha, 9072 to soil amendments was recorded in field trials conducted at Berhampur in Orissa .The nodular N, seed yield and nutrient uptake by green gram crop in creased the significantly when the seed was inoculated with Rhizobium and further by amending the soil with lime @50%LR or seed inoculation with Rhizobium and treated with micronutrient (Mo and Co) and soil liming (Pattanayak , 2002).Negi *et al.*, (1999-2000) reported the combined effect of Rhizobium , FYM and NPK along with lime in acid soil of Garwal hills , increased the growth and yield of Pea . The highest growth of yield components of garden pea was recorded by application lime @4 ton per followed by FYM+NPK. Singh *et al.*, (2003) reported that the combined application of 0.05 kg B and 250 Kg lime per ha gave maximum grain yield in gram which is 81.4% higher than control.

Raychoudary *et al.* (2001) reported that liming at 2.5t/ha increased the efficiency of phosphate solubilising microorganisms and increased the available P content of an acid hilly ultisols of Manipur by 26 .9%. Liming alone increased the nodule weight per plant (71%), pod (36%) and haulm yield (37%) and their respective N uptake (51% and 91%) and P uptake (49% & 50%) respectively in pod haulm.

2.7 Phosphogypsum

Phosphogypsum is a by-product of the phosphate fertilizer industry and emanates from the production of phosphoric acid from rock phosphate. Production of phosphogypsum in Florida is estimated to be 27.2 million Mg annually (Hunter 1989). The composition of phosphogypsum varies depending upon the source of rock phosphate and the process for manufacturing phosphoric acid (Mays and Mortvedt 1986).

The approximate composition of phosphogypsum is shown in table

Major constituents	g /kg
Ca	200–240
P	1–5
S	150–190
F	5–38

Minor constituents	mg /kg
K	100–800
Mg	8–400
Mo	65
Cd	0.23

Calcium is a yield limiting nutrient in groundnut. It is needed for both good vegetative growth and normal healthy fruit development. Its deficiency is most often seen in ground nut field as pops. For vegetative growth, its deficiency is manifested as localized pitted lesions on the lower surface of the leaves which eventually develop into brown necrotic spots. Severe deficiency of calcium can result in the death of the root tips and terminal buds (Henning et al., 1982). A calcium deficiency is also expressed as a black- ended plumule inside the seed halves known as "black heart", while its minor deficiency can result in seeds which do not germinate or produce weak or deformed seedlings (Sullivan *et al.*, 1974).

Groundnut has the unique characteristic of uptake of calcium and sulphur by the developing pegs and pods. As calcium is relatively immobile in plant tissues and is not translocated in sufficient quantities from the roots to developing pods, calcium and sulphur have to be made available in adequate quantities in pod zone. Gypsum should be finely powdered and applied by banding near the plants (pegging zone) and then stirred into the soil Can also be applied to groundnut by dusting on the plant at the early flowering stage when it falls around the plant and reaches the pod zone. The best time for application is when plants are in the full bloom stage *i.e.,* 40 to 45 days after sowing. The pod shall absorb calcium entirely from the soil.

Gypsum application is generally recommended because it provides calcium and sulphur; it has impurities that also provide magnesium. It reduces pH slightly, improves soil structure, creates a favourable environment for the micro flora and reduces impact of drought and the associated aflatoxin problem. * Excess of gypsum does not harm the plants. It is relatively soluble source of Ca and, therefore, readily available to the developing pods. It is subjected to almost complete loss from the soil by the time groundnut crop is harvested. Higher quantities of gypsum than necessary are, therefore, applied at early flowering stage to ensure adequate calcium supply in the pod zone. Since there is little residual effect of gypsum it is necessary to repeat application every season.

Gypsum ($CaS04.2H_2O$) is a readily available source of Ca. Hallock and Alli- son (1980) applied gypsum @ 605 kg/ha as banded or 907 kg/ha as broadcast to large-seeded Virginia peanut at the time of planting and at early flowering stage. They observed that the Ca treatments increased crop yields from 360 to 1200 kg/ha over check.

Application of gypsum @ 200 kg/ha as basal (at the time of sowing) and at pegging stage (on 45 DAS) is recommended to obtain higher yield in groundnut.

Under rain fed situation top dressing of gypsum can be extended up to 60 days after sowing depending upon the rainfall and available soil moisture.

The treatments include absolute control, package of practices recommendation of Kerala Agricultural University –200 kg/ha (POP), lime/PG @ full lime requirement (1 LR) and half LR, respectively and two combination treatments of both lime and PG each at ½ and ¼ LR, respectively.

Application of PG had significant influence on the acidity components except exchangeable hydrogen. The lowest values for both exchangeable acidity and Al were recorded under PG at full LR and were significantly superior to rest of the treatments. But lime was more efficient in reducing the exchangeable hydrogen content of soil and improving soil pH, compared to PG. Phosphogypsum had significant influence on the grain yield of cowpea with PG @ 1 LR recording the highest grain yield followed by the combination treatment of lime and PG each @ ¼ LR which was on par with the former. Application of PG significantly increased the uptake of N, P, K, Ca and S and the highest values were recorded under 1 LR of PG.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

In order study the effect of PMS and Phospopho gypsum applied to the acid soils on nutrient availability and crop growth of Groundnut in a Rice + Groundnut cropping system, an experiment was conducted in a farmer field at Delanga block, in an acid soils using Paper mill sludge, Phospogypsum as amending materials along with various doses of chemical fertilizers. The materials and methods followed for study are discussed under the following heads.

3.1 Experimental Site

A field experiment was conducted during Rabi 2013 at Tailasahi of Delanga block, in puri district.It is located at 25^0N latitude and 85^0E longitudes with an elevation of 30 m above mean sea level. The experimental site experiences a high temperature in summer and mild temperature during winter season and a medium rainfall. The annual rainfall is about 1482mm, out of which more than 75% is received between the months of July to October. The mean annual temperature is 28.6^0c .The mean Summer and winter temperature is 30.30^0c and 21.30^0c respectively.

3.2 Soil

The soils are alfisols and are characterized by light textured surface soil with enriched argillic subsurface horizons illuviated with oxides and hydroxides of iron and aluminum. These are medium to highly weathered soils These are light colored, low in organic carbon, poorly fertile, low base saturation and acidic In reaction (Nayak *et al,* 2002.) The charactenstics of the experimental soil are presented in Table 3.1

Table.1. Initial properties of experimental soil

Parameter	Value
Textural class	Loam
Bulk density (g cc^{-1})	1.55
Particle Density (g cc^{-1})	2.68
Pore space (%)	42.2
pH (1:2.5)	4.95
EC (dS m^{-1})	0.12
O.C. (g kg^{-1})	4.3
CEC [cmol(p+)kg^{-1}]	3.75
Avail. N (kg ha^{-1})	220
Avail. P (kg ha^{-1})	19.4
Avail. K (kg ha^{-1})	187
Avail. S (kg ha^{-1})	19

3.3 Experimental details

The experiment was laid out in a RBD with a groundnut as test crop in the acidic alluvial soils with 8 treatments and 4 replications. The groundnut variety TNV-2 was grown in Rabi 2013. PMS and Phospogypsum were applied in lines at the time of sowing. The total no of plots were 32. The soil is loam in texture with pH 4.95 organic carbon 4.3(g kg^{-1}) and nitrogen, phosphorus and potassium were applied @ 20:40:40 Kg/ ha through Urea, DAP & MOP respectively as basal application. The treatment details are presented in table 3.2.

Table.2. Treatment details

Treatments	Details
T_1	**FP** **FP= Farmers practice**
T_2	T_1 +PG @ 250 Kg/ha PG= Phosphogypsum
T_3	**RDF** **RDF=Recommended Dose of Fertilizer**
T_4	**RDF + PG** @ 250Kg/ha
T_5	T_1 + **PMS(0.5LR)** PMS= Paper mill sludge
T_6	T_2 + **PMS(0.5LR)**
T_7	T_3 + **PMS(0.5LR)**
T_8	T_4 + **PMS(0.5LR)**

LAY OUT PLAN

R_1	R_2	R_3	R_4
T1- **FP**	T3- **RDF**	T5- T_1 + **PMS**(0.5LR)	T5- T_1 + **PMS**(0.5LR)
T2- T_1 +**PG** @250Kg/ha	T8- T_4 + **PMS**(0.5LR)	T4- **RDF** + **PG** @ 250Kg/ha	T6-T2+ **PMS**(0.5LR)
T3-RDF	T7- T_3 + **PMS**(0.5LR)	T3-RDF	T1- **FP**
T4- **RDF** + **PG** @ 250Kg/ha	T2- T_1 +**PG** @250Kg/ha	T8- T_4 + **PMS**(0.5LR)	T2- T_1 +**PG** @250Kg/ha
T5- T_1 + **PMS**(0.5LR)	T5- T_1 + **PMS**(0.5LR)	T1- **FP**	T7- T_3 + **PMS**(0.5LR)
T6- T2+ **PMS**(0.5LR)	T4- **RDF** + **PG** @ 250Kg/ha	T2- T_1 +**PG** @250Kg/ha	T8- T_4 + **PMS**(0.5LR)
T7- T_3 + **PMS**(0.5LR)	T1- **FP**	T7- T_3 + **PMS**(0.5LR)	T3-RDF
T8- T_4 + **PMS**(0.5LR)	T6- T2+ **PMS**(0.5LR	T6- T2+ **PMS**(0.5LR)	T4- **RDF** + **PG** @ 250Kg/ha

3.4 Methods

Different observations related to plant growth and yield were recorded to study the effect of treatments. Plant and soil sample were collected and analyzed adopting different methods which are described below.

3.4.1 Analysis of soil samples

3.4.1.1Collection of soil samples

Composite soil samples from the experimental site before taking up the crop were collected from 0-15 cm, depth.

Similarly, soil samples from 0-15 cm depth were collected from all treatment plots after harvest of, with the help of a soil auger. The samples were dried under shade, crushed and sieved through 2mm sieve. Thus the samples were preserved in polythene covers with proper labels for analysis.

3.4.1.2 Analysis for physical & chemical properties of soil

3.4.1.3 Soil texture

The sand, silt and clay content of soil samples were determined by mechanical analysis method using Bouyoucos Hydrometer as given by Piper (1950).

3.4.1.4 Water holding capacity of soil:

The water holding capacity of the soil was determined on oven dry basis using Keen Rezowski box as described by Piper (1950).

3.4.1.5 Bulk Density of soil

The bulk density of experimental site at different depths before starting of the experiment was determined by core method as outlined by Black (1965).

3.4.1.6 Soil pH

Soil pH was determined in 1:2.5 soil water ratio by pH meter (ELICO, Model L 1613) as described by Jackson (1973).

3.4.1.7 Lime Requirement

To know the lime requirement Woodruff Buffer Reagent was used and procedure was followed as described in Page *et al.,* (1982)

Ten (10) gm of soil in a plastic beaker was taken, 10ml of distilled water was added, stirred, 2drops of $CaCI_2$ was added; pH of the soil suspension was taken with the help of a pH meter. This pH is called salt ph. Then 10cc of Woodruff buffer was added to it. Stirred and pH was recorded after30minutes. This is called as buffer pH.

Calculation

One mill equivalent weight of neutralizable acidity per 100 gm of soil is equivalent to 1000 kg/ha of pure, finely ground $CaC0_3$. The lime requirement then becomes:

Neutralizable acidity meq.mass/100gmx1000=kg/ha $CaC0_3$Iime requirement

For most crops it is neither economical nor necessary to lime soils to achieve a pH of 7. Assuming a linear relationship between the increase in soil pH and the quantity of lime applied, the lime requirement to attain a soil pH value less than 7.0 may be calculated as follows:

$$L' = L \text{ pH}'_s - pH' \div 7.0 - pH_s$$

Where L' is the Iime requirement to achieve a pH_s value less than 7.0, L is the lime requirement to achieve a pHs of 7.0, pH's is the soil pHs value desired, and pHs is the observed pHs.

3.4.1.8 Cation Exchange Capacity of soil

Cation exchange capacity of soil was determined by successive extraction with neutral 1N ammonium acetate as per the procedure outlined by jackon (1973). The excess NH^{4+}, adhered to the soil complex was washed with ethanol and then distillitation was done in kelplus Nitrogen auto analyzer to determine NH^{4+}.

3.4.1.9 Organic carbon content of soil:

The Organic carbon content of soil was determined by wet digestion procedure of walkley and Black (1934) as out lined in soil chemical analysis.(Page et al., 1982).

3.4.1.10 Available Nitrogen (N):

Available nitrogen in soil was determined by alkaline $KMno_4$ method (Subbiah and Asija, 1956) using Kelplus nitrogen auto analyzer (Kelplus: Model Classic DX).

3.4.1.11 Available phosphorus (P):

Available phosphorus in the soil was determined by Bray's method (Bray and Kurtz,1945).The reading was taken in Elico UV-VIS spectro photometer at 660 nm(Page *et al.,* 1982).

3.4.1.12 Available (K):

The available potassium fraction includes the water soluble and exchangeable K. Five grams of soil was equilibriated with 25 ml of neutral 1N ammonium acetate by shaking for 5 minutes. Then it was filtered and the K-concentration in the filtrate was determined in a flame photometer (Model: Systronics 128) after necessary dilution as described by Hanway and Heidal (1952).

3.4.1.13 Available S:

Available sulphur was determined by Turbidimetric method after extracting the soil with 0.15% $cacl_2$ as described by Williams and steinberge (1959) by using calorimeter.

3.4.2 Analysis of plant samples

Collection and processing of plant sample: At the time of harvesting five plants from each treatment were selected randomly. The different plant parts like root, shoot, husk and kernels were kept separately in envelops, labeled properly and dried in hot air oven at 50^0c. Each sample was ground separately with the help of willow mill to pass through 20 mesh sieve and was used for analysis of different elements.

Digestion: As per the method out lined by Piper (1950), 0.5g of grounded plant sample was pre-digested with 10 ml of concentrated HNO_3 followed by digestion with 5 ml of diacid (HNO_3:$HCLO_4$ = 3:2) on hot plate at 100^0c till dense white fumes evolved .The content was then filtered and transferred to a 50 ml volumetric flask and volume was made up with distilled water. This aliquot was preserved for analysis of different elements such as P, Ca, and Mg& S .Then P was analyzed by spectrophotometer (Elico UV-VIS spectrophotometer Model SI 164) at 470 mm as described by Jackon (1973).

3.4.2.1 Sulphur:

After suitable dilution of the aliquot, the samples were analysed by Spectrophotometer to determine the sulphur content of different plant parts of different treatments.

3.4.3 Yield and yield attributing characters

3.4.3.1 Plant height

About 10 plants from each plot were measured with respect to Height of plants. The height was measured in cm from ground level to the tip of the leaf.

The average height of 10 plants was considered as the height of the plant for each treatment.

3.4.3.2 Weight of Stover

Ground crop was harvested at maturity 105 days. The pods were separated from the plants. Then the plants were sun dried for three days and then weight of the stalk were measured with the help of an open pan electronic balance and the weight was expressed as q/ ha for biomass calculation.

3.4.3.3 Weight of pods

The sun dry weight of pods was measured in an electronic balance. Then one kilogram pods were dried under shade for 72 hours and the weight was taken in the balance.

3.4.3.4 Shelling percentage (%)

The weight of shell and weight of kernel was measured in an electric balance. The ratio of kernel weight to the the total weight of pods multiplied with 100 was taken as the shelling percentage.

3.4.3.5 Thousand seed weight

The weight of 100 kernels was measured in an electric balance and expressed in gram.

3.4.3.6 Number of pods per plants

The total no pods for five sample plants were counted and the average was taken as the no of pods per plant.

3.4.3.7 Estimation of Oil content of seeds

Oil content: Oil content of the grain samples was determined by the clod percolation method of kartha and Sethi (1957). About 0.5 gm of seed was accurately weighed and transferred to a porcelain mortar. Two gram each of glass powder (pyrex glass washed with conc. HCL) and anhydrous $Na_2 SO_4$ were added and the mixture was reduced to fine powder. The mixture was transferred was to a small glass percolator of 20 cm long and 1.5 cm in diameter and was packed over a layer of coarsely powdered anhydrous $Na_2 SO_4$ (0.25- 0.314 inch thick) supported on a thin layer of cotton wool over the perforated glass plate. The mortar and pestle were brushed twice with o.5 gm. of anhydrous $Na_2 SO_4$ and the washing was also packed over the seed powder. Finally the mortar and pestle were washed with 3-4 cc of freshly distilled petroleum ether BP70^0-90^0c and this washing was transferred to the packed meal powder. The initial 3-4 cc of solvent serves to wet the mixture.

This was allowed to remain as such for 5 minutes and then percolation started by adding measured quantity (20cc) of solvent on the top of the column. The collected solvent was evaporated by keeping the dish in an oven at 70^0 c till all the petroleum ether was evaporated. The remaining oil was weighed and the oil content was calculated.

3.5 Field Studies

Preparation of field

The entire plot was ploughed twice with disc plough and leveled with ladder. Plots of 4m×5m were prepared in Randomized Block Design (table 3.2). The groundnut crop was sown on 9/1/13. Seed rate was 125Kg/ha (kernel). The crop received full dose of fertilizer at the time of sowing. The crop was grown under rainfed condition. Hoeing, weeding and earthing up were done in time. Two sprayings with roger and indofil M-45 were given during pre flowering and pod formation stage to check pest and disease attack. The crop was harvested on Dt.11-5-2013 and plant Biometric observations were recorded plant & pod samples were collected for micro nutrient analysis.

Fertilizer & Lime application

Lime in the form of paper mill sludge (PMS), Phospogypsum & fertilizers were applied as per treatment plans. PMS was applied before 48 hours of sowing. Whereas Phospogypsum was applied 21 days after sowing of groundnut seeds in furrows, before flowering. A common recommended fertilizer dose of 20KgN/ ha, 40 KgP_2O_5/ha, 40Kg K_2O/ ha were applied to each plot through Urea, DAP and MOP as basal respectively.

Weed Management

Crop was weeded thrice and weeds were incorporated through crisscross runoff cone weeder at 10, 20, and 30 days after sowing.

Water management

The rainfall in the cropping season was well distributed and all the weeks were wet weeks. Hence, irrigation was not applied to any treatment. Only drainage of excess rainwater was done and water managed in the field as per the requirement of the treatments.

Plant protection

No major incidence of insect and disease attack was noticed.

Harvesting and threshing:

On dated 11.05.2013 the groundnut crop was harvested. After harvest, pod was dried under sun for three days. Treatment wise pod and Stover samples were collected, labeled and stored for analysis.

3.6 Statistical analysis

The biometric data, nutrient uptake, pod and Stover yield were recorded, compiled in appropriate tables and analyzed statistically as per the procedure prescribed for split plot design (Gomez and Gomez, 1984). To obtain the analysis of variance table, standard error of means i.e., SE(m)± were determined in all the cases , while critical difference (CD) at 5% level of significance was estimated only in cases 'F' test was found significant.

Fig.1. Taking observations

Chapter 4

Results

An experiment was conducted to find out the effect of phospho gypsum and paper mill sludge on groundnut in a Rice-Groundnut cropping system of Acid soils. Results are furnished below.

Table.1. Initial soil properties of soil

Parameter	Value
Textural class	Loam
Infiltration (cc/hr)	2.4
Bulk density (g cc^{-1})	1.55
Particle Density (g cc^{-1})	2.68
Pore space (%)	42.2
pH (1:2.5)	4.95
EC (dS m^{-1})	0.12
O.C. (g kg^{-1})	4.3
CEC [coml.(p+)kg^{-1}]	3.75
Avail. N (kg ha^{-1})	220
Avail. P (kg ha^{-1})	19.4
Avail. K (kg ha^{-1})	187
Avail. S (kg ha^{-1})	19

4.1. Effect of Amendments on Physico-Chemical Properties of Soil

4.1.1 Soil pH

Table.3. Effect of amendments on soil pH

Treatments	pH
T_1- FP	5.16
T_2- T_1 +PG @ 250 Kg/ha	5.35
T_3- RDF	5.29
T_4 - RDF + PG 250Kg/ha	5.37
T_5 -T_1 + PMS(0.5LR)	6.1
T_6 -T_2 + PMS(0.5LR)	5.92
T_7 -T_3 + PMS(0.5LR)	6.13
T_8 -T_4 + PMS(0.5LR)	6.21

4.1.2 Effect of amendments on available Nitrogen, Phosphorus, Potassium and Sulphur content in the soil

Table.4. Available nutrient status of the post harvest soil samples.

Treatments	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Av. S (kg/ha)
T_1- FP	224.75	17.45	224.88	37.1
T_2- T_1 +PG @ 250 Kg/ha	237.75	19.28	199.04	40.75
T_3- RDF	249.25	20.55	237.00	40.25
T_4 - RDF + PG 250Kg/ha	238.50	20.25	223.00	41.25
T_5 -T_1 + PMS(0.5LR)	231.00	18.68	214.25	41.75
T_6 -T_2 + PMS(0.5LR)	239.75	21.05	229.25	39.50
T_7 -T_3 + PMS(0.5LR)	256.25	27.13	239.00	41.01
T_8 -T_4 + PMS(0.5LR)	234.75	21.93	227.75	38.64
Initial soil	220	19.4	187	19

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T_7 -T_3 + PMS(0.5LR)	256.25	27.13	239.00	41.01
T_8 -T_4 + PMS(0.5LR)	234.75	21.93	227.75	38.64
Initial soil	220	19.4	187	19

4.2. Plant Uptake of nutrients as influenced by different ameliorating materials.

Table.5. Concentration, Uptake of 'Nitrogen' by Groundnut as influenced by different ameliorating materials.

Treatments	Concentration (%)	Uptake (kg/ha)
T_1- FP	8. 72	123.15
T_2- T_1 +PG @ 250 Kg/ha	10.85	127.80
T_3- RDF	12.45	140.05
T_4 - RDF + PG 250Kg/ha	8.01	132.50
T_5 -T_1 + PMS(0.5LR)	8.67	129.25
T_6 -T_2 + PMS(0.5LR)	6.72	131.80
T_7 -T_3 + PMS(0.5LR)	8.08	135.68
T_8 -T_4 + PMS(0.5LR)	7.77	129.50
CD (0.05)	0.97	4.61

Table.6. Concentration, uptake of 'Phosphorus' by Groundnut as influenced by different ameliorating materials.

Treatments	Concentration (%)	Uptake (kg/ha)
T_1- FP	0.14	6.78
T_2- T_1 +PG @ 250 Kg/ha	0.16	7.30
T_3- RDF	0.15	6.08
T_4 - RDF + PG 250Kg/ha	0.17	8.10
T_5 -T_1 + PMS(0.5LR)	0.14	7.13
T_6 -T_2 + PMS(0.5LR)	0.11	6.63
T_7 -T_3 + PMS(0.5LR)	0.16	6.88
T_8 -T_4 + PMS(0.5LR)	0.14	7.20
CD (0.05)	0.02	0.80

Table.7. Concentration, Uptake of 'Potassium' by Groundnut as influenced by different ameliorating materials.

Treatments	Concentration (%)	Uptake (kg/ha)
T_1- FP	0.68	25.25
T_2- T_1 +PG @ 250 Kg/ha	0.86	26.73
T_3- RDF	0.76	24.45
T_4 - RDF + PG 250Kg/ha	0.84	28.28
T_5 -T_1 + PMS(0.5LR)	0.81	26.90
T_6 -T_2 + PMS(0.5LR)	0.99	28.33
T_7 -T_3 + PMS(0.5LR)	0.96	30.19
T_8 -T_4 + PMS(0.5LR)	1.10	30.83
CD (0.05)	0.10	1.18

Table.8. Concentration, uptake of 'Sulphur' by Groundnut as influenced by different ameliorating materials.

Treatments	Concentration (%)	Uptake (kg/ha)
T_1- FP	0.17	1.87
T_2- T_1 +PG @ 250 Kg/ha	0.23	2.90
T_3- RDF	0.18	2.90
T_4 - RDF + PG 250Kg/ha	0.22	2.58
T_5 -T_1 + PMS(0.5LR)	0.17	2.80
T_6 -T_2 + PMS(0.5LR)	0.20	2.31
T_7 -T_3 + PMS(0.5LR)	0.18	2.77
T_8 -T_4 + PMS(0.5LR)	0.21	3.06
CD (0.05)	0.01	0.14

Table.9. Plant uptake of nutrients by Groundnut crop

Treatments	N -Uptake (kg/ha)	P -Uptake (kg/ha)	K -Uptake (kg/ha)	S -Uptake (kg/ha)
T_1- FP	123.15	6.78	25.25	1.87
T_2- T_1 +PG @ 250 Kg/ha	127.8	7.3	26.73	2.9
T_3- RDF	140.05	6.08	24.45	2.9
T_4 - RDF + PG 250Kg/ha	132.5	8.1	28.28	2.58
T_5 -T_1 + PMS(0.5LR)	129.25	7.13	26.9	2.8
T_6 -T_2 + PMS(0.5LR)	131.8	6.63	28.33	2.31
T_7 -T_3 + PMS(0.5LR)	135.68	6.88	30.19	2.77
T_8 -T_4 + PMS(0.5LR)	129.5	7.2	30.83	3.06
SE(m)±	1.57	0.27	0.4	0.87
CD(0.05)	4.61	0.8	1.18	0.14

4.3 Yield attributes as an influenced by different liming materials

Table.10. Effect of different ameliorating materials on pod yield of groundnut crop

Treatments	Pod yield(q/ha)	% increase over Farmers Practice
T_1- FP	12.25	
T_2- T_1 +PG @ 250 (Kg/ha)	13.375	9.18
T_3- RDF	12.875	5.10
T_4 - RDF + PG 250Kg/ha	13.375	9.18
T_5 -T_1 + PMS(0.5LR)	13.875	13.26
T_6 -T_2 + PMS(0.5LR)	13.375	9.18
T_7 -T_3 + PMS(0.5LR)	15.375	25.5
T_8 -T_4 + PMS(0.5LR)	14.125	15.30
CV (%)	1.46	
CD(0.05)	0.29	

Table.11. Effect of different ameliorating materials on seed yield (Quintal/ha) of groundnut crop

Treatments	Seed yield(Quintal/ha)	% increase over Farmers Practice
T_1- FP	8.35	
T_2- T_1 +PG @ 250 (Kg/ha)	9.29	11.2
T_3- RDF	9.04	8.2
T_4 - RDF + PG 250Kg/ha	9.47	13.4
T_5 -T_1 + PMS(0.5LR)	9.63	15.3
T_6 -T_2 + PMS(0.5LR)	9.32	11.6
T_7 -T_3 + PMS(0.5LR)	11.02	31.9
T_8 -T_4 + PMS(0.5LR)	10.03	20.1
CV (%)	3.42	
CD(0.05)	0.48	

Table.12. Effect of different ameliorating materials on Shelling (%) of groundnut crop

Treatments	Shelling (%)	% increase over Farmers Practice
T_1- FP	68.1	
T_2- T_1 +PG @ 250 (Kg/ha)	69.4	2
T_3- RDF	70.21	3.1
T_4 - RDF + PG 250Kg/ha	70.80	3.9
T_5 -T_1 + PMS(0.5LR)	69.47	2.01
T_6 -T_2 + PMS(0.5LR)	69.6	2.2
T_7 -T_3 + PMS(0.5LR)	70.4	3.3
T_8 -T_4 + PMS(0.5LR)	71.6	**5.1**
CV (%)	1.17	
CD(0.05)	1.20	

Table.13. Effect of different ameliorating materials on no of effective pegs per plant

Treatments	no of effective pegs per plant	% increase over Farmers Practice
T_1- FP	13.75	
T_2- T_1 +PG @ 250 (Kg/ha)	15.25	10
T_3- RDF	16.00	16
T_4- RDF + PG 250Kg/ha	16.75	21.8
T_5 -T_1 + PMS(0.5LR)	15.25	11
T_6 -T_2 + PMS(0.5LR)	15.75	14.5
T_7 -T_3 + PMS(0.5LR)	15.50	12
T_8 -T_4 + PMS(0.5LR)	17.50	**27**
CV (%)	3.66	
CD(0.05)	16.26	

Table.14. Effect of different ameliorating materials on no of seeds per pod

Treatments	no of seeds per pod	% increase over Farmers Practice
T_1- FP	1.4	
T_2- T_1 +PG @ 250 (Kg/ha)	1.58	13
T_3- RDF	1.58	13
T_4- RDF + PG 250Kg/ha	1.68	20
T_5 -T_1 + PMS(0.5LR)	1.63	16.4
T_6 -T_2 + PMS(0.5LR)	1.73	23
T_7 -T_3 + PMS(0.5LR)	1.63	16.4
T_8 -T_4 + PMS(0.5LR)	1.75	**25**
CV (%)	0.09	
CD(0.05)	3.66	

Table.15. Effect of different ameliorating materials on Weight of 100 seeds (gm)

Treatments	Weight of 100 seeds (gm)	% increase over Farmers Practice
T_{1}- FP	37.25	
T_{2}- T_{1} +PG @ 250 (Kg/ha)	42.50	14
T_{3}- RDF	38.50	3.3
T_{4} - RDF + PG 250Kg/ha	42.50	14
T_{5} -T_{1} + PMS(0.5LR)	41.50	11.4
T_{6} -T_{2} + PMS(0.5LR)	42.25	13.4
T_{7} -T_{3} + PMS(0.5LR)	38.75	4
T_{8} -T_{4} + PMS(0.5LR)	43.25	**16.1**
CV (%)	1.20	
CD(0.05	1.99	

Table.16. Effect of different ameliorating materials on Oil content of the seeds

Treatments	Oil content (%)	% increase over Farmers Practice
T_{1}- FP	38	
T_{2}- T_{1} +PG @ 250 (Kg/ha)	41.01	7.9
T_{3}- RDF	42.22	11.1
T_{4} - RDF + PG 250Kg/ha	41.01	7.9
T_{5} -T_{1} + PMS(0.5LR)	41.21	8.44
T_{6} -T_{2} + PMS(0.5LR)	42.01	10.5
T_{7} -T_{3} + PMS(0.5LR)	45.21	18.97
T_{8} -T_{4} + PMS(0.5LR)	46.21	21.6
CV (%)	2.78	
CD(0.05)	4.49	

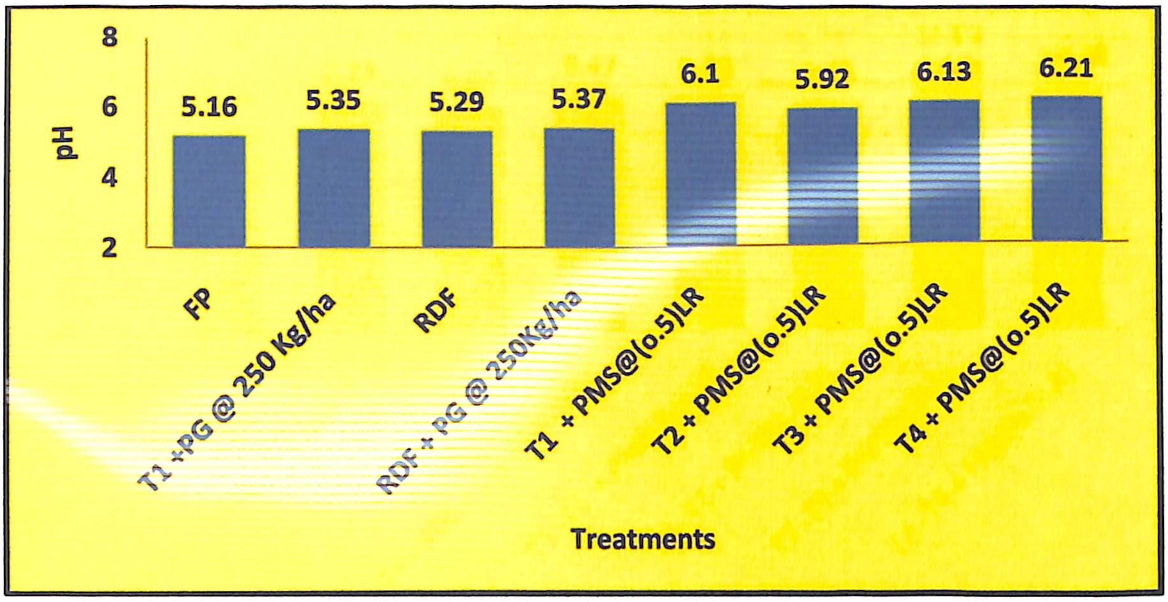

Fig.2 Effect of amendments on soil pH

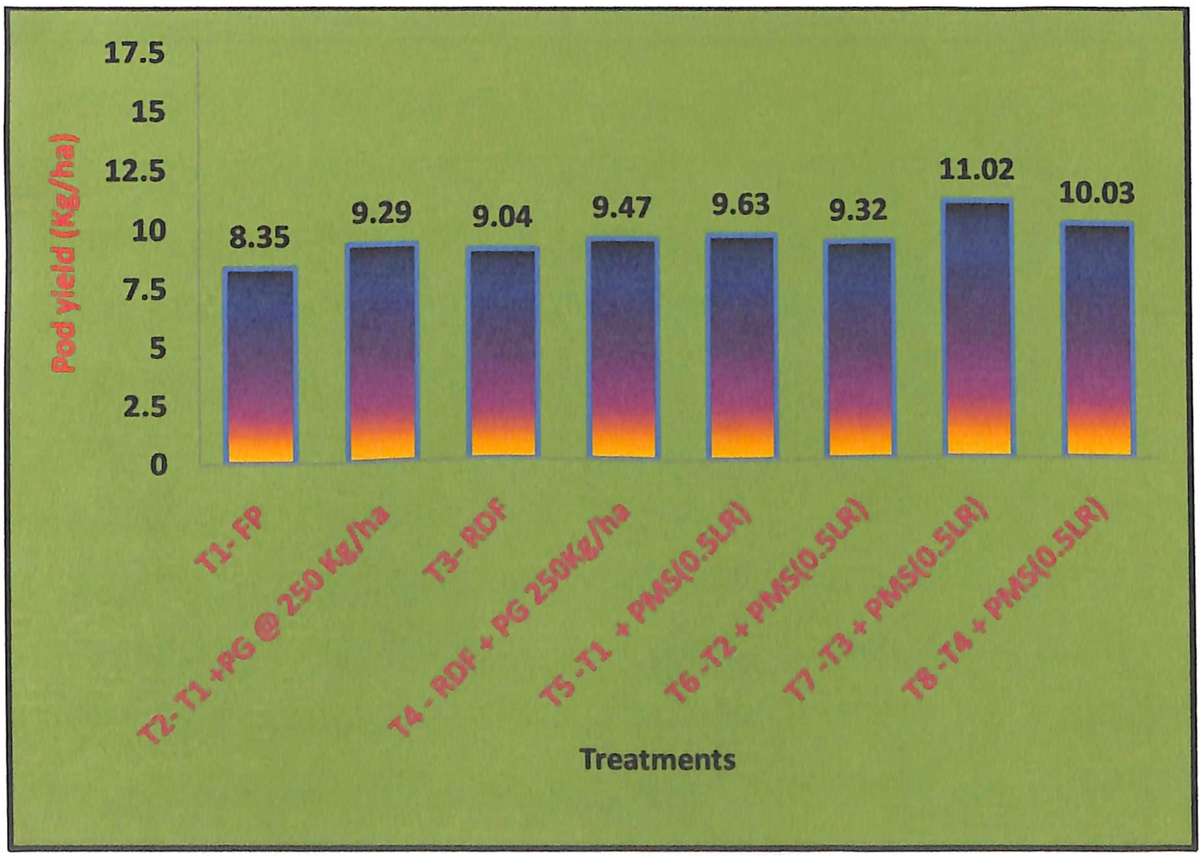

Fig.3 Effect of amendments on pod yield

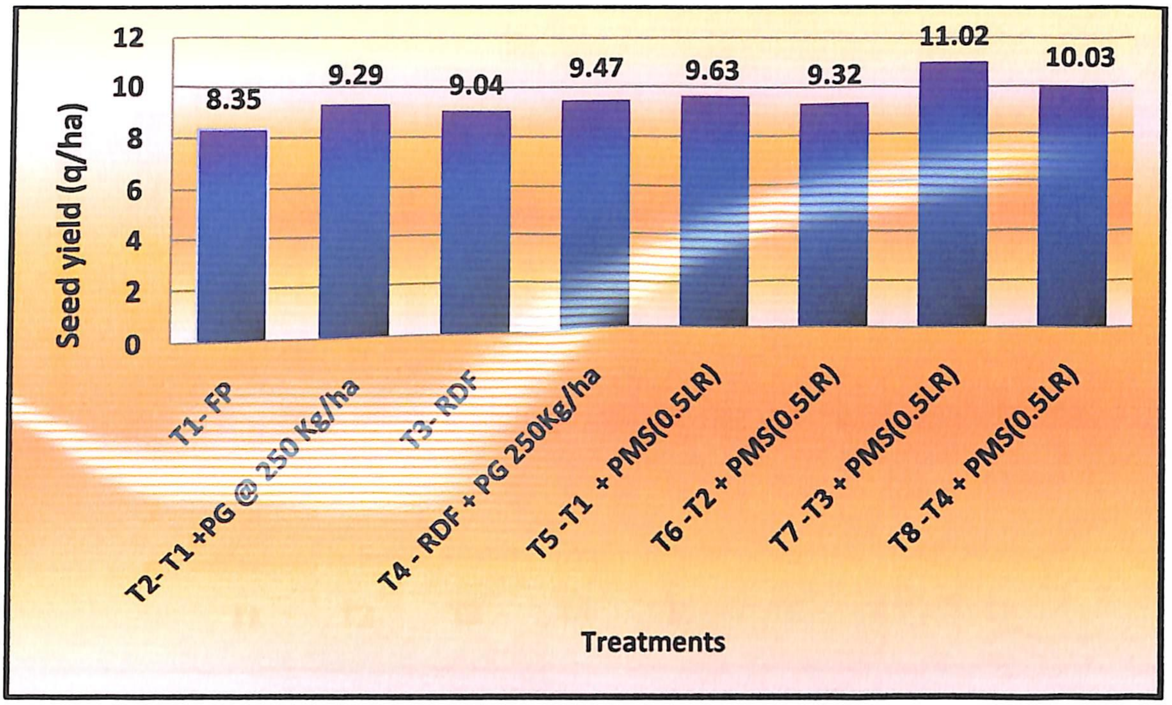

Fig.4 Effect of amendments on seed yield

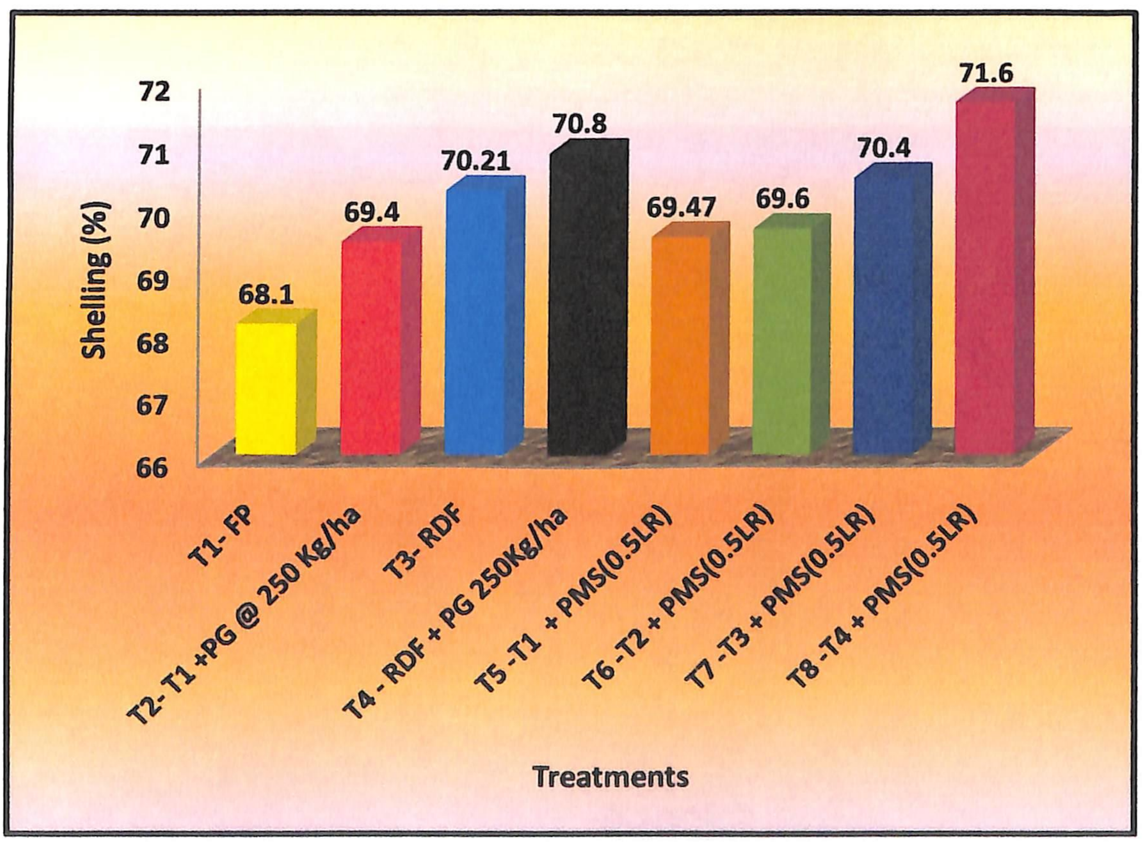

Fig.5 Effect of amendments on shelling (%)

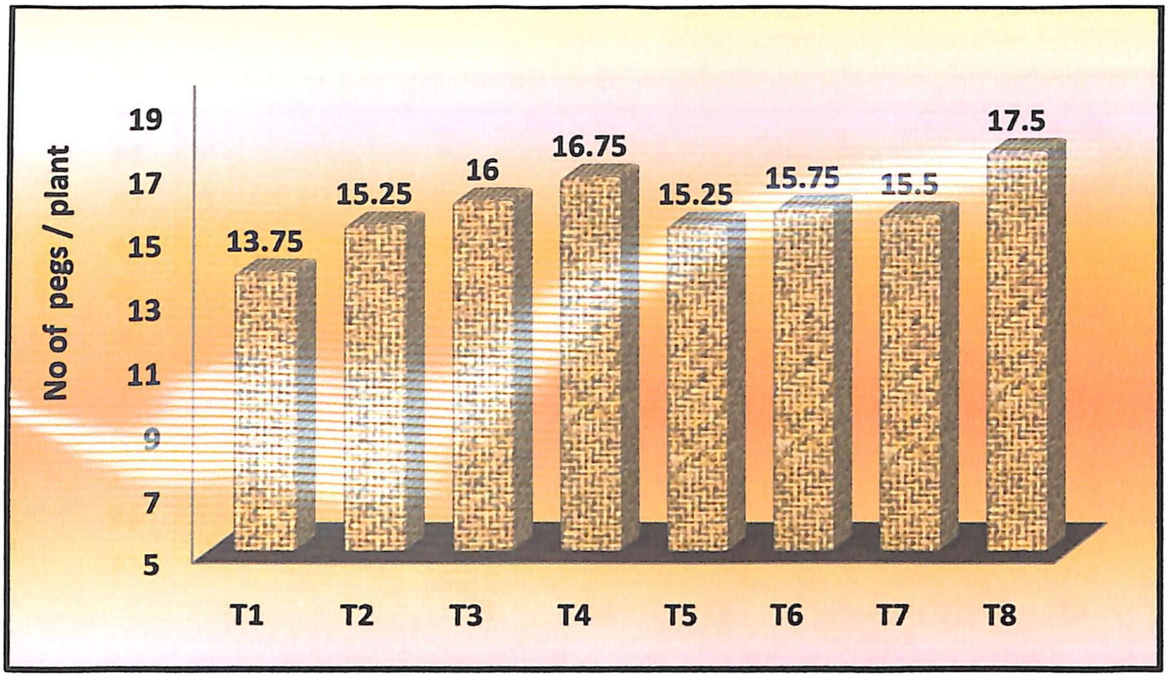

Fig.6 Effect of amendments on no of pegs/plant

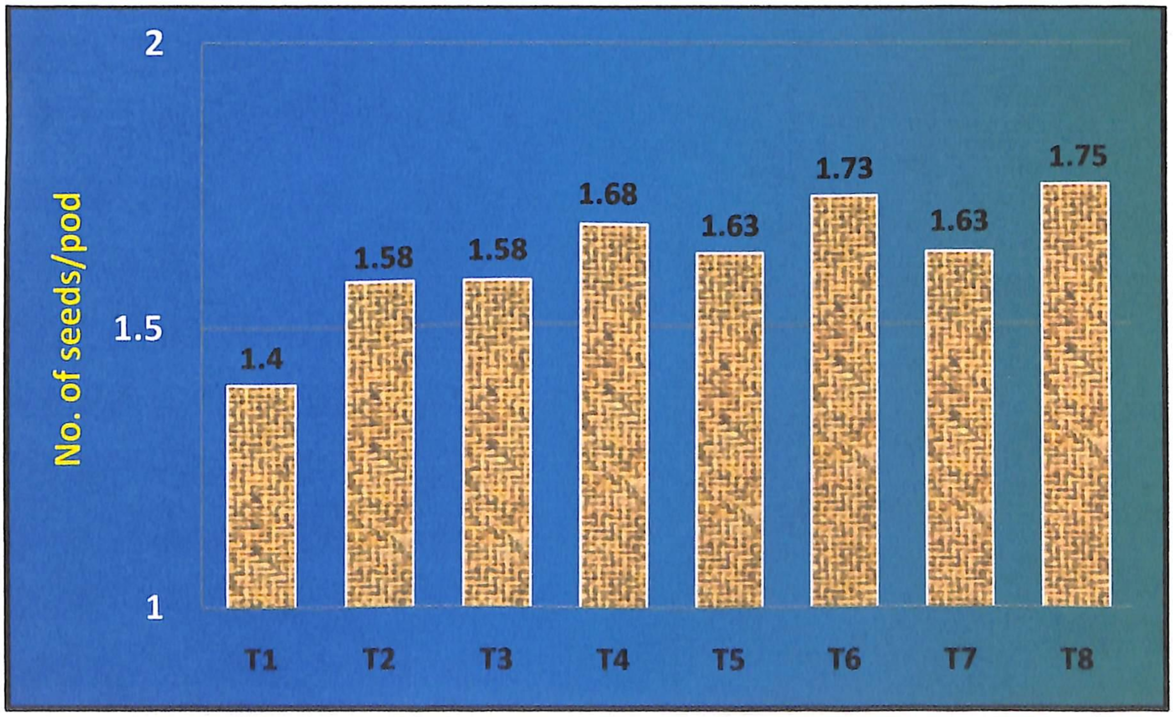

Fig.7 Effect of amendments on of seeds/pod

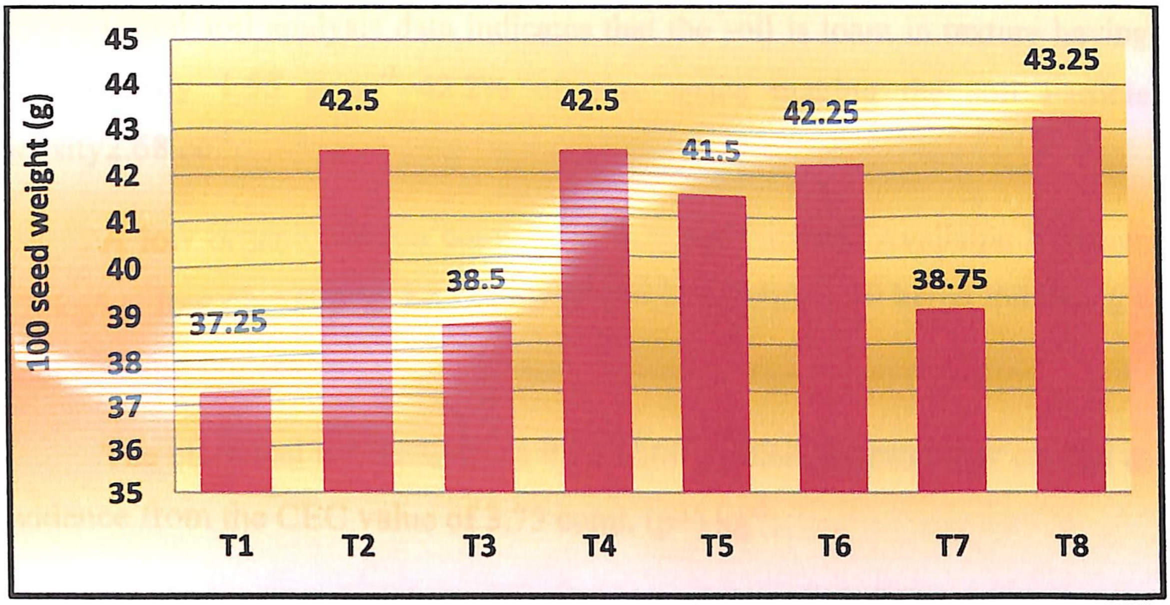

Fig.8. Effect of amendments on 100 seeds weight (g)

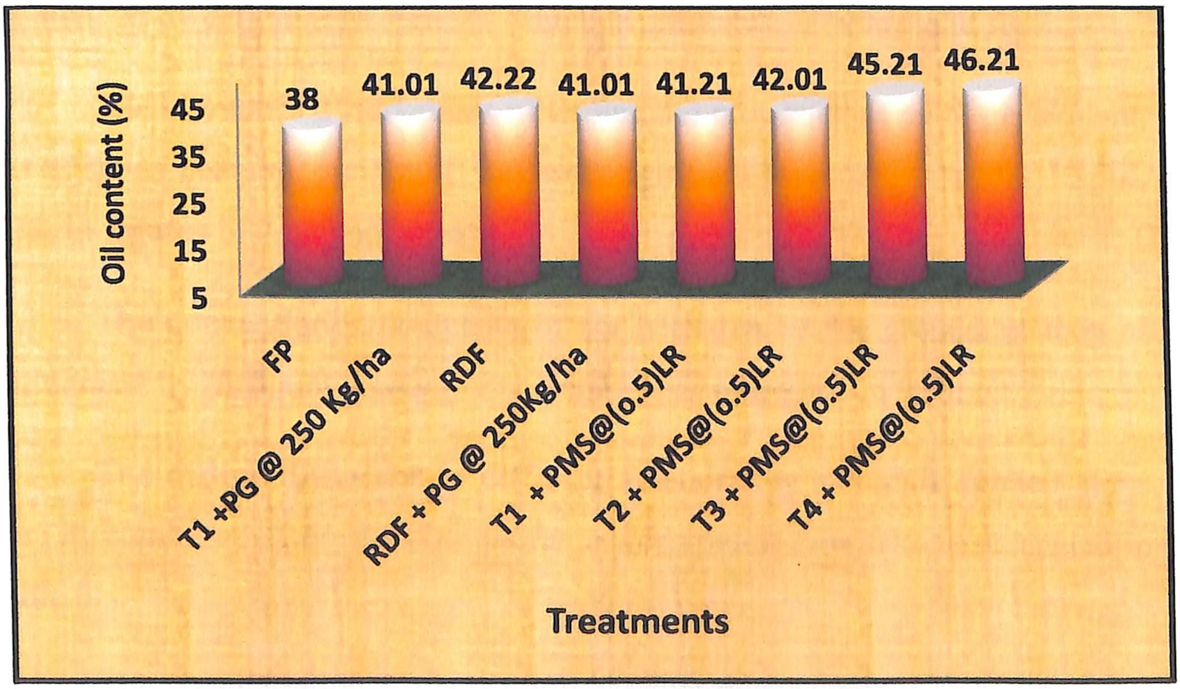

Fig.9 .Effect of amendments on Oil content (%) in the seeds

Initial soil analysis data indicates that the soil is loam in texture having bulk density 1.55 g cc^{-1} 42.2% of pore space making the soil Particle density2.68 cc^{-1}.

A low organic carbon content i.e. 4.3g/kg with low Available Nitrogen 220kg/ha, low phosphorus i.e.19.4kg/ha and low Sulphur 19 kg/ha indicating a poor soil sulphur status.

The electrical conductivity is 0.12 dSm^{-1}, which indicates low cations as evidence from the CEC value of 3.75 coml. (p+) kg^{-1}.

The first year groundnut yield as affected by treatments is presented in Table.10 and fig.3

The shelling % as affected by different treatments is presented in fig. 5 and table.12

The soil pH after harvest of the crop showed distinct variation as influenced by different treatments, which is presented in table.3 and fig 2.

The biometric observations of Groundnut crop such as no of pegs/ plant, no of seeds per pod, weight of 100 seeds (gm) are presented in tables 13, 14, 15& in figures 6, 7, 8 respectively.

The concentration & uptake of the Nitrogen by the groundnut crop as influenced by different ameliorating materials as presented in table 5.

The distinct influence of different ameliorating materials applied alone (or) in combination on the phosphorus concentration & uptake is presented in table 6.

The concentration & uptake of potassium by Groundnut crop influenced by different treatments is presented in table 7.

The vital nutrient effecting yield & oil content of the Groundnut i.e. Sulphur was applied alone & in combination with liming materials has affected the yield & Oil content along with its concentration & uptake by the groundnut crop is presented in tables 8and 16.

The post-harvested soil sample analysis for its reaction & nutrient status as pH, available Nitogen, available Phosphorus, available Potassium and available Sulphur are presented in tables 3 and 4.

Oil content of the Groundnut crop as influenced by different liming materials in different treatments is presented in table 16 and fig 9.

Chapter 5

Discussions

DISCUSSION

The initial soil analysis data gives an idea that in the experimental site the loam textured alluvial soil having low pH (4.95) low organic carbon (4.3g/kg) and low nutrients like N, P, K, S. When the ideal condition for an experiment as designed, to ascertain the effect of different ameliorating materials like soil acidity amelioration with paper mill sludge and Ca and Sulphur supplementation with gypsum.

Usually the farmers practice of imbalanced fertilizer dose for growing Groundnut in that acidic soil having loam texture and low organic matter is in appropriate to get a good crop of Groundnut with higher oil contents. The combination of treatments such as farmers practice, recommended dose of fertilizers, and application of PMS along with farmers practice and recommended dose of fertilizer and for supplementation of Ca and Sulphur for Groundnut crop Phosphogypsum is applied alone as well as along with recommended dose of fertilizer and different treatments with PMS.

The results in fig1& table 3 indicating the soil pH as influenced by PMS application alone and in combination with Phospho gypsum gives an idea that PMS when applied @0.5 LR along with farmer practice improve the soil pH from 4.9 to 5.16.

Phosphogypsum when applied along with farmers practice does not significantly reduced the soil pH. Which indicates it's suitability for the Groundnut crop in an acid alluvium at the rate of 250 Kg/ha. This is confirm the pod yield as presented as presented in table 10, but when applied along with PMS with recommended dose of fertilizer gives highest pod yield and higher shelling (%). The combined application of PMS and Phosphogypsum raises the soil pH to 6.21, as indicated in table 3 but does not significantly increase in pod yield.

Interestingly the no of effective pegs/ plant are highest where Phosphogypsum is applied with PMS along with recommended dose of fertilizer.

The effective seeds/pod is also more in case where PMS applied along with PG.

The plant uptake of different nutrients is also affected by use either of ameliorants single or in combination.

In absence of both PG and PMS as in case of treatment 3 the Nitrogen uptake by the groundnut crop is higher i.e. 140.05 Kg/ha as presented table 9.

In the entire treatments, phosphorus uptake is found highest in treatment 4 i.e. 8.1Kg/ha in absence of PMS, but Potassium uptake is guided by application of PMS as well as PG to the highest level.

The Sulphur uptake is higher in all the treatments where Phosphogypsum is applied, but its uptake is highest in presence of PMS. This is confirmed from the results as shown in table 9.

Available Nitrogen content was highest i.e.256Kg/ha in case of treatment 7 i.e. when PMS applied along with recommended dose of fertilizer. It also shows in case of available 'P' which is 23 Kg/ha.

The Potassium content of post harvest soil was also highest under the treatment 7 where PMS was added along with recommended dose of fertilizer. The highest Sulphur content i.e. 41.75 Kg/ha as in case of the Treatment 5 where farmers practice combined with PMS @0.5LR is reported.

pH of post harvest soil sample of treatment 8 indicates that Phosphogypsum whether applied alone or in combination with does not affect the soil pH .

The yield attributes such as pod yield, shelling %, seed yield, weight of 100 seeds (gm) & oil content of the seeds as detailed in 10, 11, 12, 13 tables indicates that highest pod yield of 15.3 q/ha, so also seed yield of 11.2quitols per hectare in treatment 7 may be due to a localized effect since the data is significant.

46.21 % oil content having 43.25 gm /100 seed weight indicates that PG & PMS as positive reaction on nutrient uptake by the Groundnut crop.

The relationship between different treatments on oil content, shelling % of the groundnut clearly indicates that phospho gypsum along with RDF and Paper mill sludge as got direct effect.

The 71% shelling % of the groundnut seeds under treatments indicates the proper utilization of available Ca and Sulphur by the Groundnut crop.

The shelling(%),no of effective pegs/ plant, weight of 100 seeds and oil content are highest in case of treatment 8. This clearly indicates the combined application of PG and PMS supplementing both sulphur and Ca for improvement of such qualities.

Chapter 6

Summary and Conclusion

SUMMARY AND CONCLUSION

From the present experiment conducted in an acidic alluvial soil of Delong block, it is observed that PMS applied alone & along with recommended dose of fertilizer gives significantly higher yield over the farmers practice.

The combination of Phospho gypsum & Paper mill sludge gives higher oil content as the % Oil content increased with increase in availability of Ca and Sulphur.

Thus combined application of Paper mill sludge in a Groundnut- Paddy cropping sequence in acid alluvial soils will definitely increase nutrient status of the soil.

Application of PMS along with Phospho gypsum and recommended dose of fertilizer to ground nut crop in a Rice-Groundnut cropping sequence is definitely profitable as there is increase in total production of Groundnut oil and amelioration of the soil acidity making it conducive for a higher rice yield.

Concluding best combination of Phospho gypsum with Paper mill sludge & recommended dose of fertilizer from the one year data needs further confirmation with subsequent results.

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