EFFECT OF SOIL AMELIORANTS AND NUTRIENT LEVELS ON PRODUCTIVITY OF MAIZE (*Zea mays* L.)

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EFFECT OF SOIL AMELIORANTS AND NUTRIENT LEVELS ON PRODUCTIVITY OF MAIZE (*Zea mays* L.)

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It is further certified that the assistance and help received by her during the course of investigation have been duly acknowledged.

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ABSTRACT

Topic : "EFFECT OF SOIL AMELIORANTS AND NUTRIENT LEVELS ON PRODUCTIVITY OF MAIZE (*Zea mays* L.)"

In Jharkhand, maize is being grown under upland situations. Upland soils are red and lateritic, highly permeable, coarse textured, shallow depth with low base saturation, CEC and water retention capacity, acidic in reaction, low in organic matter as well as deficient in nitrogen and phosphorus. In this situation, lime and FYM may serve as important ameliorant affecting maize production. Proper management of soil fertility with integrated use of lime, FYM and chemical fertilizers are the key factors in sustaining the productivity of maize. Keeping these facts in view, an experiment entitled "Effect of soil ameliorants and nutrient levels on productivity of maize" was conducted in acidic sandy loam soil having pH- 5.39, organic carbon 0.51% , available nitrogen 200.70 kg/ha, available phosphorus 12.76 kg/ha, available potassium 150.07 kg/ha and exchangeable calcium 2.14 m eq/100 g of soil. Treatments consisting of different combinations of soil ameliorants and nutrient levels, soil ameliorants in main plot nutrient levels in sub plot was laid out in split plot design and replicated thrice.

Results revealed that productivity of maize was influenced by ameliorants as well as levels of nutrients. Among ameliorants, FYM @5 t/ha and lime @3q/ha produced higher grain yield 50.75 q/ha, gross return Rs. 37580/ha, net return Rs.19835/ha and benefit: cost ratio 1.11, however on par with treatment receiving only FYM as ameliorant. In case of nutrient levels, treatment receiving 125% RDF (125kg/ha N, 52.5 kg/ha P_2O_5 and 31.25kg K_2O_5/ha) produced higher grain yield 52.49 q/ha, gross return Rs. 38721/ha, net return Rs. 21359/ha and benefit cost ratio 1.23. Higher productivity of maize either with ameliorants or nutrient levels was due to better growth and yield attributes of maize crop.

Nutritional status of soil was also influenced with ameliorants and nutrient levels to maize crop. In case of nitrogen, positive balance was observed where lime alone or with FYM was applied. Whereas nitrogen balance due to different levels of nutrients was negative when recommended or higher level of RDF was applied. Above change in nitrogen balance was due to higher production of maize grain and consequently removal of nutrients by crop. Phosphorus balance was positive irrespective of soil ameliorants and nutrient levels. However, phosphorus balance increased with increasing nutrient levels and with application of ameliorants. In regard to potassium and calcium, all the combinations of nutrient levels and ameliorants recorded negative balance, losses of nutrients however showed a decreasing trend with application of ameliorants and increasing nutrient levels.

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INTRODUCTION

Maize, one of the most important crops in the world, is grown as both food and feed crop. It being C-4 plant, has a highly resource efficient plant system. Actually, C-4 mechanism helps this crop in adapting to a wide range of climatic conditions. It has also got very high yield potential and hence called queen of cereals. A major shift in global cereal demand is realized and it is postulated that by 2020, demand for maize in developing countries will surpass the demand for both wheat and rice. According to IFPRI 2000 report, its requirements in developing world alone will increase from 282 m tonnes in 1995 to 504 m tonnes in 2020. Although 68% of the global maize area is in developing world, it contributes to only 46% of the world's maize production. The average maize yield in the developed countries is more than 7 t/ha, while in the developing world it is only around 3 t/ha. In India, it occupies an area of 6.8 m ha with a production of 11.4 m tonnes and productivity of 1.67 t/ha which is very less as compared to leading maize producing countries. In Jharkhand maize is grown in about 1.86 lac ha with an average production of 2.69 m tonnes and productivity of 1.45 t/ha which is again nearly 13.2% less than the national average.

In most developing countries, particularly those with large populations, the accelerating demand for maize must be met through large increases in domestic supply, largely through intensifying the productivity on current maize land. There are many factors affecting productivity of maize out of which soil fertility coupled with soil reaction as well as drainage characteristics are most important. Maize production is highly influenced by the soil fertility level, as it is a very heavy feeder of nutrients, especially N. The utilization of applied fertilizers during rainy season is further depleted owing to runoff and leaching losses of fertilizer N. Recent reports reveal that repeated growing of maize crop diminishes the soil nutrient status as recommended doses of fertilizers during the period of green revolution have become suboptimal now. Hegde and Katyal (1998) have also reported a declining trend in yields of maize over years even with NPK application.

Agro-ecological condition of Jharkhand favors successful cultivation of maize crop in upland during rainy season. This region is having undulating toposequences and maize is being grown under upland situations. Upland soils are red and lateritic, highly permeable, coarse textured, shallow depth with low base saturation, cation exchange and water retention capacity, acidic in nature, low in organic matter as well as deficient in nitrogen and phosphorus. In this situation lime may serve as an important ameliorant for correcting the soil acidity and thereby making the nutrients more available to the crops. FYM is yet another ameliorant improving physical, chemical and biological properties of soil. It plays key role in transformation, recycling and availability of nutrients to crops. Thus, FYM can help in enhancing and maintaining stability in production with least degradation in physical, chemical and biological properties of soil. Especially in Jharkhand where soils of nearly 85% of the total geographical area show moderate to strong acidic reaction and most of the maize crop is grown in upland situation, proper management of soil fertility with integrated use of lime, FYM and chemical fertilizers may be the key factors in sustaining the productivity of maize crop in this region.

Keeping these points in view, the experiment was conducted with following objectives:

- To find out the effect of soil ameliorants and nutrient level on growth, development and productivity of maize.
- To find out the effect of soil ameliorants and nutrient level on nutrient uptake and soil fertility status.
- To assess the effect of soil ameliorants and nutrient level on economics of maize cultivation.

REVIEW OF LITERATURE

Fertility is a very important factor affecting productivity of maize. High doses of fertilizers along with soil ameliorants like FYM and lime are beneficial in increasing productivity of maize. Use of chemical fertilizers alone for increasing crop production is not sustainable on long-term basis, since it may lead to nutrient imbalance. It is being increasingly realized that combined application of organic manure and chemical fertilizers is essential to maintain and improve soil and crop productivity (Subbian and Palaniappan, 1992).

2.1 Effect of FYM alone or in combination with Inorganic Fertilizers on Maize

2.1.1 Growth

Growth is the irreversible increase in size and weight on dry weight basis of plant. It is assessed by various parameters like plant height, dry matter accumulation, leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR), etc. Periodic measurement of leaf area index, dry matter accumulation, root weight and root density at flowering of maize increased on application of FYM with chemical fertilizers (Suri and Jha, 1996).

According to Singh and Totawat (2002), application of organic and chemical fertilizers resulted in better crop growth, which was evident from increased LAI and dry matter accumulation compared with only chemical fertilizers. The increased LAI and dry matter accumulation provided a better source sink relationship enabling greater synthesis and translocation of metabolites to reproductive organs leading to improved grain yield of maize.

According to Tolessa Debele *et al*. (2001), application of 4 tonnes of enriched FYM or 8 tonnes of conventional FYM/ha significantly increased leaf area index, leaf area duration, dry matter acuumulation in cobs as well as total dry matter accumulation.

Sankhyan *et al.* (2001) reported that dry matter accumulation of maize increased significantly with the application of 10 t FYM/ ha over no application of FYM.

According to Vadivel *et al*. (1999), the application of organic sources increased the dry matter production at 90 days after sowing compared to the control. Maize treated with FYM and 60 kg N/ha had the highest dry matter production.

2.1.2 Yield attributes and yield

Seed yield of maize increased significantly on application of 10 tonnes of FYM along with 50, 75 and 100% of RDF as compared to no application of organic manure because of increased seed weight per cob (Manjunath *et al*. 2006). Application of FYM at 10 t/ha significantly improved the cobs/plant, grain rows/cob, weight of cob, grain weight/cob, seed index and seed and stover yield from crop over no FYM application. The magnitude of increase in seed and stover yield was to the extent of 13.9 and 11.2%, respectively with the incorporation of 10 tonnes FYM/ha over no organic manuring. It might be owing to beneficial effect of FYM on crop growth and various physiological parameters, which affected yield attributes, yield and nutritional status of grains positively. The higher photosynthetic efficiency of plants estimated in terms of biomass accumulation seems to be one of the potential factors for improving various yield components and yield (Mehta *et al*. 2005).

Kumar and Thakur (2004) also reported increase in maize yield on addition of 10 tonnes FYM/ha along with 100% recommended dose of fertilizers to the extent of 8.03% as compared to only 100% RDF without FYM. Mahala and Shaktawat (2004), reported increased number of cobs per plant, number of grains per cob, 100 grain weight and grain yield with increasing rates of FYM up to 10 t/ha.

In a long-term experiment on organic amendments in the form of FYM, yield of maize increased significantly with application of organic manures which further led to increased organic carbon, available N, P and K contents of soil (Thind *et al*. 2002).

Maize yield was increased on application of 20, 40 and 60 tonnes FYM/ ha either alone or in combination with inorganic fertilizers. However, application of manure at 20 t/ha was considered as highly cost effective (Stefanescu, 2002). Application of 10 tonnes of FYM in addition to recommended fertilizer increased the maize grain yield by 13.98% over recommended fertilizers only (Kumar *et al*. 2002).

Verma *et al*. (2002), working on targeted yield concept suggested that fertilizer recommendations for yield target of 40 q/ha of maize, integrated with additional 5 t/ha FYM would not only increase grain yield by approximately 4.2 to 5.7 q/ha but also build-up soil fertility in terms of available N, P and K as well as micronutrients.

Deshmukh (2002), working on integrated plant nutrient supply system reported that application of 4 tonnes of compost with recommended dose of inorganic fertilizers increased the sustainability in productivity of maize compared to use of only inorganic fertilizers and also improved the soil health in due course of time.

Integrated use of organic and chemical fertilizers increased the yield attributes (cobs/plant, grains/cob, 1000 grain weight) and ultimately the grain as well as stover yield of maize compared to chemical fertilizers alone (Singh and Totawat, 2002).

According to Nanjappa *et al.* (2001), grain yield of maize increased on application of 50 or 75% RDF+12 t/ha FYM or 2.7 t/ha vermicompost because of more grains/row, grain yield/plant and test weight compared to inorganic fertilizers alone.

Brar *et al*. (2001), working on integrated use of farmyard manure and inorganic fertilizers in maize at Ludhiana in rainy season reported that crop responded well to combined use of organic and inorganic sources of nutrients. Grain yield of maize increased from 1.9 to 3.5 t/ha and straw yield from 6.6 to 10.7 t/ha with the increase in soil fertility compared to control and suggested that for sustaining higher maize yield, farmyard manure may be applied @ 10 t/ha.

According to Tolessa Debele *et al.* (2001), application of 4 tonnes of enriched FYM or 8 tonnes of conventional FYM/ha significantly increased maize grain yield. Jagpal Singh *et al*. (1996) also obtained higher grain yield with application of FYM along with inorganic fertilizers. Addition of organic manure with basal dose of N, P and K has potential to improve maize yield and yield components as well as soil physiochemical conditions. Application of 10 tonnes FYM/ha with 120, 60 and 90 kg N, P and K increased total dry matter production and total cob weight to the extent of

38 and 49% respectively, as compared to no fertilizer application or control treatment. This ultimately resulted in 50% increase in grain yield of maize over control, which was positively correlatd with total dry matter accumulation, total cob weight and stover yield of maize. A significant increase in grain and stover yields with the application of 10 tonnes FYM/ha over no FYM application, was also reported by Sarir *et al*. (2005).

According to Khan *et al.* (2000), maize yield was 4.64, 4.99, 5.26 and 5.91 t/ha with 0, 5, 10 and 15 tonnes FYM/ha, respectively, while it was 5.05, 5.20 and 5.34 kg with 0, 60 and 90 kg N/ha. Application of 5 tonnes FYM/ha alone gave similar yield as 90 kg N/ha alone, while the highest yield of 6.65 t/ha was obtained by a combination of 15 t FYM and 90 kg N/ha. Rising levels of FYM from 0, 2.5 and 5.0 t/ha progressively increased the crops yield of maize (Sakal *et al.* 1999).

Singh *et al*. (1998) working on integrated nutrient energy management in maize-wheat cropping system reported that substitution of 25% of N through FYM to maize followed by 75% recommended fertilizer NPK to wheat significantly increased the energy (31662±9014 MJ/ha) and grain (24.48±6.97 q/ha) productivity of maize with maximum energy use efficiency (3.0) and minimum specific energy (4306 MJ/ton) without any shift in stability compared with 100% recommended fertilizer NPK to the system or other integrated nutrient management treatment.

In an experiment conducted at Himachal Pradesh, the maximum grain yield was obtained with the application of FYM to maize combined with 100% of the recommended NPK, as stated by Kumar and Singh (1997).

Suri and Jha (1996) working on targeted yield concept reported that yield targeting treatments with FYM increased grain yield by 11.5% and stover yield by

6.3% as well as net retuns by 22% than those without FYM. Madhavi *et al*. (1996) also reported increase in grain yield of maize with increasing rate of poultry manure (0-4.5 t/ha) and NPK fertilizers (0, 50 and 100% of the recommended dose).

Application of 10 t/ha of farmyard manure in conjunction with fertilizers at 90:45:20 kg NPK/ha resulted in higher grain production of maize and higher benefit: cost ratios than chemical fertilizers alone (Sharma and Singh, 1996). Similarly, grain yield was found highest with 135 kg N + 67.5 kg P_2O_5 + 35 kg K_2O + 10 tonnes FYM/ha (Kamalakumari and Singaram, 1996).

2.1.3 Nutrient uptake

Nutrient uptake by maize crop increased significantly on integrated use of organic and inorganic sources due to increased availability of nutrients to the crop (Sarir *et al*. 2005, Kumar and Thakur, 2004, Thind *et al.* 2002, Kumar *et al*. 2002, Vadivel *et al.* 1999, Brar *et al*. 2001).

Combined application of organic and inorganic fertilizers not only increased the availability of nutrients but also their uptake by the crop (Nanjappa *et al*. 2001). Mehta et al. (2005) reported increased N, P, S and Fe uptake by grain, stover and total uptake by crop with application of organic manures over no organic manuring and improved nutrient status of grains positively. Babariya and Patel (1980) and Sharma and Gupta (1998) reported increase in uptake of nutrients by maize when fertilized with FYM compared to chemical fertilizers alone. Application of organic and chemical fertilizers resulted in increased N and P uptake by grain and stover. The role of organic manures in supply of nutrients as well as in improvement of physical properties of soil, which in turn brings the nutrients in soluble and available forms, is a well-known fact. This might have promoted growth of roots as well as their functional activities leading to higher nutrient extraction from the soil and their translocation to aerial parts of the plant (Singh and Totawat, 2002).

Improvement in nutrient uptake was reported by Tolessa Debele *et al*. (2001), on application of 4 tonnes of enriched FYM or 8 tonnes of conventional FYM/ha, in combination with chemical fertilizers. Mishra (2000) reported improved nutrient use efficiency by 30 to 45% on combined use of 10 tonnes FYM with fertilizers over chemical fertilizers alone. Similarly NPK uptake by the maize crop was found highest with 135 kg N + 67.5 kg P_2O_5 + 35 kg K_2O + 10 tonnes FYM/ha (Kamalakumari and Singaram, 1996).

2.1.4 Soil fertility

According to Singh and Totawat (2002) and Stefanescu (2002), integrated use of organic and chemical source significantly increased the available N, P and K status of soil when compared with only chemical fertilizer. A better response to organic matter in improving the nutrient status of the soil can be ascribed to its slow decomposition, producing acids, which in turn increases the nutrient availability (Somani, 1983) through enhanced soil biological activities (Mahmoud *et al*. 1968) and release of nutrients from the exchange sites. In general, improved nutritional status of grain and stover under FYM application primarily seems to be because of enrichment of these nutrients in soil while secondarily on maintenance of better physio-chemical and biological properties of the soils (Mehta *et al*. 2005). Nanjappa *et al*. (2001) reported 50 or 75% RDF+12 t/ha FYM or 2.7 t/ha vermicompost, apart from enhancing the productivity of maize, also reduced the loss of nutrients in the soil. FYM acting as a storehouse of several macro and micronutrients, in turn increased the availability of nutrients in soil.

Soil organic carbon, available N, P and K content was higher when FYM was applied with inorganic fertilizer compared to inorganic fertilizer only (Kumar and Thakur, 2004, Thind *et al*. 2002, Tolessa Debele *et al*. 2001, Jagpal Singh *et al*. 1996, Kamalakumari and Singaram, 1996). Soil organic carbon was increased on application of both organic manure and chemical fertilizers applied either alone or in combination, while pH decreased (Sarir *et al.* 2005). Similar results were obtained by Lamani *et al.* (2000) where higher organic carbon content in soil after maize harvest was obtained by combination of organic manures (green manure and poultry manure) with 100% RDF.

Continuous use of manures, alone or in combination with inorganic with inorganic source, improved the available nutrient status of soil. The available N, P and K content in the soils increased with increasing level of fertilizer N. Addition of organic wastes significantly increased the availability of P, K and micronutrients, but reduced nitrogen availability (Krishnan and Lourduraj, 1997, Toor and Bishnoi, 1996)).

2.2 Effect of Nutrient Levels on Maize

2.2.1 Growth and Development

Application of higher rates of nutrients results in overall improvement in growth of the plant system. Nitrogen being the component of amino acids, nucleic acids and number of co-enzymes, can induce cell elongation, cell enlargement, and cell division, is responsible for better vegetative growth of plant (Salisburry and

Ross, 1969). Likewise, phosphorus is an essential element for plant growth, being a constituent of adenosine diphosphate and adenosine triphosphate; it also helps in cell division and multiplication. Growth of plant is essentially a process of storing energy by photosynthesis and phosphorus plays a part in the photosynthetic process through the reductive pentose phosphate cycle (Pierre *et al.* 1966). Response to phosphorus also increases at higher levels of nitrogen. Potassium is a major osmotically active component in plant cell, contributing to cell turgor and enhancing the capacity of cells to retain water, which has a direct bearing on the size of cells (Arneke, 1980). These functions of nutrient NPK causes increase in plant growth with increasing fertilizer NPK. Fertilizer application positively influenced total biomass production, owing to beneficial effect of nutrient NPK on vegetative and reproductive growth.

Application of N significantly increased growth parameter of maize in maize+legumes intercropping systems (Shivay *et al.* 2001). Kumar and Puri (2001) reported 90 kg N/ha resulting in maximum plant height, 265 cm in maize. Significant response of levels of nitrogen was recorded for number and length of leaf as well as for number of nodes in a maize plant (Kaul, 1985).

Application of phosphorus @ 39.6 kg/ha gave significantly taller plants, more leaf area index, decreased days to 50% silking and maximum dry matter accumulation than the lower levels of phosphorus (Arya and Singh, 2001).

2.2.2 Yield attributes and yield

Nitrogen is a major nutrient and it is needed in large amounts for high yields of maize crop in intensive systems of agriculture. The size of the crop sets the minimum amount of nitrogen that the fertility program should supply. Provision for an adequate supply of nitrogen throughout the growing season is necessary and is one of the important functions of soil management. Phosphorus is part of the structure of many important plant compounds. Potassium is a very important nutrient for the production of maize. The crop uses large amounts of it and the total amount of potassium absorbed by the mature plant is larger than any other essential element except nitrogen. There is a positive interaction of maize on phosphorus and nitrogen in the production of maize stover but not for grain yield. (Pierre *et al.* 1966).

Manoj kumar and Singh (2003) working on effect of nitrogen and phosphorus levels on yield and nutrient uptake of maize under rainfed conditions of Nagaland reported increasing grain and stover yield with the increasing levels of nitrogen (0, 50, 100 and 150 kg/ha) and phosphorus (0, 40 and 80 kg/ha). Highest grain and stover yields were recorded with the highest level of nitrogen and phosphorus combination (N 150 and P 80 kg/ha).

The positive response of nitrogen application on yield of maize could be ascribed to overall improvement in crop growth, enabling the plant to absorb more nutrients as evident from the enhanced uptake of nutrients, which empowered the plant to manufacture more quantity of photosynthates accumulating them in reproductive parts. Such effects are reflected in terms of increased number of cobs per plant, grains per cob and 1000-grain weight, which ultimately increased the grain yield per unit area on nitrogen fertilization up to 100% RDF (Singh and Totawat, 2002). Arya and Singh (2001) reported highest grain and stover yield with application of 39.6 kg P/ha compared to lower phosphorus levels. The application of

100 kg N/ha and 120 kg K_2O/ha resulted in the maximum productivity of maize (Haque *et al*. 2001).

Yields and yield components of maize increased with increasing N application (Paliwal *et al*. 1999, Reddy and Khera, 1999, Raju and Iruthayaraj, 1995, Hussaini *et al.* 2002). The influence of N as well as P was significant on shelling percentage, harvest index, grain yield, water use and water use efficiency in maize crop.

Application of N significantly increased yield attributes, grain yield of maize in maize+legumes intercropping systems. The highest grain yield was recorded with 120 kg N/ha, which was 7.8, 39.9 and 64.4% higher over the yield obtained with 80, 40 and 0 kg N/ha, respectively (Shivay *et al*. 2001). Similarly, application of 120 kg N and 60 kg P, recorded 88 and 88.7% higher grain yield over control (Nair, 2000).

Singh and Sarkar (2001) reported an increase in grain yield of maize up to 33 % with application of 210, 90, 150 NPK kg/ha over the state recommendation of 100, 60, 40 kg NPK/ha. Length of cob, number of grains per cob, 1000 grain weight and grain as well as stover yield increased linearly with increasing levels of nitrogen fertilizers (Padmaja *et al*. 1999, Kaul, 1985).

Kumar and Puri (2001) reported 4.62 and 8.03 t/ha grain and stover yield respectively by application of 90 kg N/ha as compared to 2.26 and 3.62 tonnes/ha in control.

Novero *et al.* (1992) also reported highest yields of maize from 225 kg N/ha when crop was given 0, 75, 150, 225 or 300 kg N/ha, which decreased beyond this level.

2.2.3 Nutrient uptake

Uptake of nutrients in a plant system is the product of their content in plant tissues as well as total dry mass production. Uptake of N, P and K by maize increased significantly with increase in fertilizer dose, (Reddy and Khera, 1999, Padmaja *et al.* 1999, Paliwal *et al*. 1999, Raju and Iruthayaraj, 1995).

In an experiment conducted at Nagaland on effect of nitrogen and phosphorus levels on yield and nutrient uptake of maize, nitrogen and phosphorus uptake by grain and straw increased significantly up to 150 and 80 kg/ha N and P, respectively. Potassium uptake was also increased with application of higher levels of nitrogen and phosphorus (Manoj Kumar and Singh, 2003). Independent application of N increased N uptake in all plant parts of maize, N uptake in the leaves, leaf sheath, stem, husk and maize cob increased up to 90 days after planting but uptake in the grain increased up to maturity (Singh and Totawat, 2002, Haque *et al.* 2001).

Application of high rates of N corresponded with high concentrations in maize. At high N levels, concentration of P in stover, straw, and maize ears decreased but P content of grain was not affected. K concentrations in stover and straw increased with increasing N levels, while that of grain was not affected (Novero *et al.* 1992).

2.2.4 Soil fertility

Fertilization at higher rates led to a positive apparent balance of N and P and decreased negative K balance in soil. The available nutrient status of soil declined slightly due to cropping with lower fertilizer rates but showed a build-up when fertilizer was applied at higher rates (Reddy and Khera, 1999).

There was a build-up of available N and P in the soil with NPK fertilization and a decline in fertility status under unfertilized plots after long term fertility treatment with maize (Hegde and Katyal, 1998).

Greef (1994), reported increased N uptake with increasing rate of N application from 0 to 160 kg N/ha. Plant biomass increased from 1141 g/m^2 without N to 1614 g/m^2 with 160 kg N/ha. Nitrogen use efficiency decreased with increasing N fertilizer application. Leaf thickness and size of the mesophyll parenchyma were less at the medium nitrate supply. Other anatomical parameters were influenced in proportion to leaf nitrogen status. Stomatal index was not affected by N supply, but lengths and widths of epidermal and stomatal cells as well as the distance between stomata and vascular bundles were increased by high N supply.

Singh (1990) working on nitrogen transformations in acid alfisols of Ranchi under continuous manuring and fertilization reported lowering of pH on repeated application of high doses of chemical fertilizers. This lowering was however reduced on application of lime and manures.

2.3 Effect of Lime alone or in combination with FYM on Maize

2.3.1 Growth

Lime by correcting soil reaction and thus increasing availability of nutrients to the crops improves crop growth and increased dry matter production of maize (Martinez and Colmenares, 1995).

2.3.2 Yield attribute and yield

In an acidic red soil, production of upland crops increased considerably if soil acidity was corrected by liming before fertilizers were applied. Liming not only supplied adequate amounts of calcium to the plants, but also induced larger uptake of calcium and phosphorus from the soil and fertilizers applied. Mandal *et al.* (1966) reported that maize responded significantly to lime applied with NPK, yielding 1.72 t/ha as compared to control (0.26 t/ha), lime only (0.53 t/ha) and NPK only (1.12 t/ha) respectively.

There was a positive effect on grain yield and nutrient acquisition in treatments both, organic materials and dolomite lime (Baquerol and Rojas, 2001). Grain yield showed a significant response of maize to lime up to the third crop, from the 2 t/ha lime level upwards. Maize response to liming in the fourth and in the sixth crop was significant, respectively, from the 4 and 6 t/ha lime levels upwards. Maximum relative grain yield as an average for the four maize crops was obtained at a soil base saturation of 42% and 38%, (Miranda and Miranda 2000).

According to Mausumi Raychaudhuri and Kumar (1999), maize yielded maximum (2.76 t/ha) with 0.25 lime requirement level (10 t/ha) beyond which its yield decreased significantly.

Lime significantly increased grain yield of maize. Because Ca was applied as a basal nutrient, the lime responses were attributed mainly to the amelioration of Al and/or Mn toxicities and this was supported by the observation that 90% maximum yield was attained at pH values of around 5.0-5.5. Soil pH values of around 5.5 appeared to be adequate for optimal maize growth in the region and there was little evidence to support liming to higher pH values (Aitken *et al.* 1998).

2.3.3 Nutrient uptake

The N uptake by grain showed increasing trend on application of lime due to increase in the available soil N. Phosphorus and potassium uptake also increased. Actually, N and P concentration in the grain increased while the K concentration decreased with increasing liming levels. (Mausumi Raichaudhuri and Kumar, 1999, Dutta and Gupta, 1984).

Leaf concentration of N, P, Ca, Mg and K were higher with the incorporation of cowpea residues, chicken manure and lime (Baquerol and Rojas, 2001). Aitken *et al.* (1998) and Tagwira (1995) also reported significant increase in phosphorus concentration in maize plants due to liming.

2.3.4 Soil fertility

Role of liming to reduce soil acidity, improve microbial activity, increase organic-N content and in enhancing the availability of nitrogen is a well-established fact (Motiramani, 1971, Banerjee and Sinha, 1966). Liming in presence of organic manure and PK maintained the levels of hydrolysable NH_4^+-N and amino-N fractions in soil on a long-term basis (Sarkar *et al.* 2000).

The application of lime increased the soil pH, cation exchange capacity, exchangeable calcium and magnesium, and available P content of soil. On the other hand, exchangeable aluminium (Al^{3+}) decreased with increasing lime levels. This is because the exchangeable aluminium which contributed to the ions share in soil acidity got replaced by calcium (Ca^{2+}) resulting in an increase in the degree of base saturation and a decrease in exchangeable H^+ and Al^{3+} ions with lime application.

The available P content of the soil increased due to precipitation of exchangeable Al $^{3+}$ ions as amorphous oxides (Mausumi Raichaudhuri and Kumar, 1999).

When mixed with the soil, lime reduced the exchangeable Al and increased percentage content of Ca and Mg of the deepest soil layers. In the soil cultivated for nine years, lime influenced only the surface layer; when applied on the surface, the increase in pH, percentage Ca and Mg by lime was generally higher than when mixed to the soil (Moreira *et al.* 2001).

Liming increased phosphate availability in soil. Increase in available Pcontent of the soil with liming was reported by Tagwira (1995) and Dutta and Gupta (1984). P availability was higher at the second harvest. Lime increased soil pH when amended with 0, 3, 6, 9 or 12 meq $CaCO_3$/100 g soil (Martinez and Colmenares, 1995).

MATERIALS AND METHODS

A field experiment was conducted to study the effect of soil ameliorants and nutrient levels on growth, development and productivity of maize, as well as nutrient removal by the crop and soil fertility status after the crop. Experiment was conducted during kharif season of 2007, under rainfed upland condition at the Birsa Agricultural University farm, Ranchi [23º 17'N latitude, 85º10'E longitude and 625 m above mean sea level]. The details of materials used and methods followed during the course of study are described in this chapter.

3.1 Climate and Weather

The climate of this region is subtropical with large winter water deficiency. The region receives rainfall from both the streams of monsoon i.e. South-West monsoon and North –East monsoon. In general, pre- monsoon rains received in the month of May, monsoon usually breaks in mid June (±5 days). Late arrival as well as early cessation is not uncommon and rainfall is uneven and erratic. Some times rain occurs as high as 140 mm in 24 hours. Dry spells of 2-3 weeks or even more usually occur in July – August. Failure of Hathia rain (late September to early October) is observed once in four years, which not only adversely influence the grain development of standing crops but also affects establishment of second crop in winter season. On an average annual rainfall of this place is 1397.7 mm (average of 1956-2007), out of which about 85-86% is received during four monsoon months (June – September), where potential evapotranspiration is lower than the precipitation.

Generally, temperature starts to increase March onwards and reaches its peak in May and June. July and August are the active monsoon months during which mean temperature remains around 26^{o}C. With the start in withdrawal of monsoon from mid September, a second peak of temperature is observed in September- October, with day temperature touching upto 31^{o}C, however, nights are cooler. From November onwards, a gradual decrease in both day and night temperature is observed. In winter season, low temperature occurs in December where minimum temperature goes down to 1.8^{o}C.

The data on weather conditions prevailing during the growing period of the experimental crop have been presented in Appendix I and depicted in Figure 1. The crop received 1265.7 mm rainfall in 48 rainy days during growing period, out of which 314.1 mm, 324.3 mm and 300.7 mm in 15, 18 and 12 rainy days received during July, August and September, respectively. Therefore, amount as well as distribution of rainfall was conducive for satisfactory growth of maize. Since maize cannot withstand water logging at any stage of crop growth period, there was adequate drain system in experimental area.

Mean monthly maximum and minimum relative humidity during crop period for July, August and September was 88/69, 89/73 and 89/75%, respectively which were conducive for normal growth and high yield of maize crop.

Under rainfed conditions, maize usually begins to stress when air temperature exceed 32^{o}C during the tasseling, silking and grain filling stage. During crop period, mean maximum temperature varies from 26.3 to 31.0^{o}C whereas mean minimum temperature from 21.2 to 23.2^{o}C which falls within the range of optimum temperature requirement (20-35^{o}C) of maize crop for various phenophases.

Maize, a C-4 plant, utilized solar radiation (received during crop growth period, in terms of sunshine hours) for its efficient conversion into chemical energy.

Mean monthly wind speed during crop period for July, August and September was 1.0, 0.9 and 0.9 m/sec., respectively which were optimum wind speed for satisfactory maize growth and yield.

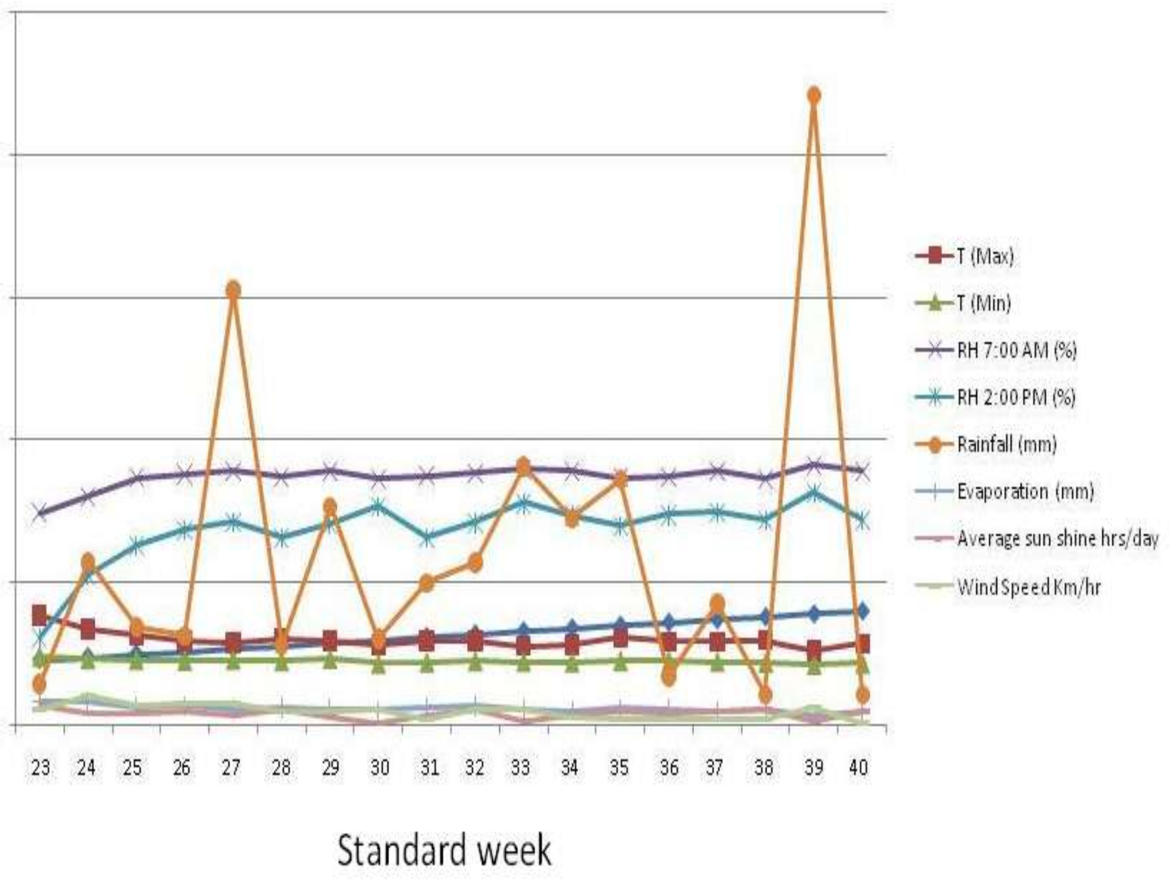

Fig 1. Weather conditions prevailing during crop period

3.2 Experimental Soil

The experiment was conducted in plot number 11 of the Lake South section of the BAU farm during Kharif 2007. The field was fairly leveled and with desired drainage outlet. The experimental site was a typical upland with shallow to medium soil depth. The soil was ultipaleustalf red type, and the red yellow-light grey category soil association group. These soils are in general high in permeability and have very poor water holding capacity due to the presence of hydrated oxides of iron and aluminum. The soil was sandy loam, acidic in reaction, medium in organic carbon, low in available nitrogen, medium in available phosphorus, exchangeable potassium and exchangeable calcium.

Data on physical and chemical properties of the soil (0-20 cm depth) of the experimental site before experimentation are given below:

Table: 1 Physical properties of the soil at the experimental site

Particulars	Value	Method
Mechanical analysis Sand % Silt % Clay % Texture	 65.28% 18% 16.72% Sandy loam	 Bouyoucos Hydrometer method (Means and Parcher, 1965)
Bulk Density (g/cc)	1.35	Core sampler method (Piper, 1966)
Field capacity at 0.3 Bars	15.13	Pressure plate apparatus (Richards, 1954)
Permanent wilting point at 15 bars	7.07	Pressure plate apparatus (Richards, 1954)

Table: 2 Chemical properties of soil at the experimental site

Particulars	Value	Method
Soil pH (1:2.5: : soil:water)	5.39	Glass Electrode pH meter (Jackson, 1973)
Organic Carbon (%)	0.51	Walkey and Black's rapid titration method
Available N (Kg/ha)	200.7	Alkaline Permanganate method (Subbiah and Asija, 1956)
Available P (Kg/ha)	12.76	Bray's P1 method (Jackson, 1973)
Exchangeable K (Kg/ha)	150.07	Ammonium acetate method (Hanway and Heidel, 1952)
Exchangeable Ca (m eq/ 100 gm of soil)	2.14	Ammonium acetate method (Hanway and Heidel, 1952)

3.3 Cropping History

Prior to the experimentation, maize was grown continuously during kharif and wheat+mustard was grown during rabi season with recommended fertilizer (100 kg N, 50 kg P_2O_5 and 25 kg K_2O for maize and 80 kg N, 40 kg P_2O_5 and 20 kg K_2O for wheat+mustard).

Table: 3 Cropping History of Experimental Area

Year	**Kharif**	**Rabi**
2002-03	Maize	Wheat+ Mustard
2003-04	Maize	Wheat+ Mustard
2004-05	Maize	Wheat+ Mustard
2005-06	Maize	Wheat+ Mustard
2006-07	Maize	Wheat+ Mustard

3.4 Experimental Details

3.4.1 Treatment

A Soil ameliorants

M_1 Control

M_2 FYM 5 t/ha

M_3 Lime 3 q/ha

M_4 FYM 5 t/ha+ Lime 3 q/ha

B Nutrient levels

F_1 50% RDF

F_2 75% RDF

F_3 100% RDF (100:50:25 kg N: P_2O_5: K_2O/ha respectively)

F_4 125% RDF

F_5 150% RDF

3.4.2 Treatment Combinations

T1	50% RDF
T2	75% RDF
T3	100% RDF
T4	125% RDF
T5	150% RDF
T6	50% RDF+FYM 5 t/ha
T7	75% RDF+FYM 5 t/ha
T8	100% RDF+FYM 5 t/ha
T9	125% RDF+FYM 5 t/ha
T10	150% RDF+FYM 5 t/ha
T11	50% RDF+ Lime 3 q/ha
T12	75% RDF+ Lime 3 q/ha
T13	100% RDF+ Lime 3 q/ha
T14	125% RDF+ Lime 3 q/ha
T15	150% RDF+ Lime 3 q/ha
T16	50% RDF+FYM 5 t/ha+ Lime 3 q/ha
T17	75% RDF+FYM 5 t/ha+ Lime 3 q/ha
T18	100% RDF+FYM 5 t/ha+ Lime 3 q/ha
T19	125% RDF+FYM 5 t/ha+ Lime 3 q/ha
T20	150% RDF+FYM 5 t/ha+ Lime 3 q/ha

3.4.3 Design of experiment

The experiment was laid out in a split plot design with four main plots, five sub plots and three replications. Soil ameliorants were kept in main plot, and nutrient levels in sub plot. Altogether twenty treatment combinations were there with three replications (Figure 2).

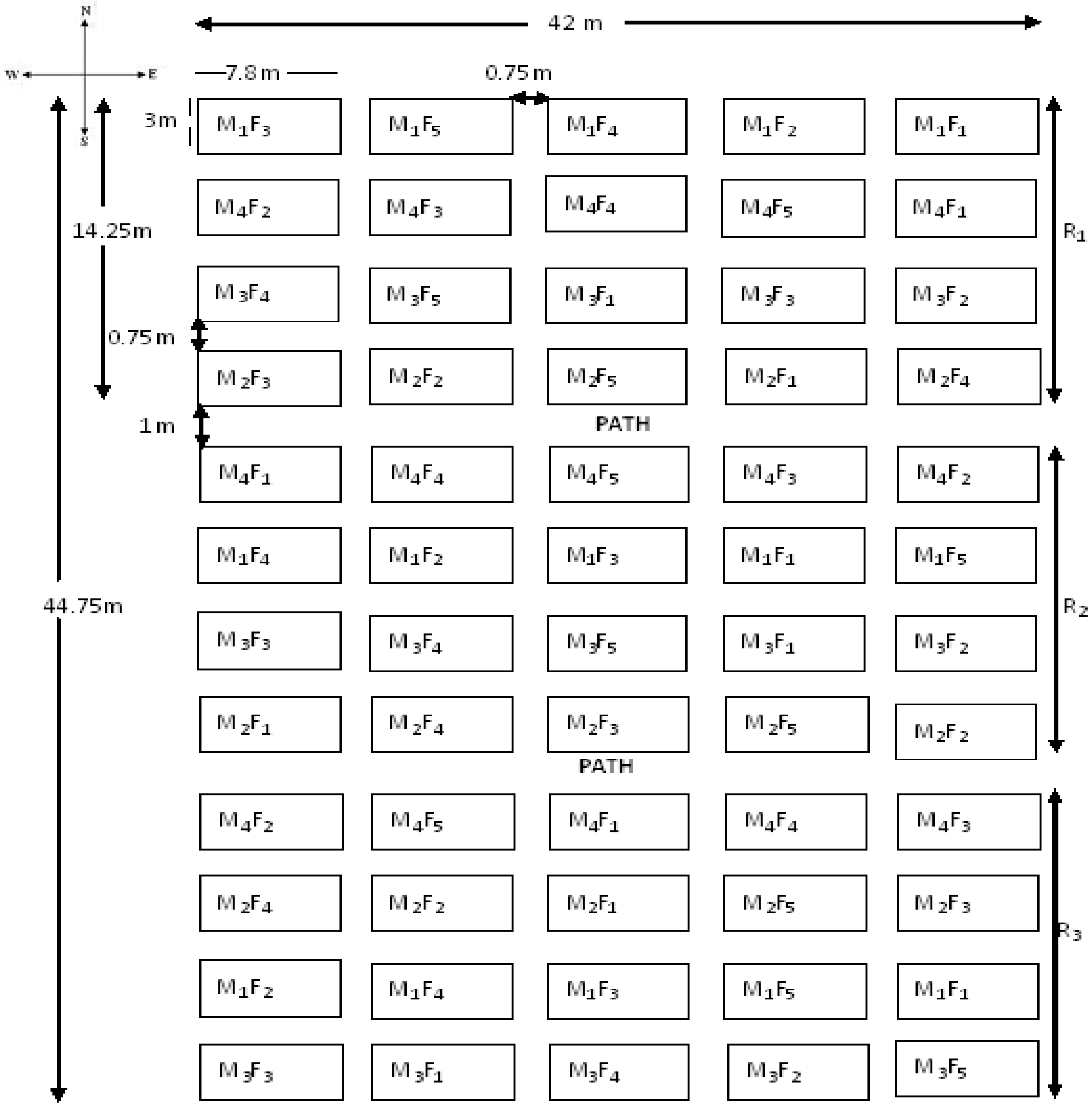

Fig. 2: Layout plan of the field experiment

Treatment

A. Soil ameliorant (Main plot) – 4

- Control (M_1)
- FYM 5t/ha (M_2)
- Lime 3q/ha (M_3)
- FYM + Lime (M_4)

B. Nutrient Levels (Subplot) - 5

- 50% RDF (F_1)
- 75% RDF (F_2)
- 100% RDF (F_3)
- 125% RDF (F_4)
- 150% RDF (F_5)

Replication :3

Plot Size : 7.8 m x 3m

100% RDF = 100 Kg N, 50 Kg P_2O_5 and 25 kg K_2O/ ha

3.5 Management:

3.5.1 Sowing

The experimental maize c.v. suwan was sown on 25th June of 2007 by line sowing method. Two seeds per hill were sown by dropping them in the furrows opened at a spacing of 60 cm, seed to seed distance was maintained at 30 cm. Seeds were then covered with soil.

3.5.2 Fertilizer application

Urea, MOP and SSP were used as fertilizers for nitrogen, potassium and phosphorus respectively. On the basis of nutrient contents of these fertilizers, the quantity to be applied was computed for one hectare and then for gross plot size. Half of N and full P and K was applied as basal at the time of sowing. Remaining half of N was applied in two equal splits at knee high and tasseling stage in all treatments.

3.5.3 Thinning

Thinning was done after germination was observed to remove extra plants from the field and maintain a proper plant population.

3.5.4 Crop protection

Lindane was applied in furrow at the time of sowing. Before dropping the seeds in furrows, it was applied and mixed thoroughly in the soil to avoid termite infestation. Shoot borer attack was observed after 25 days of sowing. Furadon granules were applied in the leaf whorl to control shoot borer.

3.5.5 Weed management

Atrazine was applied next day of sowing @ 1 kg a.i. /ha to take care of weeds. A hand weeding was also done at the time of top dressing of fertilizers at knee high stage.

3.5.6 Earthing up

Earthing up was done at knee-high stage after hand weeding and top dressing of nitrogen fertilizer to the crop.

3.5.7 Harvesting

Harvesting was done after 103 days of sowing on 4th October 2007. Harvesting was done by picking of cobs separately from each plot. Stalk was also bundled separately for each plot. The cobs and stalks were then transported to the threshing floor where they were dried in the sun and cobs were shelled manually with the help of sheller.

3.6 Pre harvest observations:

3.6.1 Germination count

Germination count per plot was taken 10 days after sowing by counting the germinated plants in each plot.

3.6.2 Growth Analysis

3.6.2.1 Dry Matter Accumulation

Periodic dry matter accumulation at 20, 40, 60, 80 days after sowing and at maturity were taken from lateral rows of each plot by random sampling. Whole plants from above the ground were cut and dried, first in sun and then in oven at around 65^0C. After reaching constant weight, dried samples were weighed on electric balance.

3.6.2.2 Leaf Area Index

Leaf area index is the leaf area per unit land area (Watson, 1962). Periodic Leaf Area Index at 20, 40, 60 and 80 days after sowing were recorded. Leaves of single plants, sampled for dry matter were separated manually and any three leaves were selected out of which 10 cm long section were cut out from middle portion of each leaf. Average of three widths, measured at top, middle and bottom of each section, was multiplied with the length of section (10 cm) to calculate the area of each section. Leaf area of whole plant was calculated from total dry weight of leaves using unitary method. Ground area per plant was calculated by plant population data. Then LAI was worked out using the following formula

LAI = Leaf area/ unit land area

3.6.2.3 Crop Growth Rate

Crop growth rate represents dry matter accumulation per unit area per unit time (Radford, 1967), expressed as $g/m^2/day$. Periodic crop growth rate was worked out from 20 to 40, 40 to 60, 60 to 80 days after sowing and 80 days after sowing to maturity by using the following formula,

$$\overline{CGR} = W_2 - W_1 / t_2 - t_1$$

Where W_2 and W_1 are dry weight per unit area at time t_2 and t_1 respectively. One of the assumptions of this equation is that dry weight changes without discontinuity from W_1 to W_2 as the time changes from t_1 to t_2.

3.6.2.4 Relative Growth Rate

Relative growth rate is an index of the amount of growing material per unit dry weight of plant per unit time (Radford, 1967) and is expressed as g/g/day. Periodic Relative Growth Rate was calculated from 20 to 40, 40 to 60, 60 to 80 days after sowing and 80 days after sowing to maturity by using the following formula,

$$\overline{RGR} = \ln W_2 - \ln W_1 / t_2 - t_1$$

Where W_2 and W_1 are dry weight per unit area at time t_2 and t_1 respectively. This is based on the assumption that changes in the dry weight is discontinuous with change in time.

3.6.2.5 Net Assimilation Rate

Net Assimilation Rate is the net gain of assimilate per unit leaf area per unit time (Radford, 1967) and is expressed as g/m^2/day. Periodic Net Assimilation Rate was calculated between 20 to 60 days after sowing at 20 days interval using the formula,

$$\overline{NAR} = (W_2 - W_1)\ (\ln L_2 - \ln L_1) / (t_2 - t_1)\ (L_2 - L_1)$$

Where W_2 and W_1 are dry weight per unit area and L_2 and L_1 are the leaf area per unit area at time t_2 and t_1 respectively. This is based on the assumption dry weight and leaf area increases continuously with increasing time.

3.6.3 Development

Days to knee high stage, tasseling stage, silking stage and maturity were recorded treatment wise and plot wise.

3.7 Post harvest observations

3.7.1 Yield components

Data on cob length, cob girth, grain rows/cob, grains/cob and1000 seed weight were recorded after harvest as the mean of a sample of five plants selected randomly from the sampling area of each plot. In the case of cob girth, measurement was done at bottom, middle and top positions of the cob with the help of a measuring tape.

Data on cobs/m^2 were recorded from the net plot area and computed for one hectare.

3.7.2 Yield

The cobs from the net plot area of each plot were harvested, sundried and shelled and weight of grains was taken. Stones from the net plot area were also weighed. After harvest of cobs, maize stalk were cut from the ground level, sun dried and weighed. Yields of seeds, stones and stalk were expressed in kg/ha. Harvest index was calculated as the percent ratio of seed yield and biomass yield. In case of grain: straw ratio, stone yield was included in straw yield.

3.7.3 Nutrient uptake by crop

Dried samples of grain, stover and stone after harvest were ground for estimation of N, P, K and Ca. Nitrogen content was determined by modified Kjeldahl method (Jackson, 1973). Phosphorus was determined colorimetrically and potassium and calcium by flame photometer, in tri acid (HNO_3: H_2SO_4: $HClO_4$:: 10: 1: 4) digests. Uptake of each nutrient was calculated separately for grain, stover and stone and by multiplying the percentage content with corresponding yield of grain, stover and stone gave the uptake of nutrients by grain, stover and stone. Summation of all three gave total uptake of nutrients by the maize crop.

3.8 Economics of Maize Production

Cost of cultivation was calculated with the current costs of inputs and it was deducted from the gross return by selling all the products of maize crop. Benefit: cost ratio was calculated on net return basis by dividing cost of cultivation (Appendix-II) from net return from the crop.

3.9 Soil fertility status after harvest

Estimation of soil fertility status of soil was done after harvest also. Soil samples from each plot were collected after harvesting of crop and chemical analysis was done in laboratory for estimation of pH, organic carbon, available N, available P, exchangeable K and exchangeable Ca.

3.10 Statistical analysis

The data recorded for different parameters were subjected to statistical analysis using the method appropriate for the design (split plot). The results were interpreted based on F test. The significant difference between different means was compared with the critical difference at 5% probability level (Steel and Torrie, 1980).

RESULTS

The results of the field experiments conducted during 2007 kharif to study the effects of different soil ameliorants alone or in combination of each other and with nutrient levels on productivity of maize are presented in this section.

4.1 Crop Growth

4.1.1 Periodic Dry Matter Accumulation

Dry matter accumulation in maize increased with crop age (Table 4) and reached its peak at maturity. Its rate of increase was, however, maximum at initial stage of growth and declined gradually. Soil ameliorants significantly influenced the dry matter production 40 and 80 days after sowing as well as at maturity. At 40 days after sowing, maize crop receiving FYM+lime and FYM alone being similar to each other, accumulated more dry matter than the crop grown with lime alone or without ameliorant (control). The magnitude of increase with FYM+lime was 29.17 and 17.55 percent compared to control and lime alone respectively. While crop with FYM alone produced, 27.2 and 15.76 percent more dry matter than control and lime alone respectively. Lime alone contributed 9.88 percent increase in dry matter over control. At 80 days after sowing, crop with FYM+lime being similar to that grown with FYM alone registered more dry matter, which was 9.66 and 5.24 percent higher than control and lime alone respectively. Similarly, crop with FYM being similar to that with lime had an edge over control. However, difference in dry matter accumulation due to lime alone or control was not significant. At maturity, FYM+lime being similar to FYM, produced 4.97 and 8.82 percent more dry matter than lime alone and control respectively. Similarly, FYM and lime alone being on par with each other, registered their edge over control.

Nutrient levels also significantly influenced dry matter production at all growth stages. At 20 and 80 days after sowing as well as at maturity, each incremental dose of nutrients produced higher dry matter than its preceding one and maximum dry matter was registered at 150% RDF (Table 4). At 40 and 60 days after sowing, 150% RDF registered more dry matter than its preceding levels tested.

Interaction of soil ameliorants and nutrient levels significantly affected dry matter production of maize at 40 days after sowing. The crop receiving FYM+lime with 150% RDF registered maximum dry matter (170.33 g/m^2), which being similar to FYM+lime at 100 or 125% RDF as well as FYM alone at 125 or 150% RDF showed its edge over remaining combinations of soil ameliorants and nutrient levels (Table 5).

4.1.2 Leaf Area Index

Leaf area index (LAI) of maize increased with crop age and its rate of increase was maximum between 20 and 40 days after sowing. Soil ameliorants had a significant effect on leaf area index of maize at all stages except at 20 days after sowing. At 40 days after sowing, FYM+lime showed edge over control, lime and FYM alone with an increase of 37.44, 24.04 and 15.91 percent respectively. FYM alone being similar to lime alone also resulted in 18.57 percent increase in leaf area index as compared to control. Leaf area index recorded with lime alone and control were similar. At 60 days after sowing, FYM+lime recorded maximum leaf area index which being similar to FYM showed its superiority over lime alone

(8.63%) and control (12.28%). FYM also being similar to lime had an edge over control resulting in 8.72% increase. Leaf area index recorded with lime alone and control were alike. At maturity, FYM+lime, FYM and lime alone being similar to each other showed their superiority over control and the magnitude of increase was 13.2, 8.6 and 11.67% respectively.

Nutrient levels also significantly influenced the LAI of maize at all stages. At 20 days after sowing, 150% RDF resulting in maximum LAI showed superiority over 50, 75 and 100% RDF while it was similar to 125% RDF, the increase in LAI with 150% RDF was 32.54, 25.84 and 17.28 percent as compared to 50, 75 and 100% RDF respectively. At 40 days after sowing, 150% RDF resulted in higher leaf area index than all other nutrient levels and the magnitude of increase was 50.49%, 42.59%, 25.88% and 10.12% over 50, 75, 100 and 125% RDF respectively. Further, 125% RDF registered more LAI than 100% RDF which in its own turn recorded more LAI than 75 and 50% RDF. However leaf area index recorded were similar with 75 and 50% RDF. At 60 days after sowing, each incremental levels of nutrients registered more LAI than its preceding level except 100 and 125% RDF where it was similar to each other and maximum LAI was noted with 150% RDF. At 80 days after sowing, 150% RDF being similar to 125% RDF recorded more LAI than remaining nutrient levels. Similarly, 125% RDF being on par with 100% RDF showed its edge over 75 and 50% RDF. Further 100% RDF had more LAI than 75% RDF which in its own turn was superior than 50% RDF.

Interaction between soil ameliorants and nutrient levels was significant at 40 days after sowing where FYM+lime at 125 and 150% RDF being similar, had more LAI than remaining treatment combinations tested.

Table 4: Periodic dry matter accumulation (g/m^2) of maize as affected by soil ameliorants and nutrient levels

Treatment	Days after sowing				At maturity
	20	40	60	80	
A. Soil ameliorant					
Control	7.53	105.02	477.37	887.89	1252.36
FYM	8.45	133.59	515.55	941.93	1321.41
LIME	7.37	115.40	503.66	925.20	1298.24
FYM+ Lime	8.28	135.65	542.04	973.65	1362.78
S Em ±	0.27	4.17	14.59	11.59	12.99
CD (P=0.05)	NS	14.44	NS	40.10	44.94
B. Nutrient level					
50% RDF	5.50	94.21	432.35	778.47	1110.07
75% RDF	6.38	100.30	468.95	874.45	1239.05
100% RDF	7.47	127.17	508.74	946.25	1326.45
125% RDF	9.55	137.14	543.58	1001.98	1397.45
150% RDF	10.64	153.25	594.66	1059.67	1470.47
S Em ±	0.15	4.22	12.43	10.31	10.16
CD (P=0.05)	0.44	12.17	35.83	29.77	29.33
Interaction					
S Em ±	0.30	8.44	24.85	20.62	20.32
CD (P=0.05)	NS	24.33	NS	NS	NS
CV%	6.65	11.94	8.45	5.83	5.69

Table 5: Interaction of soil ameliorants and nutrient levels on dry matter accumulation (g/m^2) of maize at 40 days after sowing

TREATMENT	CONTROL	FYM	LIME	FYM+LIME
50% RDF	88.08	94.70	97.59	96.48
75% RDF	90.10	111.17	104.32	95.61
100% RDF	91.50	144.49	112.92	159.77
125% RDF	112.59	160.12	119.81	156.05
150% RDF	142.82	157.49	142.36	170.33

Table 6: Periodic leaf area index of maize affected by soil ameliorants and nutrient levels

Treatment	Days after sowing			
	20	40	60	80
A. Soil ameliorant				
Control	0.186	1.723	3.924	4.235
FYM	0.196	2.043	4.266	4.599
LIME	0.187	1.909	4.056	4.729
FYM+ Lime	0.201	2.368	4.406	4.794
S Em ±	0.011	0.056	0.080	0.084
CD (P=0.05)	NS	0.195	0.278	0.291
B. Nutrient level				
50% RDF	0.169	1.642	3.428	3.738
75% RDF	0.178	1.733	3.774	4.463
100% RDF	0.191	1.963	4.228	4.672
125% RDF	0.202	2.244	4.495	4.808
150% RDF	0.224	2.471	4.889	5.266
S Em ±	0.011	0.055	0.105	0.066
CD (P=0.05)	0.031	0.157	0.304	0.191
Interaction				
S Em ±	0.022	0.109	0.211	0.133
CD (P=0.05)	NS	0.315	NS	NS
CV%	19.65	9.48	8.76	5.00

Table 7: Interaction of soil ameliorants and nutrient levels on leaf area index of maize at 40 days after sowing

TREATMENT	CONTROL	FYM	LIME	FYM+LIME
50% RDF	1.38	1.83	1.52	1.83
75% RDF	1.63	1.73	1.73	1.84
100% RDF	1.59	2.00	2.02	2.24
125% RDF	1.91	2.09	2.14	2.85
150% RDF	2.11	2.57	2.13	3.08

4.1.3 Crop Growth Rate

Crop growth rate of maize increased with crop age up to 60 to 80 days after sowing and thereafter decreased. Soil ameliorants affected CGR of maize between 20 and 40 days after sowing and 80 days after sowing to maturity. Between 20 and 40 days after sowing, FYM+lime resulted in higher CGR of maize than lime alone and control and the magnitude of increase was 17.96 and 30.8 percent respectively. However, differences in crop growth rate between FYM+lime and FYM alone as well as between lime alone and control were not significant. Between 80 days after sowing and maturity, FYM+lime being similar to FYM alone showed superiority over control and lime alone by 6.75 and 4.29 percent respectively. FYM alone being similar to lime alone recorded more CGR than control. Further lime alone and control being on par registered similar CGR.

Nutrient levels significantly influenced crop growth rate at different stages of growth. Crops receiving 150% RDF had more mean CGR than remaining nutrient levels except 125% RDF at all the stages of growth. 125% RDF also had an edge over 100, 75 and 50% RDF between 20 and 40 days after sowing, over 75 and 50% RDF between 40 and 60 days after sowing and only over 50% RDF between 60 and 80 days after sowing. Similarly, 100% RDF registered edge over 75 and 50% RDF during 20 to 40 days after sowing while it was superior to 50% RDF at later stages of growth.

Interaction of soil ameliorants and nutrient levels was not significant at different stages of growth.

Table 8: Periodic crop growth rate ($g/m^2/day$) of maize affected by soil ameliorants and nutrient levels

Treatment	Days after sowing			
	20-40	40-60	60-80	80-Maturity
A. Soil ameliorant				
Control	4.87	18.63	20.53	18.22
FYM	6.27	19.10	21.32	18.97
LIME	5.40	19.41	21.08	18.65
FYM+ Lime	6.37	20.32	21.58	19.45
S Em ±	0.21	0.67	0.88	0.16
CD (P=0.05)	0.71	NS	NS	0.55
B. Nutrient level				
50% RDF	4.44	16.91	17.31	16.58
75% RDF	4.70	18.43	20.28	18.23
100% RDF	5.99	19.09	21.88	19.01
125% RDF	6.93	20.32	22.92	19.77
150% RDF	7.13	22.07	23.25	20.54
S Em ±	0.21	0.65	0.73	0.30
CD (P=0.05)	0.73	1.87	2.12	0.87
Interaction				
S Em ±	0.42	1.30	1.47	0.61
CD (P=0.05)	NS	NS	NS	NS
CV%	12.68	11.62	12.02	5.57

4.1.4 Relative Growth Rate

Relative growth rate (RGR) of maize declined gradually with increasing age of the crop (Table 9). Soil ameliorants significantly influenced RGR only between 40 to 60 days after sowing. Control treatment resulted in highest mean relative growth rate.

Nutrient levels influenced relative growth rate significantly between 20 to 40 days and 40 to 60 days after sowing. Highest mean relative growth rate was observed in the treatment receiving 50% RDF and 75% and 100% RDF were on par during 20 to 40 days after sowing. Between 40 to 60 days after sowing, 75% RDF resulted in maximum relative growth rate and on par with 50% RDF.

In case of interaction between soil ameliorants and nutrient levels, effect was significant only between 20 to 40 days of crop growth after sowing. 100% RDF applied with both FYM and lime as soil ameliorants resulted in maximum relative growth rate among all treatments, whereas 100% RDF with only FYM as soil ameliorant and 50% RDF without either of the ameliorants showed similar results.

Table 9: Periodic relative growth rate (g/g/day) of maize affected by soil ameliorants and nutrient levels

Treatment	Days after sowing			
	20-40	40-60	60-80	80-Maturity
A. Soil ameliorant				
Control	0.133	0.076	0.031	0.017
FYM	0.138	0.068	0.030	0.017
LIME	0.138	0.073	0.030	0.017
FYM+ Lime	0.140	0.071	0.029	0.017
S Em ±	0.002	0.001	0.002	0.0002
CD (P=0.05)	NS	0.005	NS	NS
B. Nutrient level				
50% RDF	0.142	0.076	0.029	0.018
75% RDF	0.137	0.077	0.031	0.017
100% RDF	0.140	0.071	0.031	0.017
125% RDF	0.133	0.068	0.030	0.017
150% RDF	0.134	0.068	0.029	0.017
S Em ±	0.002	0.002	0.001	0.0003
CD (P=0.05)	0.006	0.006	NS	NS
Interaction				
S Em ±	0.004	0.004	0.003	0.0006
CD (P=0.05)	0.011	NS	NS	NS
CV%	4.93	10.57	14.45	6.54

Table 10: Interaction of soil ameliorants and nutrient levels on periodic relative growth rate (g/g/day) maize at 40 days after sowing

TREATMENT	CONTROL	FYM	LIME	FYM+LIME
50% RDF	0.147	0.139	0.142	0.139
75% RDF	0.136	0.139	0.142	0.133
100% RDF	0.117	0.146	0.142	0.155
125% RDF	0.124	0.135	0.133	0.138
150% RDF	0.138	0.131	0.131	0.133

4.1.5 Net Assimilation Rate

Mean net assimilation rate of maize remained more or less the same during the two observation periods, i.e. 20 to 40 and 40 to 60 days after sowing. Neither soil ameliorants nor nutrient levels imparted any significant influence on net assimilation rate of maize (Table 11).

Table 11: Periodic net assimilation rate ($g/m^2/day$) of maize affected by soil ameliorants and nutrient levels

Treatment	Days after sowing	
	20-40	40-60
A. Soil ameliorant		
Control	7.09	7.03
FYM	8.00	6.39
LIME	7.36	6.91
FYM+ Lime	7.24	6.30
S Em ±	0.26	0.28
CD (P=0.05)	NS	NS
B. Nutrient level		
50% RDF	6.96	7.03
75% RDF	7.00	7.12
100% RDF	7.83	6.50
125% RDF	7.65	6.36
150% RDF	7.74	6.27
S Em ±	0.34	0.31
CD (P=0.05)	NS	NS
Interaction		
S Em ±	0.67	0.63
CD (P=0.05)	NS	NS
CV%	15.68	16.28

4.2 Development

4.2.1 Days to Knee-high stage

Soil ameliorants significantly affected days to knee-high stage. Crop receiving FYM+lime attained knee-high stage earlier than those grown with FYM or lime alone or without ameliorants. Further, crops grown with FYM alone and without ameliorants attained knee-high stage earlier than that grown with lime alone.

Nutrient levels affected days to knee-high stage significantly. The crop fertilized with 150% RDF attained knee-high stage earlier than those grown with low levels of nutrients did. Days taken to attain knee-high stage was similar with 125 or 100% RDF as well as with 100 or 75% RDF. However, crops receiving 50% RDF took more days to attain knee-high stage.

Interaction of soil ameliorants and nutrient levels failed to affect number of days taken by crop to reach knee-high stage significantly.

4.2.2 Days to tasseling and silking

Soil ameliorants had significant impact on days to tasseling and silking. Tasseling and silking were observed earlier in treatments receiving FYM alone or in combination with lime than no ameliorant. Lime had no effect on days to attain tasseling and silking over control and was on par with FYM and FYM+lime.

Nutrient levels significantly affected days to tasseling and silking. Crops grown with increasing fertility attained tasseling and silking stage earlier than the crop grown with 50% RDF. Crops grown with 150% RDF being on par with 125% RDF reached tasseling and silking stage earlier compared to those grown with100, 75 and 50% RDF. 100 and 125% RDF were similar among themselves and in case of silking, superior to 50 and 75% RDF. Crops grown with 100 and 75% RDF took similar days to reach tasseling.

Interaction of soil ameliorants and nutrient levels did not affected days to tasseling and silking significantly.

4.2.3 Days to maturity

Soil ameliorants significantly affected days to physiological maturity in maize crop. Crops grown without soil ameliorants reached physiological maturity earlier than the crops grown with soil ameliorants. Further, crop receiving lime alone attained physiological maturity earlier than crops grown with FYM as well as FYM+lime. Crops grown with FYM+lime also reached physiological maturity earlier than crop grown with FYM alone. However, nutrient levels and interaction of soil ameliorants and nutrient levels could not affect days to physiological maturity significantly.

4.3 Yield Attributes

Soil ameliorants significantly affected cobs per unit area at the time of harvesting. The crops receiving FYM+lime, FYM alone and lime alone, being similar to each other, had more cobs per unit area than control. Nutrient levels had significant impact on cobs per unit area. Each incremental level of nutrients registered more cobs per unit area than its preceding level and maximum cobs per unit area was recorded at 150% RDF, the highest level tested. Interaction of soil ameliorants and nutrient levels had a significant effect on number of cobs per unit area. 75% RDF with FYM+lime was as good as 150% RDF, with or without soil ameliorants or 125% RDF with soil ameliorants or 100% RDF with FYM+lime.

Table 12: Days taken to different phenophases of maize affected by soil ameliorants and nutrient levels

Treatment	Knee high stage	Tasseling	Silking	Physiological maturity
A. Soil ameliorant				
Control	30.06	58.00	62.27	97.33
FYM	30.20	57.07	61.20	100.47
LIME	31.58	57.40	61.80	97.80
FYM+ Lime	29.60	57.13	61.27	100.10
S Em ±	0.10	0.19	0.22	0.10
CD (P=0.05)	0.33	0.65	0.77	0.36
B. Nutrient level				
50% RDF	31.83	58.50	62.83	99.17
75% RDF	31.33	57.75	62.08	99.33
100% RDF	30.75	57.25	61.33	99.00
125% RDF	30.58	56.92	61.08	99.08
150% RDF	29.83	56.58	60.83	98.42
S Em ±	0.21	0.24	0.21	0.22
CD (P=0.05)	0.60	0.68	0.62	NS
Interaction				
S Em ±	0.42	0.47	0.43	0.44
CD (P=0.05)	NS	NS	NS	NS
CV%	2.36	1.42	1.20	0.76

Soil ameliorants did not have any significant influence on length of cobs. However, nutrient levels had significant differential impact on length of cobs. Maximum cob length was recorded in the treatment receiving 150% RDF, which being similar to 100 and 125% RDF, had an edge over rest of the treatments, 50% and 75% RDF, and the magnitude of increase was 11.35 and 6.23 % respectively. Interaction of soil ameliorants and nutrient levels was not significant on cob length of maize.

Soil ameliorants did not have any significant differential effect on cob girth. Nutrient levels significantly influenced cob girth of maize. Maximum cob girth was recorded in the treatment receiving 150% RDF, which being similar to 125%

RDF, had an edge over remaining nutrient levels, viz 100, 75 and 50% RDF. Further, nutrient levels, 125, 100, 75 and 50% RDF had similar cob girth. Interaction of soil ameliorants and nutrient levels did not have any significant influence on cob girth of maize.

Soil ameliorants significantly influenced grain rows in a cob. FYM+lime treatment, being similar to lime alone, had an edge over FYM alone and control, in terms of grain rows/cob. Similarly, both lime and FYM alone having similar grain rows, showed their superiority over control. Application of increasing nutrient levels also had significant effect on number of grain rows/cob. Maximum number of grain rows in a cob was recorded at 150% RDF, which being similar to 125 and 100% RDF, recorded its superiority over 75 and 50% RDF. Similarly, nutrient level of 125% RDF being similar to 100% RDF registered more number of grain rows/cob than 75 and 50% RDF. However, differences in grain rows/cob due to 100, 75 and 50% RDF were not significant. Interaction of soil ameliorants and nutrient levels failed to impart any significant impact on number of grain rows/cob of maize.

Soil ameliorants significantly influenced grains/cob. FYM+lime being similar to FYM alone, produced number of grains/cob which was 4.14 and 12.1 percent higher than lime alone and control respectively. FYM alone also exhibited 3.56 and 11.48 percent more grains/cob than lime alone and control respectively. Lime alone also had 7.65% more grains/cob than control. Nutrient levels had significant differential impact on grains/cob. 150 and 125% RDF being similar to each other registered more grains/cob than the remaining nutrient levels tested. 100% RDF also showed its superiority over 75 and 50% RDF.

However, difference in grains/cob due to 75 and 50% RDF was not significant. Interaction of soil ameliorants and nutrient levels showed no significant difference on number of grains in a cob.

Soil ameliorants could not significantly influence 1000-grain weight of maize. However, nutrient levels had significant differential impact on 1000-grain weight of maize. Highest 1000-grain weight was recorded in the treatment receiving 150% RDF, which was superior to all other nutrient levels, showing an increase of 11.1, 8.05, 6.04 and 4.63% over 50, 75, 100 and 125% RDF respectively. Differences in 1000-grain weight between nutrient levels 125 and 100% RDF as well as 100 and 75% RDF were not significant. However, all these nutrient levels had higher 1000-grain weights than the lowest nutrient level (50% RDF). The interaction of soil ameliorants and nutrient levels was not significant.

4.4 Yield

4.4.1 Grain yield

Soil ameliorants significantly affected grain yield of maize. the crop receiving FYM+lime being similar to that receiving FYM alone (48.59 q/ha) produced maximum grain yield of 50.75 q/ha, which was 16.37 and 26.21% higher than the crops receiving lime alone and control, respectively. Similarly, FYM alone produced 11.42 and 20.84% higher grain yield than lime alone and control respectively. Lime alone also registered 8.46 percent more yield than control (40.21 q/ha).

Nutrient application also significantly affected grain yield of maize. Each incremental dose of nutrients produced significantly higher yield than its preceding level. The magnitude of increase at 150% RDF (55.4 q/ha) was 64.78, 35.65, 18.48 and 5.54% compared to 50, 75, 100 and 125% recommended fertilizer, respectively. Interaction of soil ameliorants and nutrient levels was not significant (Table 16).

4.4.2 Stover yield

Stover yield of maize was significantly influenced by soil ameliorants. FYM+lime resulted in maximum stover yield (87.53 q/ha), which being similar to FYM alone as well as lime alone, showed their edge over control. The increase in stover yield was to the tune of 2.95, 3.08 and 4.85% on application of FYM, lime and FYM+lime respectively, over control.

Nutrient levels significantly affected stover yield of maize. Each incremental dose of nutrient recorded higher stover yield than its preceding one and maximum stover yield was obtained at 150% RDF, and the magnitude of increase was 21.54, 9.35, 5.94 and 2.98% over 50, 75, 100 and 125% RDF respectively. Interaction of soil ameliorants and nutrient levels was not significant (Table 16).

4.4.3 Stone yield

Soil ameliorants and nutrient levels both affected stone yield of maize significantly. FYM+lime had maximum stone yield of 10.16q/ha, which was 10.08, 9.84 and 18.83% higher than FYM alone, lime alone and control, respectively. Further, difference in stone yield due to FYM and lime was not significant. However, FYM alone and lime alone recorded an increase of 7.95 and 8.19% in stone yield respectively over control.

Table 13: Yield attributes of maize affected by soil ameliorants and nutrient levels

Treatment	Cobs/ sq m	Cob length (cm)	Cob girth (cm)	Grain rows/ cob	Grains/ cob	1000 seed weight (g)
A. Soil ameliorant						
Control	4.53	14.09	13.15	13.51	433.36	207.59
FYM	4.78	15.39	13.50	14.04	483.12	212.05
LIME	4.76	14.90	13.57	14.24	466.51	211.01
FYM+ Lime	4.97	15.41	13.59	14.45	485.80	214.89
S Em ±	0.06	0.32	0.11	0.11	4.29	1.69
CD (P=0.05)	0.22	NS	NS	0.38	14.84	NS
B. Nutrient level						
50% RDF	4.41	14.10	13.14	13.58	429.33	201.37
75% RDF	4.59	14.78	13.36	13.78	442.20	207.05
100% RDF	4.78	14.98	13.35	14.06	466.07	210.97
125% RDF	4.93	15.20	13.51	14.38	494.75	213.82
150% RDF	5.09	15.70	13.89	14.49	503.64	223.72
S Em ±	0.04	0.32	0.15	0.19	4.62	1.26
CD (P=0.05)	0.12	0.91	0.44	0.54	13.29	3.64
Interaction						
S Em ±	0.08	0.63	0.31	0.38	9.23	2.53
CD (P=0.05)	0.24	NS	NS	NS	26.59	NS
CV%	5.03	7.33	3.94	4.62	3.42	2.07

Table 14: Interaction of soil ameliorants and nutrient levels on number of cobs/ sq m affected by soil ameliorants and nutrient levels

TREATMENT	CONTROL	FYM	LIME	FYM+LIME
50% RDF	3.83	4.56	4.45	4.80
75% RDF	4.23	4.63	4.60	4.89
100% RDF	4.71	4.67	4.76	4.97
125% RDF	4.80	4.94	4.89	5.07
150% RDF	5.07	5.11	5.07	5.11

Table 15: Interaction of soil ameliorants and nutrient levels on number of grains/ cob affected by soil ameliorants and nutrient levels

TREATMENT	CONTROL	FYM	LIME	FYM+LIME
50% RDF	402.13	439.53	441.06	434.60
75% RDF	403.73	485.26	446.66	466.46
100% RDF	445.53	487.66	450.00	481.06
125% RDF	462.60	499.20	494.20	523.00
150% RDF	486.13	503.93	500.63	523.86

In case of nutrient levels, each incremental dose produced significantly higher stone yield than its preceding one and maximum stone yield was noted at 150% RDF. Interaction of soil ameliorants and nutrient levels had no effect on production of stone (Table 16).

4.4.4 Grain: Straw Ratio

Soil ameliorants significantly influenced grain: straw ratio(Table 16). Corresponding FYM+lime as well as FYM alone, having similar grain: straw ratio, showed their edge over the crops grown with lime or without any ameliorant. Further, crops grown with lime alone or without ameliorant had similar grain: straw ratio.

Nutrient levels also significantly influenced grain: straw ratio. Crop receiving 150 and 125% RDF, having similar grain: straw ratio registered their edge over the crops receiving lower nutrient levels. Further, crops receiving 100 and 75% RDF, being similar to each other, recorded higher grain: straw ratio than the crop receiving 50% recommended fertilizer.

Interaction of soil ameliorants and nutrient levels could not affect grain: straw ratio significantly.

4.4.5 Harvest Index

Soil ameliorants significantly influenced harvest index of maize (Table 16). Corresponding FYM+lime as well as FYM alone, having similar harvest index, showed their edge over the crops grown with lime or without any ameliorant. Further, crops grown with lime alone or without ameliorant had similar harvest index.

Table 16: Grain, stover and stone yield, grain: straw ratio and harvest index of maize affected by soil ameliorants and nutrient levels

Treatment	Yield (q/ha)			Grain: Straw ratio	Harvest Index
	Grain	Stover	Stone		
A. Soil ameliorant					
Control	40.21	83.48	8.55	0.43	29.91
FYM	48.59	85.94	9.23	0.51	33.68
LIME	43.61	86.05	9.25	0.45	30.95
FYM+ Lime	50.75	87.53	10.16	0.51	33.97
S Em ±	0.93	0.53	0.07	0.01	0.56
CD (P=0.05)	3.23	1.83	0.24	0.04	1.94
B. Nutrient level					
50% RDF	33.62	75.83	8.01	0.40	28.34
75% RDF	40.84	84.28	8.64	0.45	30.38
100% RDF	46.76	86.99	9.35	0.48	32.64
125% RDF	52.49	89.49	9.97	0.53	34.27
150% RDF	55.40	92.16	10.52	0.54	35.01
S Em ±	0.90	0.82	0.13	0.01	0.47
CD (P=0.05)	2.60	2.38	0.36	0.03	1.37
Interaction					
S Em ±	1.81	1.65	0.25	0.02	0.95
CD (P=0.05)	NS	NS	NS	NS	NS
CV%	6.83	18.82	6.68	7.12	5.11

Nutrient levels also significantly influenced harvest index. Each incremental dose of nutrients resulted in higher harvest index than its preceding level up to 125% RDF. Further increase of nutrient level to 150% RDF could not increase the harvest index of maize.

Interaction of soil ameliorants and nutrient levels could not affect harvest index significantly.

4.5 Nutrient studies

4.5.1 N, P, K and Ca contents in plant parts

4.5.1.1 Grain

Soil ameliorants or nutrient levels or their interaction did not influenced nitrogen and calcium content in maize grain. Phosphorus content was also not affected by soil ameliorants but nutrient levels significantly affected it. 150% RDF registered highest content of phosphorus in maize grain, which being similar with 125 and 100% RDF, had edge over 50 and 75% RDF. Rest all the treatments were alike. Interaction of soil ameliorants and nutrient levels had not influenced phosphorus content in maize grain.

Potassium content in maize grain was significantly influenced by soil ameliorants and was highest in the treatment receiving FYM+lime, showing superiority over remaining treatments, which on their own turn were similar to each other. Nutrient levels and their interaction with soil ameliorants had not influenced potassium content in maize grain (Table 17).

4.5.1.2 Stover

Soil ameliorants did not have significant impact on nitrogen content in stover. However, nutrient levels significantly affected it. 150 and 125% RDF being similar with each other, showed their edge over 50 and 75% RDF. Differences in nitrogen content due to 50, 75 and 100% RDF were not significant. Interaction of soil ameliorants and nutrient levels did not influenced nitrogen content in maize stover.

Phosphorus content in maize stover was significantly influenced by soil ameliorants. FYM or lime when applied alone could not increase phosphorus content in stover, but when applied in combination, registered higher phosphorus content than control and FYM, which was similar to that of lime alone. Nutrient levels and their interaction with soil ameliorants failed to register any significant influence on phosphorus content in maize stover.

Soil ameliorants and nutrient levels and their interaction did not have differential impact on potassium and calcium content in maize stover (Table 18).

4.5.1.3 Stone

Either of the soil ameliorants, nutrient levels or their interaction did not influence nitrogen and phosphorus content in maize stone. Similarly, soil ameliorants could also not affect potassium and calcium content in stone but nutrient levels significantly affected them. In case of potassium content in maize stone, 150% RDF being similar to that of 125% RDF recorded higher potassium content than lower nutrient levels. 125% RDF also had edge over 50% RDF while it was similar to that of 100 and 75% RDF.

In case of calcium content, 150 and 125% RDF being similar to 100% RDF showed edge over 50 and 75% RDF. Further, 50, 75 and 100% RDF were similar among themselves. Interaction of soil ameliorants and nutrient levels failed to impart any difference (Table 19).

4.5.2 Uptake of N, P, K and Ca (Kg/ha)

4.5.2.1 Nitrogen

Soil ameliorants significantly affected nitrogen uptake by grain and stone as well as total uptake (Table 20). In case of grain, application of soil ameliorants resulted in higher uptake of nitrogen than control. FYM+lime showed edge over all the treatments with 38.35, 22.88 and 8.93% increase over control, lime alone and FYM alone, respectively. FYM alone also recorded 27.01 and 12.81% more nitrogen uptake than control and lime respectively, whereas lime alone contributed to 12.58% increase over control.

In case of stone, FYM+lime showed edge over control, lime alone and FYM alone with 22.54, 13.69 and 13.69% increase in nitrogen uptake respectively. However, nitrogen removal under FYM alone or lime alone or control was similar.

Total nitrogen removal was maximum in FYM+lime, which being similar to FYM alone had edge over control and lime with 24.56 and 14.05% increase respectively. FYM and lime, alone, were on par with each other and showed superiority over control.

Nutrient levels significantly influenced nitrogen uptake in grain, stover and stone as well as total uptake. Each incremental dose of nutrients resulted in higher uptake of nitrogen than its preceding level in grain and the maximum uptake (73 kg N/ha) was with 150% RDF. In stover, 150 and 125% RDF, being similar to each other showed their edge over lower levels of nutrients. Further, 75 and 100% RDF, also being on par, showed their superiority over 50% RDF. In case of stone also, each incremental dose of nutrients registered higher uptake of nitrogen over their preceding levels except 75 and 100% RDF, which were similar with each other. Total uptake of nitrogen showed similar trends as that in grains and maximum nitrogen removal (124.03 kg/ha) was noted at 150% RDF. Interaction of soil ameliorants and nutrient levels could not affect nitrogen uptake significantly.

Table 17: Nutrient content (%) in maize grain affected by soil ameliorants and nutrient levels

Treatment	Nitrogen	Phosphorus	Potassium	Calcium
A. Soil ameliorants				
Control	1.21	0.246	0.179	0.127
FYM	1.27	0.269	0.179	0.128
LIME	1.26	0.268	0.183	0.128
FYM+ Lime	1.33	0.281	0.190	0.128
S Em ±	0.02	0.011	0.001	0.001
CD (P=0.05)	NS	NS	0.005	NS
B. Nutrient levels				
50% RDF	1.23	0.244	0.180	0.127
75% RDF	1.25	0.247	0.180	0.127
100% RDF	1.26	0.264	0.182	0.128
125% RDF	1.28	0.277	0.185	0.128
150% RDF	1.31	0.298	0.186	0.129
S Em ±	0.25	0.012	0.002	0.001
CD (P=0.05)	NS	0.036	NS	NS
Interaction				
S Em ±	0.05	0.249	0.004	0.002
CD (P=0.05)	NS	NS	NS	NS
CV%	6.89	16.19	3.66	2.19

Table 18: Nutrient content (%) in maize stover affected by soil ameliorants and nutrient levels

Treatment	Nitrogen	Phosphorus	Potassium	Calcium
A. Soil ameliorants				
Control	0.49	0.088	0.493	0.086
FYM	0.50	0.088	0.493	0 .089
LIME	0.50	0.091	0.499	0.090
FYM+ Lime	0.51	0.092	0.499	0.092
S Em ±	0.01	0.001	0.002	0.002
CD (P=0.05)	NS	0.003	NS	NS
B. Nutrient levels				
50% RDF	0.48	0.087	0.493	0.087
75% RDF	0.48	0.089	0.492	0.088
100% RDF	0.49	0.090	0.495	0.091
125% RDF	0.52	0.090	0.499	0.091
150% RDF	0.52	0.090	0. 502	0.091
S Em ±	0.01	0.001	0.003	0.002
CD (P=0.05)	0.03	NS	NS	NS
Interaction				
S Em ±	0.02	0.003	0.007	0.005
CD (P=0.05)	NS	NS	NS	NS
CV%	8.18	4.89	2.36	10.20

Table 19: Nutrient content (%) in maize stone affected by soil ameliorants and nutrient levels

Treatment	Nitrogen	Phosphorus	Potassium	Calcium
A. Soil ameliorants				
Control	0.29	0.089	0.180	0.093
FYM	0.29	0.089	0.182	0.094
LIME	0.29	0.090	0.184	0.097
FYM+ Lime	0.29	0.090	0.186	0.098
S Em ±	0.01	0.001	0.001	0.002
CD (P=0.05)	NS	NS	NS	NS
B. Nutrient levels				
50% RDF	0.28	0.089	0.180	0.090
75% RDF	0.29	0.089	0.182	0.092
100% RDF	0.28	0.090	0.182	0.095
125% RDF	0.29	0.090	0.185	0.100
150% RDF	0.30	0.090	0.186	0.100
S Em ±	0.01	0.001	0.001	0.003
CD (P=0.05)	NS	NS	0.003	0.007
Interaction				
S Em ±	0.01	0.001	0.002	0.005
CD (P=0.05)	NS	NS	NS	NS
CV%	7.55	0.90	2.08	9.26

4.5.2.2 Phosphorus

Soil ameliorants significantly affected uptake of phosphorus by grain, stover and stone as well as total phosphorus uptake (Table 21). In case of grain, maximum phosphorus uptake (14.39 kg/ha) was recorded in the treatment receiving FYM+lime, which being similar to FYM alone , had edge over lime alone and control. FYM alone also being on par with lime alone, had edge over control, while lime and control were alike. In case of stover, FYM+lime recorded higher uptake of phosphorus than FYM alone and control, while it was on par with lime alone. Lime alone, in its own turn was similar to that of FYM alone but had edge over control. Further, FYM alone could not increase the uptake of phosphorus in stover when compared with no ameliorant. In case of stone, uptake was increased on application of soil ameliorants. Higher uptake (0.91

kg/ha) was recorded in FYM+lime treatment than remaining treatments. However, FYM and lime, when applied alone, had no difference among them but showed their superiority over control. Total uptake was also increased with application of either FYM or lime, alone or in combination, than control. FYM+lime being similar to FYM alone, had edge over lime alone and control, while FYM alone and lime alone being on par, had their edge over control.

Nutrient levels significantly affected phosphorus uptake in grain, stover and stone as well as total uptake. In case of grain, 150 and 125% RDF being on par, had their edge over lower nutrient levels. 100% RDF also recorded higher phosphorus content than 50 and 75% RDF, which in their own turn were similar to each other. In case of stover, 150% RDF registered higher phosphorus removal (8.5 kg/ha) than lower levels of nutrients. Difference in P removal between 125 and 100% RDF as well as100 and 75% RDF was similar to each other and showed edge over 50% RDF. in case of uptake in stone and total uptake, higher uptake was recorded on each level than its preceding one. Total uptake in 150% RDF was 64.13, 40.88, 21.08 and 10.01% more than 50, 75, 100 and 125% RDF respectively.

Interaction of soil ameliorants and nutrient levels failed to impart any difference in phosphorus uptake.

4.5.2.3 Potassium

Potassium uptake in grain, stover and stone and total uptake was significantly influenced by soil ameliorants and nutrient levels (Table 22). In case of grain, maximum uptake was recorded in the treatment receiving FYM+lime, which was superior to all other treatments. FYM alone also showed its superiority over control and lime alone, whereas lime alone had edge over control. Uptake in stover was also highest in FYM+lime, which being similar to lime alone, had edge over FYM alone and control. Lime alone was superior to that of control while it was on par with FYM alone, which in its own turn, was similar to control. In case of stone, FYM+lime recorded higher uptake than all other treatments, while FYM alone and lime alone were similar to each other, but both exhibited significant edge over control. Same trend as that in the case of stone was observed in total uptake also where FYM+lime recorded 10.76, 4.99 and 4.82% higher potassium uptake than control, lime alone and FYM alone respectively. Crops with lime alone and FYM alone absorbed more potassium to the tune of 5.49 and 5.67 percent than the crop rose without soil ameliorants (control) respectively.

Further, crops with each incremental dose of nutrients removed more potassium than that with its preceding level, in grain, stover and stone as well as total uptake and maximum removal was noted at 150% RDF. Total uptake with 150% RDF was 30.35, 16.03, 9.84 and 4.06 percent higher than with 50, 75, 100 and 125% RDF respectively.

Interaction of soil ameliorants and nutrient levels could not affect uptake of potassium significantly.

4.5.2.4 Calcium

Calcium uptake by crop was influenced by soil ameliorants (Table 23). In case of grain, FYM alone or in combination with lime, being similar to each other, showed their superiority over lime alone and control in uptake of calcium. Lime alone also had edge over control. In case of stover, application of either FYM or lime, alone or in combination, being similar to each other, registered more uptake of calcium than control. In case of stone, FYM+lime showed its superiority over all the treatments. FYM alone and lime alone, being on par with each other, also had edge over control. Similarly, in case of total uptake, FYM+lime recorded 19.02, 9.33 and 5.63% more calcium uptake than control, lime alone and FYM alone respectively.

Nutrient levels also significantly influenced calcium uptake in maize crop. In case of grain, each incremental dose of nutrients registered higher calcium uptake than its preceding levels and maximum (7.12 kg/ha) being at 150% RDF. In case of stover, calcium uptake was maximum in treatment receiving 150% RDF, which being similar to 100 and 125% RDF, had edge over 50 and 75% RDF. Further, 125% RDF was also superior to 50 and 75% RDF, whereas 75 and 100% RDF, being similar to each other, had edge on 50% RDF. In case of stone also, 150 and 125% RDF, having similar calcium uptake, showed superiority on lower nutrient levels. In case of total uptake of calcium, incremental doses of nutrients resulted in higher uptake than its preceding level up to 125% RDF and thereafter no further increase was recorded. Total uptake in 150% RDF was 43.38, 23.86 and 7.17% higher than 50, 75 and 100% RDF, respectively.

Interaction of soil ameliorants and nutrient levels did not affect calcium uptake significantly.

4.6 Soil nutrient status

Soil ameliorants and nutrient levels affected nutrient status of soil after crop harvest (Table 24). pH of post harvest samples were increased where soil ameliorants were applied. FYM+lime, being similar to that of lime alone, recorded maximum pH and both of them showed superiority over FYM alone and control. FYM alone, in its own turn recorded higher pH than control. Nutrient levels also significantly influenced pH of soil and it was lowered on application of higher levels of nutrients, lowest being recorded with highest nutrient level, which was similar to 125% RDF. 125% RDF was similar to 100 and 75% RDF, 50% RDF showing edge on 125% RDF. 50, 75 and 100% RDF were similar among themselves.

Soil ameliorants and nutrient levels influenced organic carbon content of soil. Organic carbon was increased on application of soil ameliorants. Treatment receiving FYM+lime recorded higher organic carbon (0.64%) than FYM alone, lime alone and control. Further, FYM and lime alone, being on par with each other, showed edge over control. Nutrient levels also influenced organic carbon. Highest organic carbon was recorded in the treatment receiving 150% RDF, which being similar to 125% RDF, showed edge over lower nutrient levels. 125 and 100% RDF registered similar organic carbon and showed edge over50 and 75% RDF, which on their own turn were similar to each other.

Available nitrogen in soil was increased on application of soil ameliorants. Highest available nitrogen (224.54 kg/ha) was recorded in the treatment receiving FYM+lime which was similar to FYM and lime alone and showed their edge over control. Application of nutrient levels also significantly influenced available N (221.87 kg/ha) was recorded in the treatment with 150% RDF, which being similar to 125% RDF showed edge over 50, 75 and 100% RDF. 125% RDF being similar to those of 100 and 75% RDF, was superior to control. 50, 75 and 100% RDF, on their own turn were alike.

Table 20: Nitrogen uptake (kg/ha) in maize grain, stover and stone, and total uptake affected by soil ameliorants and nutrient levels

Treatment	Grain	Stover	Stone	Total
A. Soil ameliorants				
Control	48.87	40.99	2.44	92.30
FYM	62.07	42.70	2.63	107.40
LIME	55.02	43.16	2.63	100.81
FYM+ Lime	67.61	44.34	2.99	114.97
S Em ±	1.48	1.34	0.06	2.19
CD (P=0.05)	5.12	NS	0.19	7.58
B. Nutrient levels				
50% RDF	41.47	36.40	2.23	80.11
75% RDF	51.42	40.45	2.48	94.34
100% RDF	59.00	42.96	2.62	104.59
125% RDF	67.06	46.34	2.85	116.27
150% RDF	73.00	47.84	3.19	124.03
S Em ±	1.99	1.01	0.06	1.83
CD (P=0.05)	5.75	2.93	0.20	5.27
Interaction				
S Em ±	3.98	2.03	0.13	3.47
CD (P=0.05)	NS	NS	NS	NS
CV%	11.79	8.21	8.41	6.09

Table 21: Phosphorus uptake (kg/ha) in maize grain, stover and stone, and total uptake affected by soil ameliorants and nutrient levels

Treatment	Grain	Stover	Stone	Total
A. Soil ameliorants				
Control	10.03	7.34	0.76	18.13
FYM	13.21	7.56	0.82	21.59
LIME	11.87	7.86	0.83	20.56
FYM+ Lime	14.39	8.07	0.91	23.37
S Em ±	0.54	0.12	0.01	0.52
CD (P=0.05)	1.87	0.40	0.02	1.81
B. Nutrient levels				
50% RDF	8.26	6.59	0.71	15.56
75% RDF	10.15	7.50	0.77	18.42
100% RDF	12.37	7.85	0.84	21.06
125% RDF	14.59	8.09	0.89	23.57
150% RDF	16.50	8.50	0.95	25.95
S Em ±	0.72	0.12	0.01	0.76
CD (P=0.05)	2.08	0.36	0.03	2.21
Interaction				
S Em ±	1.44	0.25	0.02	1.53
CD (P=0.05)	NS	NS	NS	NS
CV%	20.21	5.63	4.97	13.12

Table 22: Potassium uptake (kg/ha) in maize grain, stover and stone, and total uptake affected by soil ameliorants and nutrient levels

Treatment	Grain	Stover	Stone	Total
A. Soil ameliorants				
Control	7.22	41.17	1.54	49.92
FYM	8.68	42.39	1.68	52.75
LIME	7.99	42.97	1.70	52.66
FYM+ Lime	9.68	43.73	1.89	55.29
S Em ±	0.16	0.36	0.02	0.40
CD (P=0.05)	0.55	1.24	0.07	1.38
B. Nutrient levels				
50% RDF	6.08	37.36	1.44	44.88
75% RDF	7.38	41.47	1.57	50.42
100% RDF	8.51	43.07	1.69	53.26
125% RDF	9.69	44.69	1.85	56.22
150% RDF	10.31	46.23	1.95	58.50
S Em ±	0.18	0.48	0.02	0.52
CD (P=0.05)	0.52	1.44	0.07	1.52
Interaction				
S Em ±	0.36	1.00	0.05	1.06
CD (P=0.05)	NS	NS	NS	NS
CV%	7.48	6.06	4.73	5.47

Table 23: Calcium uptake (kg/ha) in maize grain, stover and stone, and total uptake affected by soil ameliorants and nutrient levels

Treatment	Grain	Stover	Stone	Total
A. Soil ameliorants				
Control	5.11	7.19	0.80	13.09
FYM	6.20	7.69	0.87	14.75
LIME	5.56	7.78	0.90	14.25
FYM+ Lime	6.51	8.06	1.00	15.58
S Em ±	0.12	0.14	0.02	0.21
CD (P=0.05)	0.42	0.47	0.06	0.73
B. Nutrient levels				
50% RDF	4.26	6.58	0.72	11.55
75% RDF	5.20	7.38	0.79	13.37
100% RDF	5.97	7.92	0.89	14.78
125% RDF	6.70	8.14	0.99	15.84
150% RDF	7.12	8.38	1.06	16.56
S Em ±	0.12	0.23	0.03	0.26
CD (P=0.05)	0.35	0.67	0.08	0.74
Interaction				
S Em ±	0.24	0.47	0.06	0.52
CD (P=0.05)	NS	NS	NS	NS
CV%	7.09	10.52	10.88	6.19

Soil ameliorants and nutrient levels significantly influenced available phosphorus. Highest available P was recorded in the treatment receiving FYM+lime than all other treatments. Lime alone showed its superiority over FYM alone and control, while FYM alone also registered higher available P than control. Each incremental dose of nutrients registered significantly higher available phosphorus than its preceding levels, highest being recorded in 150% RDF.

Soil ameliorants and nutrient levels significantly influenced available potassium. Treatment receiving FYM alone registered maximum available potassium (127.68 kg/ha), which being similar to FYM+lime, showed their edge over control and lime alone.

Application of higher doses of nutrients increased available potassium status of soil and maximum was recorded in 150% RDF (129.5 kg/ha), which being similar to 125% RDF, had edge over rest of the treatments.

Soil ameliorants and nutrient levels significantly influenced exchangeable calcium in soil. Treatments receiving lime either alone or in combination with FYM had maximum exchangeable calcium in soil or showed their edge over FYM alone and control. FYM alone also increased exchangeable calcium in soil than control. Application of each incremental dose of nutrients resulted in higher exchangeable calcium and maximum (2.35 m eq/ 100 gm soil) was recorded in 150% RDF.

Interaction of soil ameliorants and nutrient levels did not affect nutrient status of soil after harvest of maize crop.

Table 24: Nutrient status and pH of soil after maize harvest affected by soil ameliorants and nutrient levels

Treatment	pH	Organic Carbon (%)	Available Nutrients (Kg/ha)			Exchangeable calcium m eq/ 100 gm soil
			Nitrogen	Phosphorus	Potassium	
A. Soil ameliorant						
Control	5.34	0.52	184.40	20.48	111.44	2.15
FYM	5.45	0.59	210.74	26.27	127.68	2.19
LIME	5.58	0.58	220.15	28.72	113.08	2.33
FYM+ Lime	5.61	0.64	224.54	31.80	126.56	2.33
S Em ±	0.01	0.01	4.11	0.33	1.67	0.01
CD (P=0.05)	0.04	0.02	14.24	1.13	5.77	0.03
B. Nutrient level						
50% RDF	5.49	0.55	201.49	14.17	111.28	2.13
75% RDF	5.48	0.56	204.62	20.83	114.78	2.18
100% RDF	5.48	0.59	208.54	26.66	119.00	2.25
125% RDF	5.45	0.60	213.25	32.29	123.90	2.30
150% RDF	5.43	0.62	221.87	40.14	129.50	2.35
S Em ±	0.01	0.01	3.46	0.52	2.34	0.01
CD (P=0.05)	0.03	0.02	9.96	1.51	6.76	0.03
Interaction						
S Em ±	0.02	0.01	6.91	1.05	4.68	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS
CV%	6.71	7.98	5.70	6.73	6.77	7.45
Initial value	5.39	0.51	200.7	12.76	150.07	2.14

4.7 Balance sheet

The data related to nutrient balance (0-20 cm soil depth) as affected by different soil ameliorants and nutrients levels have been presented in the tables 25, 26, 27 and 28. Total quantity of N, P, K and Ca removed by crop was subtracted from the sum of the nutrients applied and initially available soil nutrients. The deviation from this balance gave the actual change in fertility status of soil. Positive balance indicates soil build up and negative balance soil depletion.

Nitrogen balance in soil was negative when FYM alone or no ameliorant was applied. However, the magnitude of nitrogen loss was decreased on application of FYM than control. Nitrogen balance turned to positive when lime was applied, either alone or in combination with FYM. Balance was higher in the treatment receiving lime alone (+20.26 kg/ha) than FYM+lime (+14 kg/ha). Nitrogen balance decreased with increasing nutrient levels. The magnitude of negative balance was more with 150% RDF followed by 125 and 100% RDF, while it was positive at lower levels, i.e. 50 and 75% RDF.

Positive phosphorus balance in soil increased on application of soil ameliorants as well as increasing nutrient levels. Maximum positive balance (14.69 kg/ha) was recorded in the treatment receiving lime alone whereas a slightly lower positive balance (14.1 kg/ha) was observed with FYM+lime. Lowest positive balance of phosphorus was observed in control. On application of increasing nutrient levels, balance of phosphorus in soil was increased from 2.77 kg/ha in 50% RDF to 17.3 kg/ha in 150% RDF.

Potassium balance in soil was negative in all treatments tested. But the magnitude of loss was reduced on application of soil ameliorants as well as higher nutrient levels. Loss of potassium was minimum in the treatment receiving lime only (5.16 kg/ha). On application of increasing nutrient levels, potassium loss in soil was reduced from 12.66 kg/ha in 50% RDF to 1.65 kg/ha in 150% RDF.

Calcium balance in soil was negative in all the treatments. Loss was however, reduced on application of soil ameliorants and nutrient levels. Reduction in loss was more on application of lime, either alone (24.25 kg/ha) or in combination with FYM (20.61 kg/ha). On application of increasing nutrient levels, loss of calcium in soil was reduced from 52.2 kg/ha in 50% RDF to 13.85 kg/ha in 150% RDF.

Table 25: Nitrogen balance sheet (Kg/ha) after maize harvest affected by soil ameliorants and nutrient levels

Treatment	Soil initial (A)	Addition through fertilizer (B)	Total A+B=C	Crop removal (D)	Expected balance C-D=E	Final available (F)	Gain/ loss F-E=G
A. Soil ameliorant							
Control	200.70	100.00	300.70	92.30	208.40	184.40	-24.00
FYM	200.70	125.00	325.70	107.40	218.30	210.74	-7.56
LIME	200.70	100.00	300.70	100.81	199.89	220.15	+20.26
FYM+ Lime	200.70	125.00	325.70	114.97	210.73	224.15	+14.00
B. Nutrient level							
50% RDF	200.70	62.50	263.20	80.11	183.09	201.49	+18.00
75% RDF	200.70	87.50	228.20	94.34	193.86	204.62	+10.76
100% RDF	200.70	112.50	313.20	104.59	208.61	208.54	-0.07
125% RDF	200.70	137.50	338.20	116.27	221.93	213.25	-8.68
150% RDF	200.70	162.50	363.20	124.03	239.17	221.87	-17.30

Table 26: Phosphorus balance sheet (Kg/ha) after maize harvest affected by soil ameliorants and nutrient levels

Treatment	Soil initial (A)	Addition through fertilizer (B)	Total A+B=C	Crop removal (D)	Expected balance C-D=E	Final available (F)	Gain/ loss F-E=G
A. Soil ameliorant							
Control	12.76	21.83	34.59	18.13	16.46	20.48	+4.02
FYM	12.76	28.31	41.07	21.59	19.48	26.27	+6.79
LIME	12.76	21.83	34.59	20.56	14.03	28.72	+14.69
FYM+ Lime	12.76	28.31	41.07	23.37	17.70	31.80	+14.10
B. Nutrient level							
50% RDF	12.76	14.20	26.96	15.56	11.40	14.17	+2.77
75% RDF	12.76	19.65	32.41	18.42	13.99	20.83	+6.84
100% RDF	12.76	25.11	37.87	21.06	16.81	26.66	+9.85
125% RDF	12.76	30.57	43.33	23.57	19.76	32.29	+12.53
150% RDF	12.76	36.03	48.79	25.95	22.84	40.14	+17.30

Table 27: Potassium balance sheet (Kg/ha) after maize harvest affected by soil ameliorants and nutrient levels

Treatment	Soil initial (A)	Addition through fertilizer (B)	Total A+B=C	Crop removal (D)	Expected balance C-D=E	Final available (F)	Gain/ loss F-E=G
A. Soil ameliorant							
Control	150.07	20.83	170.90	49.92	120.98	111.44	-9.54
FYM	150.07	37.49	187.56	52.75	134.81	127.68	-7.13
LIME	150.07	20.83	170.90	52.66	118.24	113.08	-5.16
FYM+ Lime	150.07	37.49	187.56	55.29	132.27	126.56	-5.71
B. Nutrient level							
50% RDF	150.07	18.75	168.82	44.88	123.94	111.28	-12.66
75% RDF	150.07	23.96	174.03	50.42	123.61	114.78	-8.83
100% RDF	150.07	29.16	179.23	53.26	125.97	119.00	-6.97
125% RDF	150.07	34.37	184.44	56.22	128.22	123.90	-4.32
150% RDF	150.07	39.58	189.65	58.50	131.15	129.50	-1.65

Table 28: Calcium balance sheet (Kg/ha) after maize harvest affected by soil ameliorants and nutrient levels

Treatment	Soil initial (A)	Addition through fertilizer (B)	Total A+B=C	Crop removal (D)	Expected balance C-D=E	Final available (F)	Gain/ loss F-E=G
A. Soil ameliorant							
Control	960.00	62.50	1022.50	13.09	1009.41	964..00	-45.41
FYM	960.00	62.50	1022.50	14.75	1007.75	981.94	-25.81
LIME	960.00	122.50	1082.50	14.25	1068.25	1044.00	-24.25
FYM+ Lime	960.00	122.50	1082.50	15.58	1066.92	1046.31	-20.61
B. Nutrient level							
50% RDF	960.00	61.25	1021.25	11.55	1009.70	957.50	-52.20
75% RDF	960.00	76.87	1036.87	13.37	1023.50	980.00	-43.50
100% RDF	960.00	92.50	1052.50	14.78	1037.72	1007.50	-30.22
125% RDF	960.00	108.12	1068.12	15.84	1052.28	1030.84	-21.44
150% RDF	960.00	123.75	1083.75	16.56	1067.19	1053.34	-13.85

4.8 Economics of Maize Production

4.8.1 Gross Return

Gross return was significantly influenced by soil ameliorants. Highest gross return was recorded with crop receiving FYM+lime (Rs 37580) which was similar to the crop receiving FYM alone (Rs 36008). The gross return with FYM+lime was 15.55 and 24.96% higher than those obtained with lime alone and control. Similarly, gross return with FYM was 10.72 and 19.73% higher than the crops with lime alone and control. Crop grown with lime alone had 8.14% higher gross return than control.

Each incremental dose of nutrients recorded higher gross return than its preceding level and maximum being Rs 40937/ha at 150% RDF. The increase in gross return at 150% RDF was to the tune of 61.86, 34.07,17.8 and 5.72% than 50, 75, 100 and 125% RDF respectively.

Interaction of soil ameliorants and nutrient levels could not affect gross return significantly (Table 29).

4.8.2 Net Return

Net return was significantly influenced by soil ameliorants. FYM+lime and FYM alone, being similar to each other, resulted in higher net return, which was to the tune of 18.21 and 10.64% respectively than lime and 35.57 and 26.89% than control. Lime alone also registered 14.69% higher net return than control.

In case of nutrient levels, each incremental dose of nutrients resulted in higher net return than its preceding level up to 125% RDF (Rs 21359/ha) and after this, increasing the nutrient level to 150% RDF did not made any significant difference.

Interaction of soil ameliorants and nutrient levels failed to affect net return significantly (Table 29).

Table 29: Economic aspects of maize affected by soil ameliorants and nutrient levels

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit:: Cost ratio
A. Soil ameliorant				
Control	15444	30074	14631	0.93
FYM	17444	36008	18565	1.06
LIME	15744	32523	16780	1.05
FYM+ Lime	17744	37580	19835	1.11
S Em ±	-	662	668	0.05
CD (P=0.05)	-	2290	2312	0.16
B. Nutrient level				
50% RDF	15058	25291	10233	0.67
75% RDF	15826	30532	14705	0.92
100% RDF	16594	34752	18159	1.09
125% RDF	17361	38721	21359	1.23
150% RDF	18129	40937	22807	1.26
S Em ±	-	637	635	0.04
CD (P=0.05)	-	1839	1833	0.11
Interaction				
S Em ±	-	1274	1269	0.08
CD (P=0.05)	-	NS	NS	NS
CV%	-	6.48	12.60	13.25

4.8.3 Benefit: Cost Ratio

Benefit: cost ratio was influenced by soil ameliorants. Highest benefit: cost ratio was recorded in the treatment receiving FYM+lime, which being similar to those receiving either FYM or lime alone, had an edge over control. FYM or lime when applied alone, did not affect benefit: cost ratio compared to control.

Each incremental nutrient doses significantly increased benefit: costratio over its preceding level up to 125% RDF. Further increase on nutrient level beyond 150% RDF could not increase the benefit: cost ratio.

Interaction of soil ameliorants and nutrient levels did not had any significant effect on benefit: cost ratio (Table 29).

DISCUSSION

The results of the experiment 'Effect of soil ameliorants and nutrient levels on productivity of maize (*Zea mays* L.)' presented in the preceding chapter have been discussed herewith establishing cause and effect relationship in the light of available literature on the subject. The sequence of discussion is around growth and development, yield and yield components, economics, nutrient uptake and soil fertility status after harvest of maize.

5.1 Growth and Development

Dry matter accumulation in maize increased continuously with crop age and reached its peak at maturity (Table 4). Similarly, crop growth rate of maize increased with crop age up to 80 days after sowing and decreased slightly thereafter. Actually, there was a fast growth rate at initial phase of crop growth and then it formed a plateau and finally declined thereafter. Leaf area index of maize also increased with age and reached its peak in 80 days after sowing. This confirms the findings of Singh (1993).

Soil ameliorants, FYM and lime, alone or in combination, positively influenced leaf area index (Fig 3), crop growth rate (Fig 5) and dry matter production (Table 4). This was due to increased availability of mineral nutrients thus increased uptake of nutrients (Table 20, 21, 22, 23) resulting in better vegetative growth. Actually, FYM is a storehouse of nutrients, increases soil microbial activity, acts as buffering agent for soil pH and increases water retention capacity of soil resulting in favorable growth of crops (Mehta *et al*. 2005, Nanjappa *et al*. 2001). Similarly, liming reduces soil acidity, improves soil microbial activity, increases organic N content and enhances the availability of nutrients, is a well-established fact (Motiramani, 1971, Banerjee and Sinha, 1966). Liming in presence of organic manure is known to maintain the levels of hydrolysable NH_4^+-N and amino-N fractions in soil, thus growth of crops (Sarkar *et al.* 2000).

Nutrient levels favorably influenced the growth parameters and thus accumulated more dry matter with higher growth rate at 150% RDF. Nitrogen being the component of amino acids, nucleic acids and number of co-enzymes, can induce cell elongation, cell enlargement, and cell division. Likewise, phosphorus being a constituent of adenosine diphosphate and adenosine triphosphate, also helps in cell division and multiplication. Potassium is a major osmotically active component in plant cell, contributing to cell turgor and enhancing the capacity of cells to retain water, which has a direct bearing on the size of cells. These functions of nutrients caused increase in plant growth with increasing nutrient levels (Pierre *et al.* 1966).

The nutrient status of crop plant is known to influence phasic development of maize crop. Increasing rate of nutrients fastened the onset of various phenophases of maize i.e. knee high, tasseling and silking stage because of faster growth rate. However, total duration of the crop was similar in all the nutrient levels. Thus duration of reproductive growth phase, silking-tasseling to maturity, was increased in higher nutrient levels resulting in increase in yield components and yield. This confirms the findings of Singh and Totawat (2002), Tolessa Debele *et al*. (2001), Raichaudhuri and Kumar (1999), Suri and Jha (1996), Dutta and Gupta (1984) and Mandal *et al.* (1966).

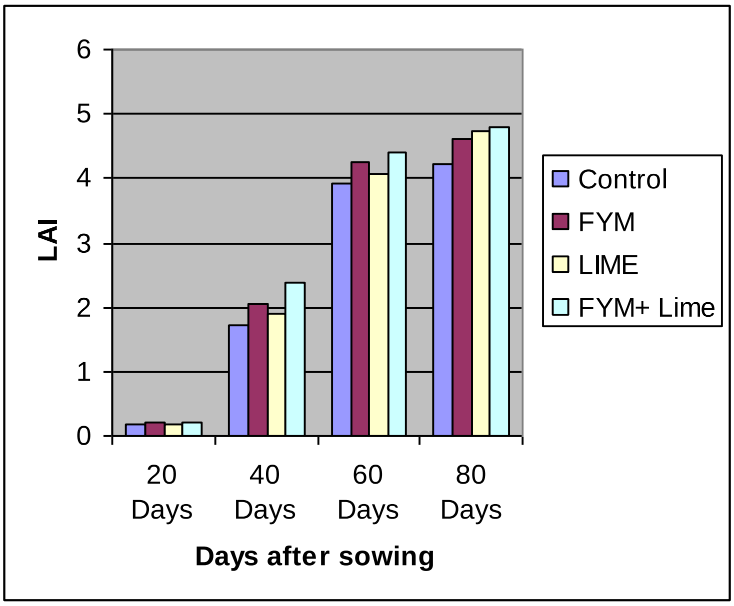

Fig. 3 Leaf area index of maize as influenced by soil ameliorants

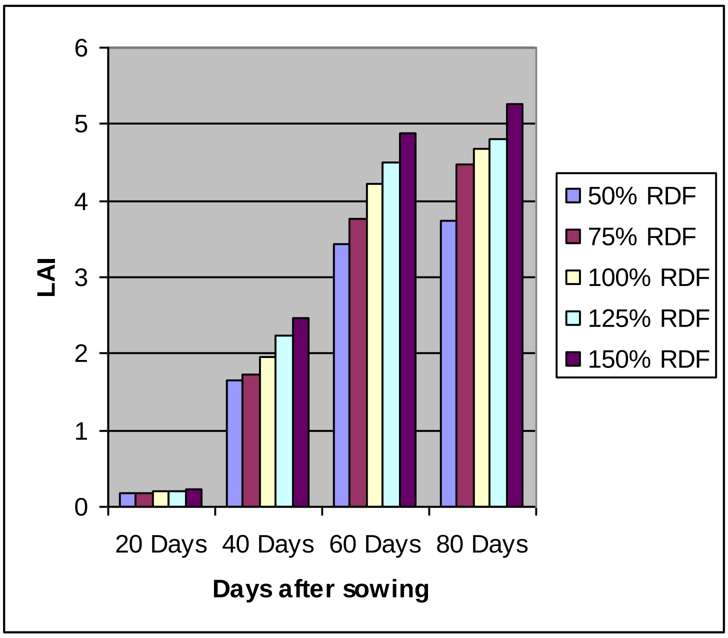

Fig. 4 Leaf area index of maize as influenced by nutrient levels

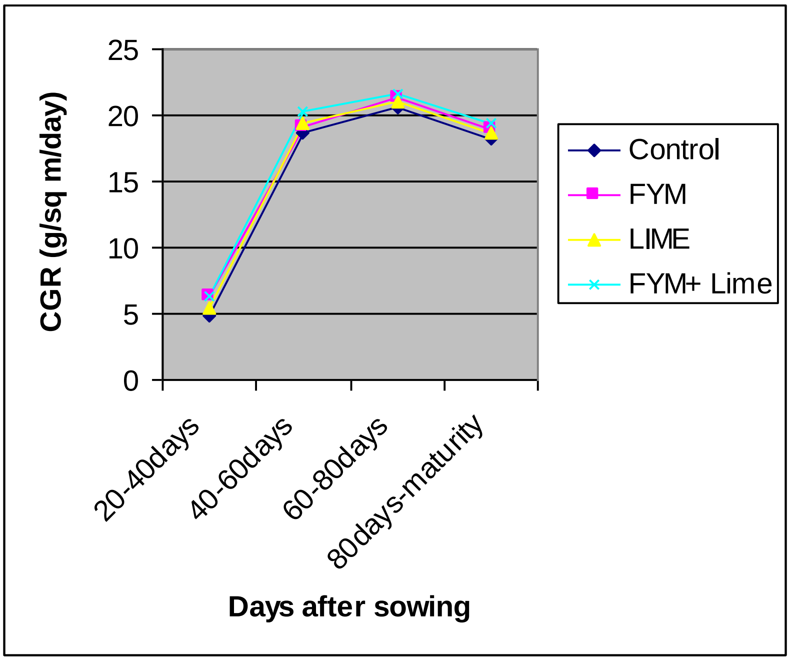

Fig. 5 Crop growth rate of maize as influenced by soil ameliorants

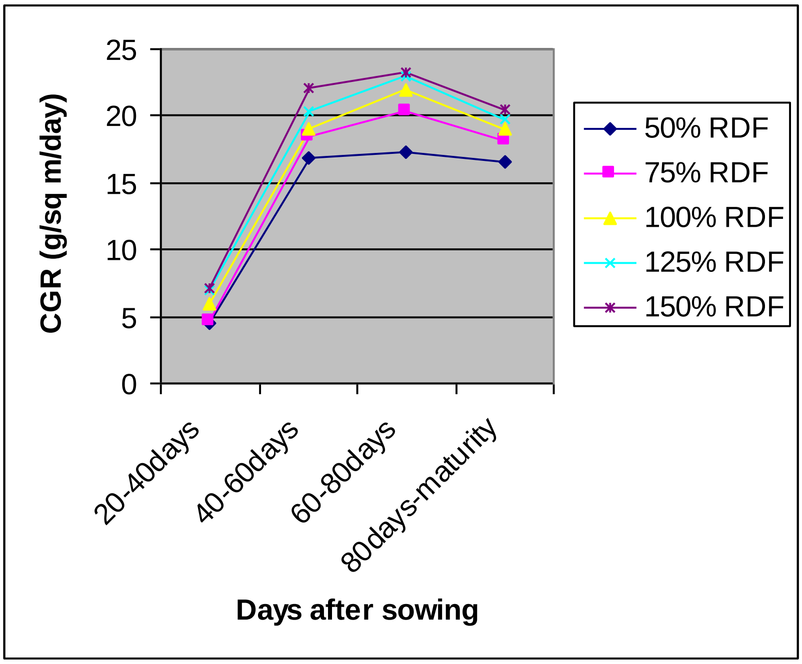

Fig. 6 Crop growth rate of maize as influenced by nutrient levels

5.2 Yield and Yield Attributes

Soil ameliorants positively affected grain, stone and stover yield. The crop receiving FYM+lime, being similar to that receiving FYM alone (48.59 q/ha), produced maximum grain yield of 50.75 q/ha which was 16.37 and 26.21% higher than the crops receiving lime alone and control, respectively. Similarly, FYM alone produced 11.42 and 20.84% higher grain yield than lime alone and control, respectively. Lime alone also registered 8.46 percent more yield than control (40.21 q/ha). This is owing to beneficial effects of farmyard manure on growth and development of the crop, which ultimately improved yield components.

Increase in nutrient level markedly increased grain yield of maize and maximum grain yield of 55.4 q/ha produced at 150% RDF. Grain yield is a cumulative expression of growth, development and yield components in a given environment. In the present investigation, 150% RDF favorably influenced growth and development of crop, number of cobs/m^2, cob length, cob girth, grain rows/cob, grains/cob and 1000 grain weight than lower levels of fertilizers. It is a well established fact that nitrogen and phosphorus, having a complementary relationship, help in better nutrition of flower primordia, which directly produced cobs and grain rows, whereas potassium helps in development of reproductive organs and filling of grains with photosynthates. This confirms the findings of Singh and Totawat (2002), Singh and Sarkar (2001) and Rusu and Rusu (2001).

Actually better growth conditions in treatments receiving soil ameliorants and higher fertilizer dose provided a better source sink relationship enabling greater synthesis and translocation of metabolites to reproductive organs resulting in improved yield attributing characters and ultimately leading to improved grain yield of maize. Increase in yield of maize could be ascribed to overall improvement in crop growth, enabling the plant to absorb more nutrients as evident from the enhanced uptake of nutrients in present investigation, which empowered the plant to manufacture more quantity of photosynthates accumulating them in reproductive parts. Ultimately these beneficial effects of soil ameliorants and higher nutrient levels resulted in better expression of yield components at which led to higher grain yield as well as stone yield. This confirms the findings of Mehta *et al*. (2005), Sarir *et al*. (2005), Kumar and Thakur (2004), Tolessa Debele *et al*. (2001), Arya and Singh (2001), Raichaudhuri and Kumar (1999), Aitken *et al*. (1998), Dutta and Gupta (1984) and Mandal *et al.* (1966).

Stover yield is an indication of vegetative growth of the crop in terms of leaf area index, crop growth rate and total dry matter production/unit area. In the present investigation, all these components were favorably influenced with soil ameliorants and increasing dose of fertilizer. Crop with 150% RDF produced 21.53, 9.35, 5.94 and 2.98% higher stover yield than that of 50, 75, 100 and 125% RDF, respectively.

Soil ameliorants also influenced grain: straw ratio and harvest index. FYM+lime and FYM alone produced higher grain: straw ratio and harvest index than control and lime alone. In case of nutrient levels, 150 and 125% RDF being similar to each other, produced higher grain: straw ratio and harvest index than 50, 75 and 100% RDF. This was because more accumulation of photosynthates in the reproductive parts. A number of studies conducted earlier (Mehta *et al.*

2005, Sarir *et al*. 2005, Kumar and Thakur, 2004, Singh and Totawat, 2002, Sharanappa *et al.* 2001, Arya and Singh, 2001, Aitken *et al*. 1998, Raichaudhuri and Kumar, 1999, Dutta and Gupta, 1984 and Mandal *et al.* 1966) support this result.

5.3 Nutrient Uptake

Nutrient uptake by maize crop was influenced by soil ameliorants. Nitrogen uptake was increased by 24.56%, 16.36% and 9.22% on application of FYM+lime, FYM and lime respectively than control. The corresponding increase was 28.9%, 19.08% and 13.4% in case of phosphorus, 10.76%, 5.67% and 5.49% in case of potassium and 19.02%, 12.68% and 8.86% in case of calcium. FYM or lime, alone or in combination increases microbial activity in soil system, thus availability of nutrients, which might have increased the total uptake of N, P, K and Ca by increasing the total biomass production. Increasing rate of nutrients also led to increased removal of N, P, K and Ca. Consequently, crop grown with 150% RDF absorbed 54.82, 66.77, 30.35 and 43.38% more N, P, K and Ca, respectively, than 50% RDF.

Nutrient uptake by a crop is the net result of a number of processes, most of which are under metabolic control. Total uptake of nutrients is governed by nutrient content and total dry matter production. More than anything else, N, P, K and Ca uptake is controlled by concentrations of nitrogen (NH_4^+, NO_3^-), phosphorus ($H_2PO_4^-$, HPO_4^{--}), potassium (K^+) and calcium (Ca^{++}) in the root zone. Increase in P application produces deeper and more prolific roots and thus crop takes up nutrients and water from a larger volume of soil. Response of phosphorus also increases at higher levels of nitrogen. Potassium also improves utilization of nitrogen and phosphorus. Uptake of potassium by plants is closely associated with the metabolism and specially root respiration. ATP generated by respiration is believed to be closely linked with the transport of K^+ ions across the biological membrane.

The result confirms by the findings of Mehta *et al.* (2005), Sarir *et al*. (2005),Kumar and Thakur (2004), Singh and Totawat (2002), Haque *et al.* (2001), Padmaja *et al*. (1999) and Greef (1994).

5.4 Soil Fertility Status after Harvest of Crop

Soil ameliorants, FYM and lime alone or in combination, improved the soil reaction, organic carbon, available N, P, K and exchangeable Ca, thus soil fertility after maize harvest, compared to control. It is obvious as lime by correcting the soil reaction increases availability of nutrients for plant growth (Mausumi Raichaudhuri and Kumar, 1999, Martinez and Colmenares, 1995, Mandal *et al.* 1966). FYM helps in improving soil fertility, being storehouse of nutrients (Nanjappa, 2001).

Increasing nutrient levels favorably improved available nitrogen, phosphorus, potassium, and exchangeable calcium status of soil after harvest of crop. However, soil reaction decreased with increasing nutrient level. Results were confirmed by the findings of Mehta *et al.* (2005), Sarir *et al.* (2005), Singh and Totawat (2002), Stefanescu (2002), Singh *et al.* (1996), Kamalakumari and Singaram (1996), Reddy and Khera (1999), Hegde and Katyal (1998) and Singh (1990).

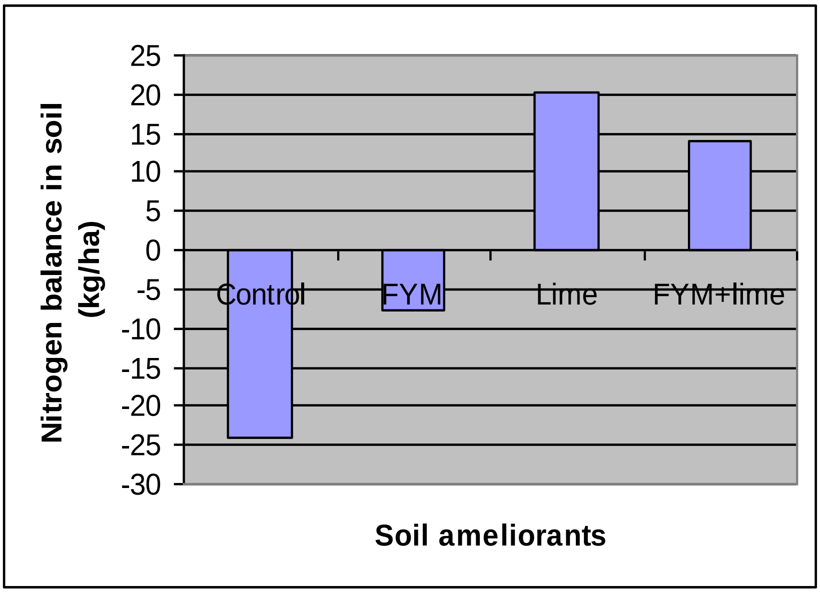

Fig. 7 Balance sheet of nitrogen as influenced by soil ameliorants

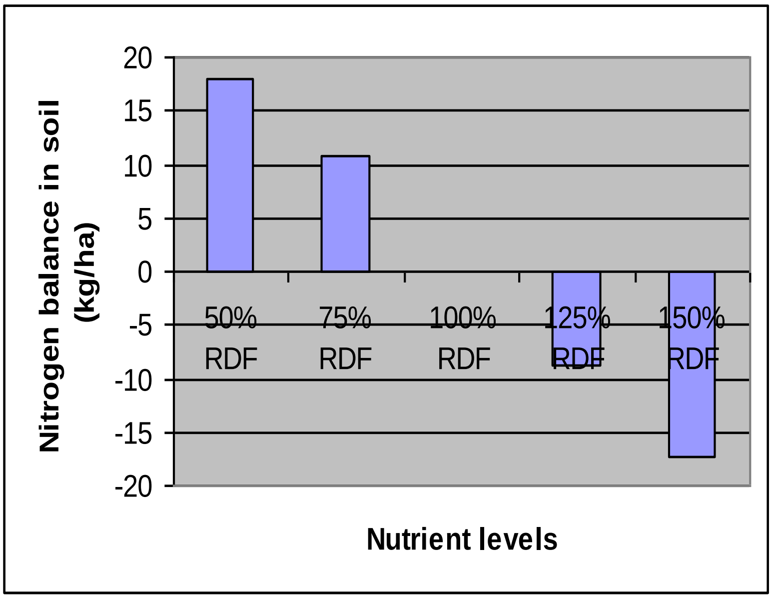

Fig. 8 Balance sheet of nitrogen as influenced by nutrient levels

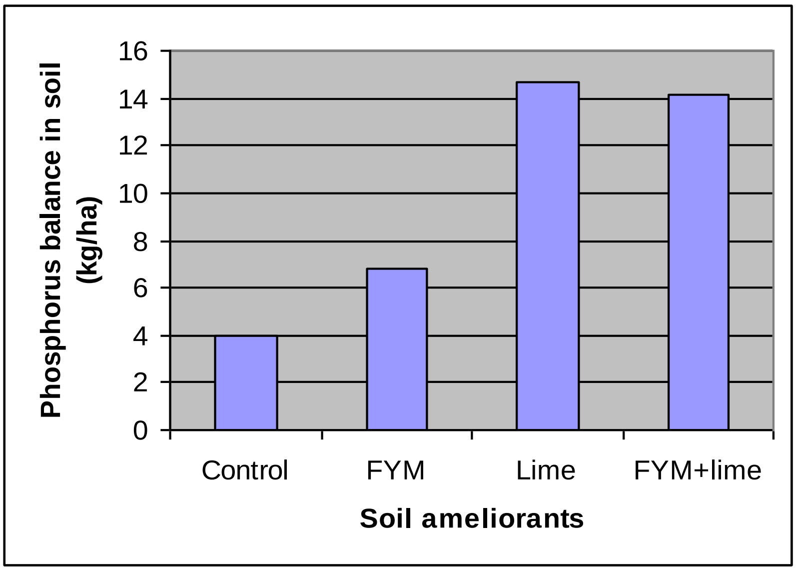

Fig. 9 Balance sheet of phosphorus as influenced by soil ameliorants

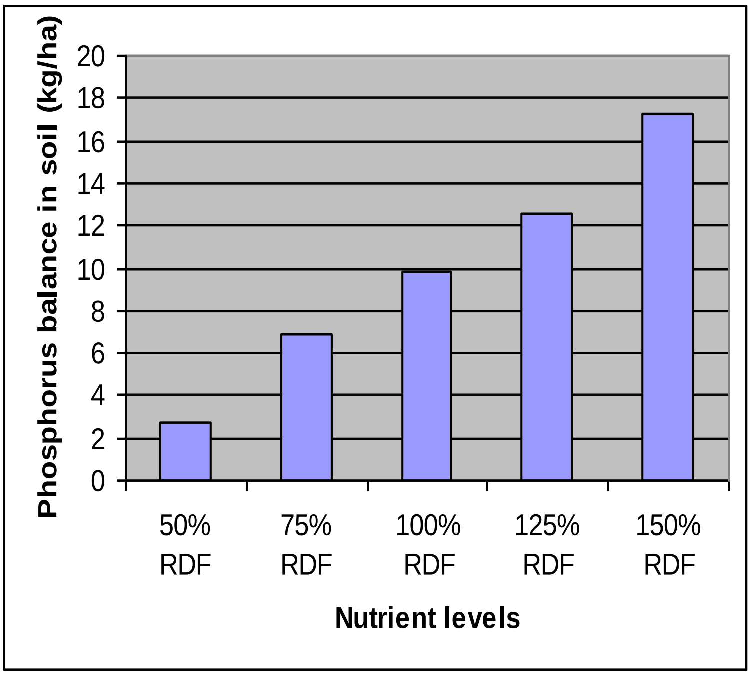

Fig. 10 Balance sheet of phosphorus as influenced by nutrient levels

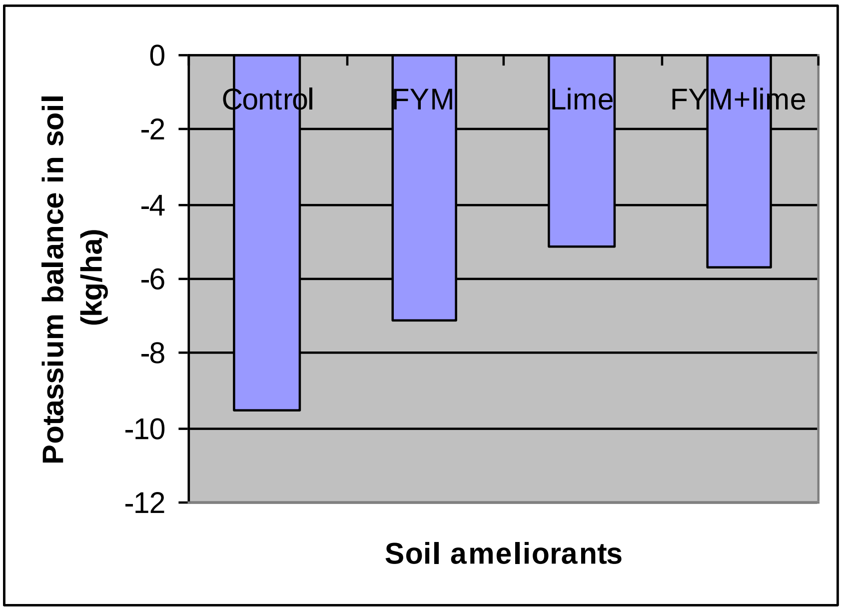

Fig. 11 Balance sheet of potassium as influenced by soil ameliorants

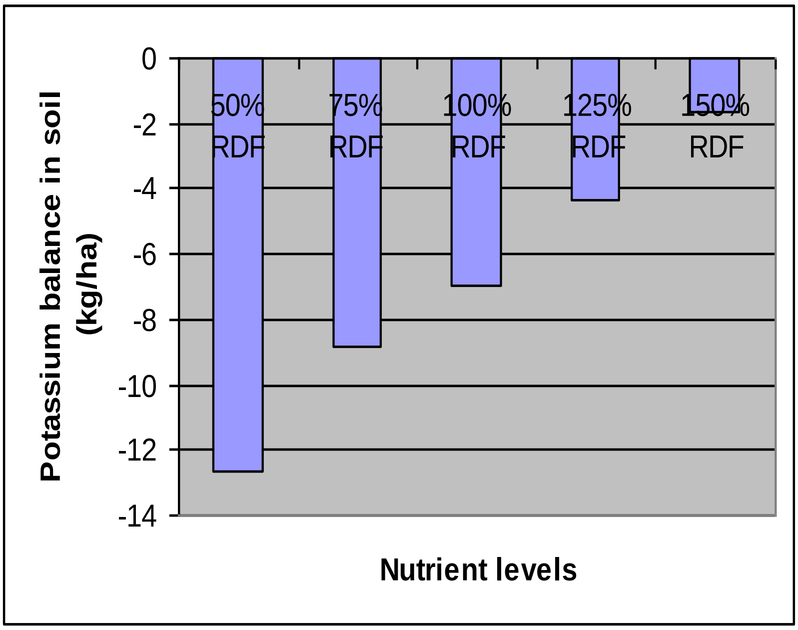

Fig. 12 Balance sheet of potassium as influenced by nutrient levels

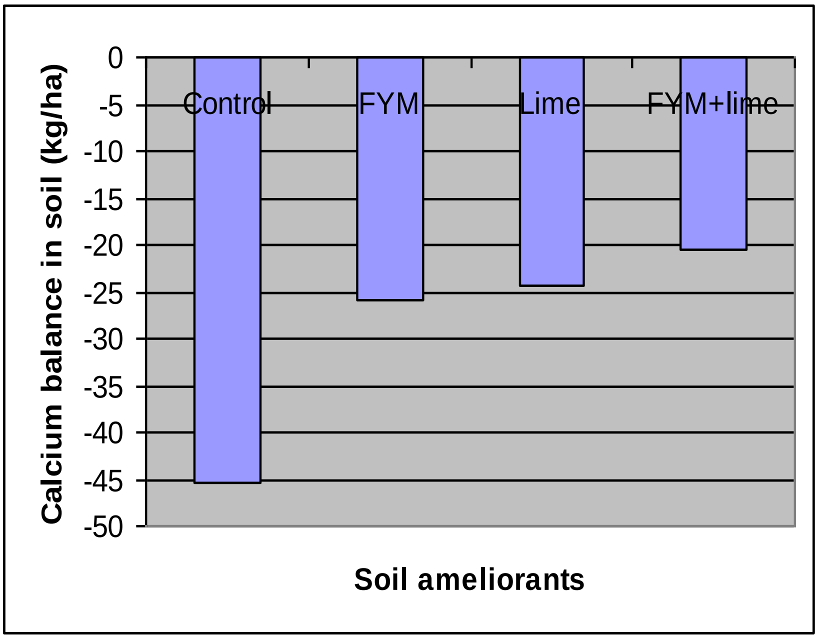

Fig. 13 Balance sheet of calcium as influenced by soil ameliorants

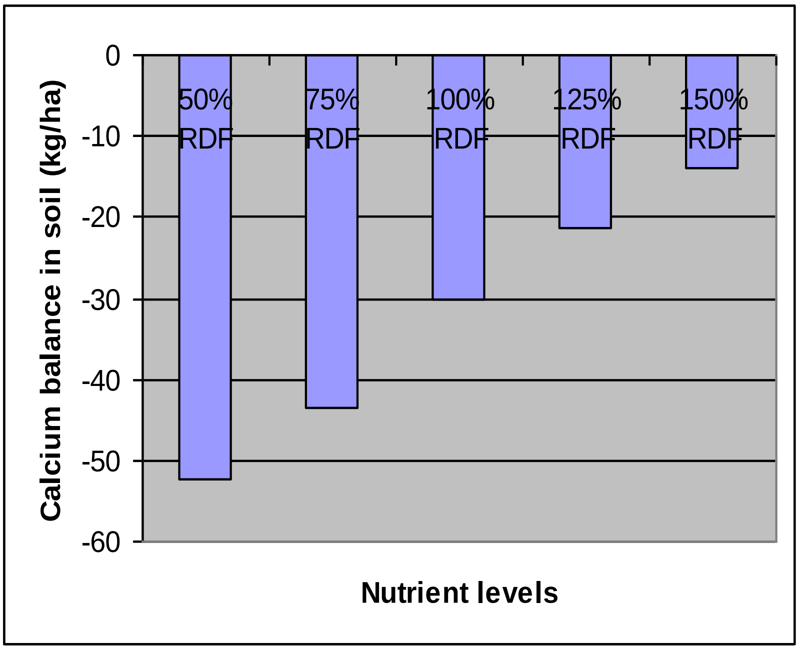

Fig. 14 Balance sheet of calcium as influenced by nutrient levels

5.5 Nutrient Balance Sheet

Nutrient balance sheet approach is used for judicious application of nutrients aiming at maintaining soil fertility and productivity on long term basis. In present investigation the soil was sandy loam, low in available N, medium in available P and K and low in exchangeable Ca. Nitrogen balance was increased on application of soil ameliorants (Fig 7). Being on the negative side, the magnitude of loss was lower on application of FYM than control while it turned towards positive on application of lime, alone or in combination with FYM. This was because liming increases the availability of nitrogen in soil. Magnitude of gain was more in case of lime alone than FYM+lime inspite of higher N value was because of higher yield and hence more uptake of nitrogen in FYM+lime. Nitrogen balance was decreased on application of higher dose of N (Fig 8). At 50% RDF, it was positive, turning towards negative from 100% RDF to 150% RDF.

Phosphorus balance was positive with all the treatments. However, magnitude of gain increased on application of soil ameliorants, maximum being with lime alone (Fig 9). It also increased with increase in nutrient levels from 50% RDF to 150% RDF (Fig 10).

Potassium balance was negative in all the treatments but in decreasing order on application of soil ameliorants and increasing levels of nutrients (Fig 11 and 12). Similarly, calcium balance was also on negative side and magnitude of loss decreasing with application of soil ameliorants and increasing levels of nutrients (Fig 13 and 14). This indicates depletion of potassium and calcium, even on application of nutrients. This behavior might be explained in the light of the fact that upland soil are rich in Koalinite type of mineral with low ion retentivity along with high rainfall in this region.

5.6 Economics

Crop production technology must be met economically viable for adoption. In present investigation, economics of maize production was significantly influenced on application of soil ameliorants. FYM+lime (Rs 19835/ha) and FYM alone (Rs 18565/ha) being similar to each other, resulted in higher net return than lime alone (Rs 16780/ha) and control (Rs 14631/ha). This followed the path of grain yield.

Highest net benefit ratio was recorded in the treatment receiving FYM+lime, which being similar to those receiving either FYM or lime, alone, had an edge over control. This is because of input output ratio where FYM was costlier than lime.

Each incremental dose of nutrients resulted in higher net return and net benefit cost ratio than their preceding levels up to 125% RDF (Rs 21359/ha with net benefit cost ratio of 1.23 per rupee investment) and further increase in nutrient level (150% RDF) was not economically viable. This is because of prevailing market price, inspite of the fact that grain, stone and stover yield was higher with 150% RDF than 125% RDF. The results were in agreement to the findings of Stefanescu (2002), Suri and Jha (1996) and Sharma and Singh (1996).

SUMMARY AND CONCLUSION

Soil fertility is one of the most important factors to limit productivity of maize in this region. Soil fertility status is in general low with prevailing soil acidity and low organic carbon. In this situation lime, by improving the soil reaction and hereby-making nutrients more available to the crops, and FYM being storehouse of nutrients, improving overall fertility status of soil, are the key factors to improve productivity of maize. Hence a field experiment was conducted during kharif season of 2007 to find out the effects of soil ameliorants and nutrient levels on productivity of maize on sandy loam soil, acidic in reaction, medium in organic carbon, low in available nitrogen, medium in available phosphorus, exchangeable potassium and exchangeable calcium, of Ranchi. The experiment was laid out in split plot design of four-soil ameliorant treatments (control, FYM, lime and FYM+lime) in main plot and five nutrient levels (50, 75, 100, 125 and 150% RDF) in sub plot and replicated thrice.

6.1 Effects of soil ameliorants

1. FYM+lime produced highest grain yield of 50.75 q/ha which was significantly higher than control (40.21 q/ha) and lime alone (43.61 q/ha) and on par with FYM alone (48.59 q/ha). Stover and stone yield was also higher in FYM+lime treatment.
2. FYM+lime recorded higher number of cobs per unit area than control, being on par with FYM and lime alone, more grain rows/cob than control and FYM alone and more grains/cob than control and lime alone, which ultimately reflected in the grain yield of maize.

3. FYM+lime resulted in early onset of knee high, tasseling and silking stage while maturity was delayed where FYM alone or in combination with lime was applied.
4. FYM+lime accumulated more dry matter at maturity with higher crop growth rate and leaf area index resulting in higher biomass production in this treatment.
5. FYM+lime recorded higher uptake of N, P, K and Ca from soil as compared to other treatments.
6. FYM+lime and lime alone helped retaining soil fertility by increasing balance of nitrogen and phosphorus in soil and reducing loss of potassium and calcium in soil.
7. FYM and lime, alone or in combination, resulted in higher net return and net benefit cost ratio than no application of soil ameliorants.

6.2 Effects of nutrient levels

1. 150% RDF produced maximum grain yield of 55.4 q/ha as compared to 52.49 q/ha in 125% RDF, 46.76 q/ha in 100% RDF, 40.84 q/ha in 75% RDF and 33.62 q/ha in 50% RDF. Each incremental dose of nutrients resulted in higher grain yield than its preceding level. Stone and stover yield followed the trend of grain yield.
2. 150% RDF recorded higher cobs per unit area, cob length, cob girth, grain rows/cob, grain/cob and 1000-grain weight than lower levels of nutrients, which ultimately led to higher grain production in maize.
3. 150% RDF resulted in early onset of knee high, tasseling and silking stage in maize reflecting its better growth and development.

4. 150% RDF accumulated maximum dry matter at maturity with higher crop growth rate and leaf area index during its whole span of life resulting in higher stone and stover yield in this treatment.
5. 150% RDF recorded higher uptake of N, P, K and Ca than lower levels.
6. 150% RDF resulted in higher availability of mineral nutrients than all other levels. Nitrogen balance in soil was reduced on application of higher levels while phosphorus balance was increased. Potassium and calcium was however negative but loss was reduced on application of higher levels of nutrients.
7. Crop receiving 150% RDF and 125% RDF, being similar with each other, resulted in higher net return and net benefit cost ratio than rest of the treatments.

6.3 Effects of soil ameliorants X nutrient levels

1. Interaction of soil ameliorants and nutrient levels significantly affected dry matter production of maize at 40 days after sowing. The crop receiving FYM+lime with 150% RDF registered maximum dry matter (170.33 g/m^2), which being similar to FYM+lime at 100 or 125% RDF as well as FYM alone at 125 or 150% RDF showed its edge over remaining combinations of soil ameliorants and nutrient levels.
2. Interaction of soil amelirants and nutrient levels was significant in case of LAI at 40 DAS where FYM+lime with 125 and 150% RDF resulted in higher LAI than all other treatments.
3. Interaction of soil ameliorants and nutrient levels had a significant effect on number of cobs per unit area. 75% RDF with FYM+lime was as good as 150% RDF, with or without soil ameliorants or 125% RDF with soil ameliorants or 100% RDF with FYM+lime.

CONCLUSION

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

- Application of FYM @ 5t/ha and lime @3 q/ha, alone or in combination, in maize improves growth and development of the crop resulting in higher productivity and economic returns and helps in maintaining soil health.
- Maize crop with 125% RDF (125kg/ha N, 52.5 kg/ha P_2O_5 and 31.25 kg/ha K_2O) had better crop growth, yield attributes and yield as well as net return and benefit: cost ratio.

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APPENDIX-1:WEEKLY WEATHER DATA DURING THE EXPERIMENT

Standard week and Period	T (Max)	T (Min)	RH 7:00 AM (%)	RH 2:00 PM (%)	Rainfall (mm)	Evaporation (mm)	Average sun shine hrs/day	Wind Speed Km/hr
23	38.75	24.18	74.57	31.14	14.8	8.42	7.24	5.46
24	33.98	23.18	80.28	53	57.8	8.37	4.41	10.51
25	31.92	22.94	86.85	63.14	34.6	6.65	4.61	7.03
26	29.74	22.64	88.14	68.85	31.6	6.74	4.91	7.91
27	29.28	22.97	89.42	71.42	152.9	5.8	3.18	7.90
28	30.60	22.40	87.14	66.00	28.00	6.6	5.81	4.67
29	29.82	23.20	89.00	70.85	77.1	5.47	2.82	5.33
30	28.58	21.57	86.71	76.71	30.5	5.41	0.52	5.49
31	29.90	22.05	87.57	66.14	50.00	6.38	3.32	2.37
32	29.88	22.48	88.71	71.14	57.3	6.91	5.77	5.57
33	28.02	22.27	90.14	78.00	90.9	5.97	1.15	5.86
34	28.51	22.14	89.28	73.71	73.00	5.34	3.34	3.06
35	31.00	22.47	86.85	70.14	86.3	6.08	4.77	2.46
36	29.57	22.44	87.00	73.85	17.6	5.62	3.97	2.19
37	29.57	22.21	89.00	74.85	42.8	5.31	5.17	2.14
38	30.10	21.94	86.71	72.00	11.1	5.65	6.07	2.19
39	26.32	21.17	91.28	81.57	221	3.68	1.08	6.53
40	28.92	21.61	89.28	72.28	11.2	5.05	5.10	0.86

APPENDIX-2: COST OF CULTIVATION

	Fixed inputs	Cost (Rs)
1.	Land preparation with tractor 2 Ploughings @ Rs 250/plough	500.00
2.	Cost of seed 18 kg/ha @ Rs 20/kg	360.00
3.	Cost of sowing + basal dressing of fertilizers 3 Plough @ Rs 100/Plough= Rs 300 5 Labors @ Rs 100/labor= Rs 500	800.00
4.	Cost of interculture (Hand weeding, drainage, top dressing, earthing up) 40 Labors @ Rs 100/labor	4000.00
5.	Plant protection cost Atrazine 2 kg/ha @ Rs 243/kg = 486 Furadon 1.75 kg/ha @ Rs 65/ha = 113.75 4 Labors @ Rs 100/labor= Rs 400	999.75
6.	Harvesting and transportation 12 Labors @ Rs 100/labor	1200.00
7.	Shelling and threshing 25 Labors @ Rs 100/labor	2500.00
8.	Watching cost 1 Labor for 20 days @ Rs 100/labor	2000.00
9.	Cost of land @ Rs 25/ha	12.50
	Total	**12372.25**

Continued……………

	Variable inputs	Cost (Rs)
1.	FYM @ Rs 400/ton	2000.00
2.	Lime @ Rs 100/q	300.00
3.	Fertilizer cost	
	(Urea @ Rs 5.04, MOP @ Rs 4.50, SSP @ Rs 5.20/kg)	
	50% RDF	1535.50
	75% RDF	2303.27
	100% RDF (100 kg N, 50 kg P_2O_5, 25 kg K_2O)	3071.03
	125% RDF	3838.78
	150% RDF	4606.54