"PERFORMANCE OF NON-CONVENTIONAL SOIL AMELIORANTS IN BANANA (*Musa spp*) var. Nendran"

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Performance of non-conventional soil ameliorants in banana (*Musa spp*) var. Nendran"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate, fellowship or other similar title, of any other University or society.

Place: Padannakkad

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Certified that this thesis entitled **"Performance of non-conventional soil ameliorants in banana (*Musa spp*) var. Nendran"** is a record of research work done independently by Mr. Amalendu M.V under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

%	: Percentage
@	: at the rate of
Al	: Aluminium
$Al(OH)_3$	: Aluminium hydroxide
$Al_2(SO_4)$	: Aluminium sulphate
Ca	: Calcium
$Ca (OH)_2$	: Calcium hydroxide
$CaCO_3$	: Calcium carbonate
$CaMg(CO_3)_2$	: Calcium Magnesium Carbonate (Dolomite)
CaO	: Calcium oxide (Burnt lime)
$CaSiO_3$	: Calcium Silicate
$CaSO_4. 2H_2O$	: Calcium sulphate dihydrate (Gypsum)
CD	: Critical difference
CEC	: Cation Exchange Capacity
cm	: Centimetre
cmol (P+) kg^{-1}	: Cent mol (proton) per Kilogram
CoA	: College of Agriculture
CRD	: Completely Randomized Design
Cu	: Copper
DAP	: Days after planting
dS m^{-1}	: Deci Siemens per meter
EC	: Electrical Conductivity
ECEC	: Effective Cation Exchange Capacity
et al	: And others
Fe	: Iron
Fig.	: Figure
g	: Gram
g cm^{-3}	: gram per centimeter cube
g/plant	: gram per plant
K	: Potassium
K_2O	: Potassium oxide
KAU	: Kerala Agricultural University

KCl	: Potassium chloride
kg ha^{-1}	: Kilogram per hectare
KVK	: Krishi Vigyan Kendra
Lakh/ha	: Lakh per hacter
m	: Meter
MAP	: Months after Planting
meq $100g^{-1}$	: Mili-equivalence per 100 gram
meq/L	: Mili-equivalence per litre
Mg	: Magnesium
mg/ kg	: Milligram per Kilogram
$MgCO_3$	: Magnesium carbonate
ml	: Millilitre
mm	: Milimeter
Mn	: Manganese
N	: Nitrogen
Na	: Sodium
NaOH	: Sodium hydroxide
NS	: Non significant
P	: Phosphorus
P_2O_5	: Diphosphate pentaoxide
Pb	: Lead
PG	: Phosphogypsum
pH	: Soil reaction
ppm	: Parts per million
RARS	: Regional Agricultural Research Station
Rs ha^{-1}	: Rupees per hectare
S	: Sulphur
SB	: Sum of Exchangable Basic cations
SE(m)	: Standard error mean
Si	: Silicon
SiO_2	: Silicon dioxide
T	: Treatment
t ha^{-1}	: Tonnes per hectare
Viz.	: Namely
Zn	: Zinc

Introduction

1. INTRODUCTION

Banana is the second most important fruit crop in India after mango. At present, banana is cultivated in an area of 5.6 million ha over 150 countries with an overall production status of 114 million tonnes (FAO stat, 2017). According to Singh (2007) banana contributes highest to the Agriculture Gross Domestic Product. India is the leading producer of banana with an annual production of 29 million tonnes, from 8.8 lakh ha contributing 33.4 percent of fruit production with an average productivity of 60 T/ha (FAO stat, 2017). In Kerala banana is a main remunerative crop grown in an area of 62108 ha with a production of 565829 tonnes and productivity of 15.3 tonnes/ha (Indiastat, 2017). Soil related constrains leading to low nutrient efficiency is one of the major reason for incidence of pest and disease and low productivity in the state (Rajasekharan *et al.,* 2014).

Kerala soils are the resultant of intense weathering due to the prevailing humid tropical climate which enables the formation of strong sesquioxides rich soils with poor clay content. Soils with low activity clays are acidic which exhibits aluminium and iron toxicity, which in turn leads to the reduction in the availability of N, P, K, Ca, Mg and Zn in soil. According to Varghese and Byju (1993) aluminium toxicity coupled with Ca and Mg deficiency occur in 70% of acid infertile regions of tropics. The chemical properties of soil revealed that high acidity coupled with iron aluminium toxicity, low organic carbon content and nutrient deficiencies leads to biotic and abiotic stresses, contributing to low productivity of banana in Kerala, especially in the northern midland lateritic soils.

Banana requires a soil with good drainage, adequate fertility and moisture, rich organic matter and adequate sources of nutrients. The physical and chemical constraints for crop production in lateritic soils of Kerala was reported by Jose *et al.* (1998). The physical constrains include soil erosion, hardening of laterite at the surface, low water holding capacity, reduced effective soil volume due to concretion, drought stress and chemical constrains including high soil acidity, high exchangeable Al, low CEC with high AEC and low level of Ca and Mg are the main constraints in crop production. The present study was conducted to manage the acidity of the soil in the rooting zone during the entire crop period by using different sources and methods of application of ameliorants.

Different non-conventional soil ameliorants used for the study are Calcium silicate, lime, dolomite and gypsum. Addition of these ameliorants improved the soil acidity and availability of micro and macro nutrients in the soil. Liming influences the crop production by improving the fertility status of soil, by increasing the availability of macro and micro nutrients in soil (Magdoff and Bartlett, 1979; Nakayama *et al.*, 1987). Generally the farmers were using these ameliorants as single basal dose but by the split application of them could improve the efficiency of nutrients thus enhancing the fertility status of the soil and yield.

Considering the above facts the present study on "Performance of non-conventional soil ameliorants in banana (*Musa spp*) var .Nendran" was carried out with the following objectives.

- To study the effect of non- conventional soil ameliorants in improving the nutrient status of northern lateritic soil.
- To evaluate their effect on yield, quality and nutrient status of TC banana (*Musa spp*) var. Nendran.

Review of Literature

2. REVIEW OF LITERATURE

Soil acidification is a major natural phenomenon which hinders the growth of plants. As the acidity of soil increases, pH below 4.5 the production of the crops decreases. In humid tropics the soil acidity was sever, due to high precipitation leaching of basic cations like (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) from the surface layer of soil takes place. Exchangeable aluminium and hydrogen ions are mainly responsible for soil acidity.

When plants were grown in acid soils with pH below 5.5 the root system was affected due to high uptake of aluminium which simultaneously decreases the uptake of other elements. High degree of soil acidity (pH 5 to 6.5) decreases the availability of plant nutrients particularly phosphorus, calcium, magnesium, molybdenum, potassium, sulphur, nitrogen and boron.

2.1 LATERITIC SOIL AND ITS CHARACTERISTICS

On a global scale, about 80 per cent of the ultisols are in tropical regions and about 18 percent of tropical region are under ultisols (Eswaran, 1993). Humid tropics of India is predominantly covered by laterite soil (ultisols) (Velayutham *et al.*, 2004). In humid tropics leaching of nutrients is high due to undulating topography and high precipitation (more than 3000 mm). According to Shivaprasad *et al.*, (1998) the nutrient retention capacity of these soils are low due to low CEC (3-14 cmol kg^{-1}). These soils are poor in native fertility due to abundant sesquioxides and low bases (Babu, 1981). Badrinath *et al.* (1998) reported deficiency of nitrogen, potassium and zinc in lateritic soils. Phosphorous availability was low due to presence of hydrated and amorphous oxides of Fe and Al (Perur, 1996; West *et al.*, 1997). Kaolinite is the dominant clay mineral low in K fixation. These soils are deficient in zinc and possess high zinc fixation.

2.2 NATURE OF SOIL ACIDITY IN LATERITIC SOIL

In highly weathered lateritic soil aluminium and hydrogen ions contributes highly to fraction of permanent negative charge and is known as exchangeable acidity. Research conducted by Coleman and Thomas (1967) and McCart and Kamprath (1965) reported that the acidity in highly weathered acid soil was mainly contributed by exchangeable aluminium than any other ions. Research done by Kaminiski and Bohnen (1976) concluded that higher level of exchangeable aluminium and organic matter levels showed higher level of soil acidity.

Duchanfour and Souchier (1980) reported that Al^{3+} ion was more harmful to plant than H^+ ion in acid soil but Manrique (1986) obtained negative relationship between Al saturation and pH in 1 molar KCl ultisoils.

According to Sarkar *et al*. (1989) and Jose *et al.* (1998) more than 60 percent of Kerala soils were lateritic type with pH less than 5.5. Soil acidity and other allied problems were major chemical drawbacks for crop production in these soils.

Work conducted by Sharma *et al*, (1990) in red soils of Trivandrum concluded that total acidity was contributed by exchangeable aluminium (6%) and pH dependent acidity (60%). However exchangeable aluminium all together contributed more than 90 percent. These were the major factors contributing to exchangeable acidity in these soils. In lateritic soil acidity was increased by the long term use of acid forming fertilizers. (Nambiar and Meelu, 1996)

Recent study conducted by GOK (2013) on soil fertility status of Kerala reported that about 90% of the soils were acidic in nature. Among them 35 per cent of the soil samples showed excess nitrogen, 31 per cent showed high level of potassium, 62 per cent high in phosphorus, 74 per cent low in Mg and 59 per cent were deficient in boron

2.3 AMELIORATING EFFECT OF LIME AND DOLOMITE

2.3.1 Effect on soil acidity

Studies conducted on the application of calcium and magnesium compounds to red and lateritic soils of vellayani showed a raise in soil pH (Varghese and Mooney, 1965). Work conducted by Abraham (1984) showed that application of lime @1200kg ha^{-1} in kari soil raised the pH from 3.8 to 5.7. Maria *et al.* (1985) suggested liming increased the pH value of soil. Researchers found out that liming had a positive influence on pH (Staley, 2002; Caires *et al.*, 2002; Whalen *et al.*, 2002, Nkana and Tonye, 2003) and Tang *et al.* (2003).

Research done at the research station near Brasilia, Brazil, on the effects of subsoil acidity on crop yields, water uptake, root growth, and amelioration of subsoil acidity, concluded that liming the surface soil was usually successful in reducing subsoil acidity within 2-4 years (Bouldin ,1979).

Liming decreased the exchangeable and total acidity in oxic soil to a depth of 100cm, moreover it enhanced lateral migration of calcium and magnesium (Moralli *et al.*, 1971). Bertic *et al.* (2008) reported that the application of higher rate of lime caused a decrease in Fe content from 34.1 ppm (unlimed plot) to 14.1 ppm. At the same time, decreasing titrable acidity from 16.0 to 1.5 ra equ/100 g of soil and exchangeable acidity from 3.0 to 0.1 mequ/100 g of soil.

Due to slow solubility and mobility of lime in subsurface soil the surface application of lime has limited ameliorating effect (Shainberg *et al.*, 1989; Farina *et al.*, 2000a; Liu and Hue, 2001; Conyers *et al.*, 2003)

2.3.2 Effect on nitrogen, phosphorus and potassium availability

According to Magdoff and Bartlett (1979) liming improved the pH and CEC of the soil but decreased the potassium in the soil. Work conducted by Nakayama *et al.* (1987) proposed the use of lime in acid soil increased the N, P, K, Ca, Mg content.

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Addition of calcium carbonate causes an increase in the release of non-exchangable potassium in acid soil (Gama, 1987). The amount of exchangeable Mg and K or extractable P in the soil is least affected by liming (Ross *et al.*, 1964).

Work conducted by Mandal *et al.* (1975) and Tripathi *et al.* (1997) reported increase in the available Ca & P and crop yields by the addition of Ca sources (burnt lime or quick lime, slaked lime, calcite, dolomite and limestone). It reduced solubility of Al, Fe, Mn in the soil.

Liming enhanced nitrogen mineralization and helps in alleviating Al toxicity (Bailey and Stevens, 1989).

2.3.3 Effect on calcium, magnesium and sulphur availability

Lime application increased the availability of calcium, pH, effective CEC and lime potential of soil at the same time it decreased the potassium, iron and aluminum, aluminum saturation and free energy (Gupta *et al.*, 1989). Rojas and Adams (1980) reported that lime application caused Ca + Mg: K ratio to increase while K: Ca and K: Mg ratios decreased. Grove *et al.* (1981) demonstrated that exchangeable Mg was reduced by liming. Similar results were obtained by Myers *et al.* (1988). This was due to the co precipitation of Al with exchangeable Mg.

According to Blaszcyk *et al.* (1986) concentration of calcium, sulphur, potassium and magnesium in topsoil was increased when liming done at the rate of 18.4 t ha^{-1}. Haynes and Ludecke (1981) reported that application of lime causes an increase in percentage base saturation and excahangable Ca in the soil. Moreover it reduces the level of Al, Fe and Mn in the soil and increased the phosphorous level.

Application of dolomite and $MgCO_3$ to oil palm alleviated soil acidity. It increased the magnesium, nitrate and chlorine concentration and decreased the aluminum and manganese concentration in acid soil. (Cristancho *et al.*, 2014)

2.3.4 Effect on Iron, manganese and aluminium toxicity

Scientists reported that lime application increased the pH, exchangeable Ca content and decreased the aluminium saturation in acid soil (Lin *et al.,* 1988; Broadbent *et al.,* 1989). According to (Pires *et al.*, 2003) the use of lime in the furrows and surface soil helped in increasing pH by decreasing the exchangeable Al in the acid soil. Abruna *et al.* (1964) proposed liming elevates the pH of humid topics by decreasing the exchangeable aluminum and manganese in the soil, thus improves the yield of grasses.

Research conducted by Helyar and Anderson (1974) demonstrated that concentration of exchangable Ca was increased while the exchangeable Al and Mn concentration was decreased by the application of calcium carbonate. Lime application reduces the extractable and exchangeable Fe, Al and Mn in acid soil (Bishnoi *et al.,* 1987).

2.3.5 Effect on yield and rooting parameters

An investigation carried out by Cahn *et al.* (1991) on the effect of fertilizer N and lime on subsoil acidity and root growth pattern of maize in oxisols of amazon basin reported that liming increased the soil pH and increased the rooting pattern of maize. Study conducted by Cahn *et al.* (1993) on maize reported, more root growth in limed pot than in unlimed plot.

Experiment conducted by Kovacevic and Rastija, (2010) on the effect of dolomitic lime on yield and nutritional status of maize and barley and concluded that dolomite application increased the pH level of the soil, it enhanced the yield of both barley and maize. Liming increased the maize nutritional status and increased the P, Ca, Mg, Mo and decreased the Mn concentration to desirable level. Yield of barley and maize was increased by the application of lime @ 2.5 t ha^{-1}, promoting available P and Ca in the acid soil. (Prasad *et al.,* 1984)

Work conducted by Alemu *et al.* (2017) to evaluate the effect of lime and phosphorous fertilizer application on grain yield of barley and soil chemical properties of acid soil of Ethiopia revealed that liming results in sharp increase in the soil pH and improves the available phosphorus and exchangeable Ca^{2+} in the soil . Lime application at the rate of 1.65 t/ha coupled with 20 kg/ha Phosphorus fertilizer enhanced the yield of barley.

Field experiment was carried out in Sodo Zuria Woreda, Kutosorpelakebele on Nitisol loam soil with an inherent property of high Phosphorus fixation and acidity reported that liming increases the soil pH, CEC, available phosphorous content in acid soil and showed an increment in the yield of haricot bean (Buni, 2014). Hoyt (1981) reported that application of lime improved the soil tilth by decreasing the pulverization of the soils by tillage machinery and increased the emergence of rapeseed in acid soil.

According to Oliveira and Pavan (1996) in a non tillage system the surface application of dolomite improved the fertility of acid soil by reducing Al and increasing Ca and Mg and improved the grain yield of soybean. Haynes and Naidu (1997) concluded long term application of lime improved organic matter content, soil aggregation and crop yield. Lime application enhances root penetration of soyabean and enhanced the nodule distribution in taproot and lateral roots of Rhizobium by enhancing Ca level in soil (Balatti *et al.*, 1991).

2.4 AMELIORATING EFFECT OF GYPSUM

2.4.1 Effect on soil acidity

From the leaching experiments by Ritchey *et al.* (1980) reported gypsum as an effective ameliorant for acid soils. Similar result is obtained by (Alva *et al.*, 1990; McLay and Ritchie, 1994).

Gypsum ameliorates acidity by combining dissociated SO_4^{2-} with Al to form aluminium sulfate which is less phytotoxic to plants, but gypsum did not change the soil pH much (Evanylo, 1989; Ismail *et al.*, 1993; Sumner, 1993). Soil column experiment conducted by Sun *et al.* (2000) in southern china and reported that application of gypsum reduced the soil acidity by decreasing the activity of toxic Al and increased $AlSO_4^+$ and calcium activity in the subsoil solution.

An experiment conducted by Sun *et al.* (2000) on the effect of slaked lime and gypsum on soil acidity, nutrient leaching in acid soil and soil chemistry of acid soil it was reported that slaked lime caused an increase in pH at the topsoil and at 5cm below the point of application. Mora *et al.* (2002) reported the application of lime, dolomite and gypsum in combination causes raise in pH and decreased the Al saturation from 20 % to less than 1%.

The surface application of phosphogypsum alleviates soil acidity by increasing the movement of Ca^{2+} and Mg^{2+} throughout the soil profile. It improves carbon and sulphate concentration in the soil profile, it improves the root growth, crop nutrition and yield of soybean and sorghum (Da Costa *et al.*, 2016).

2.4.2 Effect on nitrogen, phosphorus and potassium availability

An experiment conducted by O' Brien and Sumner (1988) in ultisoil soils of Georgia reported that the application of phosphogypsum improves the potassium, magnesium and silicon concentration in the soil. It also reduced the soil acidity by increasing calcium absorption and reducing exchangeable aluminum concentration in the soil. Phosphogypsum application reduced the fixation of phosphorus by iron and aluminium in acid soils (Phillips *et al.*, 2000).

Surface application of the ameliorants results in the movement of base cations from surface horizon, this transport was controlled by the amount of water and cations in the leaching solution. The amount of cations depends on the concentration of anions like sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-) and bicarbonates (HCO_3^-). The base cations causes the displacement of exchangeable Al^{3+} on the sub soil surface. (Pleysier and Juo, 1981; Pavan *et al.*, 1984; Cahn *et al.*, 1993).

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Work conducted by Belkacem and Nys (1997) reported that the gypsum application increased the calcium concentration, base saturation, reduces the exchangeable Al in the soil. Lime application caused increased leaching of nitrogen in the form of $N\text{-}NO_3$ and gypsum reduces nitrification when nitrogen is in $N\text{-}NH_4$ form.

2.4.3 Effect on calcium, magnesium and sulphur availability

Research done by Sumner *et al.* (1986); Shainberg *et al.* (1989) concluded that gypsum is more soluble than lime and enables faster movement of Ca^{2+} and SO_4^{2-}but gypsum has minimal effect on pH. Gypsum application improved the downward movement of Ca and decreased Al saturation in lower depth (Jacob and Venugopal, 1993).

Gypsum application improved the movement of exchangeable Mg to subsoils (Quaggio *et al.*, 1993; Oliveira and Pavan, 1996), but lesser in clayey soil (Caires *et al.*, 2003). Ismail *et al.* (1993) concluded gypsum application improved the calcium and magnesium concentration in the soil and reducing aluminium concentration thus improves corn yield in ultisols and oxisols.

Field experiment conducted by Soratto and Crusciol (2008) on the effect of surface application of phosphogypsum and dolomite on yield and nutrition in rice and bean reported that dolomite application increased the rice yield and Ca, Mg and Mn concentration in the rice flag leaf. Liming increased the shoot dry weight of rice cultivar and K content of bean leaves. Phosphogypsum application increased the S content of rice cultivar and increased the yield of rice. In the bean leaves phosphogypsum application increased the Ca, S and reduces the Mg concentration.

Research conducted by Rampim and Lana (2015) reported that gypsum application causes an increase in the Ca^{2+} content, $Ca^{2+}/K^{+}+Mg^{2+}$ ratio, sum of exchangeable basic cations (SB) and effective cation exchange capacity (ECEC), reduction of $K^{+}+Mg^{2+}$ content and aluminum saturation (m%) in the soil profile.it also improves soil base saturation. It increases the grain yield of wheat and reduces soil acidity.

2.4.4 Effect on iron, manganese and aluminium toxicity

Studies conducted by Sumner (1970) and Reeve and Sumner (1972) suggested gypsum for neutralizing Al toxicity in acid soils, as the gypsum is more soluble that lime it moves down the subsoil and precipitates toxic Al. Ameliorants containing Ca is used frequently used to reduce toxicity and phytotoxicity of Al in acid soils (Toma and Saigusa, 1997; Mora *et al.,* 2002), which includes lime, gypsum or phosphogypsum (PG) (Campbell *et al.,* 2006; Takahashi *et al.,* 2006a). Application of phosphogypsum increased the soil pH and reduced the toxic effects of Fe and Al in acid sulphate soils of Kuttanad (Ebimol *et al.,* 2017).

Application of gypsum on the surface of acid soil causes a reduction in exchangable Al^{3+} ion by incorporating Ca^{2+} without neutralizing the subsoil acidity (Wendell and Ritchey, 1996; Toma *et al.,* 1999). Alva and Sumner (1990) reported phosphogypsum application improves the growth response in kaolinitic Cecil and Wedowee soils by releasing OH^- due to ligand exchange between SO^{2-} and OH^-, as well as a decrease in exchangeable AI in the soil. Ca leached from gypsum and slaked lime decreased the Al toxicity in acid soils (Sun *et al.,* 2000).

2.4.5 Effect on yield and rooting parameter

Surface application of gypsum shows higher increment in the yield compared to lime in acid soils of Brazil, South Africa and the United States (Shainberg *et al.*, 1989; Sumner, 1993).

Gypsum application improved the yield of groundnut by increasing readily available Ca supply to the developing pods (Snyman, 1972; Walker, 1975; Cox *et al.*, 1982). Hammel *et al.*, (1985) reported gypsum application improved the yield of soybean (*Glycine max L.*), maize *(Zea mays L.)* and alfalfa (*Medicago sativa L.)* by increasing Ca and decreasing soluble and/or exchangeable Al of the subsoil.

The preplant, broadcast applications of gypsum resulted in 30% increment in the yield off two cultivars of Brussels sprouts (*Brassica oleracea var. gemmifera*). Analysis of leaf tissue collected when the sprouts began to form indicated that Ca, Mg, Mn and Zn concentrations were approximately 1.4-2.6% , 0.25-0.32% , 88-274 pg g-r and 26-35 pg g^{-1}, respectively, were in the sufficiency range (Cutcliffe, 1988).

Study conducted by Blum *et al.* (2013) on loamy oxisols of Brazil reported that the phosphogypsum application had positive benefits on maize and triticale (*X Triticosecale*) yields by improving the supply of Ca^{2+} and $SO4^{-2}$ to the plants. (Quaggio *et al.,* 1993; Caires *et al.,* 2003) reported that gypsum application improves the chemical properties, mineral nutrition and yield of grapes grown in acid soils.

According to Messenger *et al.* (2000) the application of gypsum reduces the infestation of *Phytophthora cinnamomi* on avocado seedling to 71 percent by improving root resistance or by reducing root permeability. Gypsum application improved the rooting environment upto a depth of 0.75 cm (Farina *et al.*, 2000a).

2.5 AMELIORATING EFFECT OF CALCIUM SILICATE AND SILICA

2.5.1 Effect on soil acidity

Research conducted by Li *et al.* (2012) reported that the application of 800 mg kg^{-1} silicon in the form of calcium silicate to banana grown in lead contaminated soil increased the pH and provides resistance against lead toxicity in banana.

2.5.2 Effect on nitrogen, phosphorus and potassium availability

Application of Si at the rate of 120 Kg/ha increased the N uptake by increasing available N in the soil (Ho *et al.*, 1980). Work conducted by Ohyama (1985) concluded toxicity caused due to excess nitrogen application is alleviated by the application of silicon.

According to Ma and Takahashi (2002) Si application increases nitrogen availability in the soil. It also reduces aluminum toxicity in acid soil. Nitrogen level in the grain and straw of rice was increased when 180 $kgha^{-1}$ silicon was applied (Singh *et al.*, 2006). Chanchareonsook *et al.* (2002) suggested the N uptake of rice is increased by the application of silicon long with NPK fertilizers.

According to Epstain (1994) and Marshner (1995) nutrient imbalance of zinc and phosphorous is alleviated by silicon application. Subramanian and Gopalswamy (1990) reported the application of silicon along with phosphatic fertilizers increased the efficiency of phosphatic fertilizers as silicon increased the phosphorous solubility. Phosphorous uptake was increased by the addition of silicon as silicon blocks excess uptake of Mn (Ma and Takahashi, 1990).

According to Liang (1999) Si application improved the potassium uptake by promoting H-ATPase in the membranes. Patrick and Mikkelsen (1971) and Marshner (1995) concluded the application of silicon to rice in flooded soil increases k availability by promoting the reduction of toxic Fe and Al, resulting the production of H^+ ions. Which helped in releasing the available K from the fixed pool.

Work conducted by Bridgit (1999) on rice suggested the application of silicon at 250 kg ha^{-1} limits the K uptake by the crop and reported that Zn content in root and shoot of rice was increased by the application of silicon in the form of sodium silicate. Singh *et al.* (2006); Jawahar and Vaiyapuri (2008) suggested that silicon application have a positive influence on the uptake of sulphur.

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2.5.3 Effect on calcium, magnesium and sulphur availability

Addition of silicon along with other nutrients to the culture solution decreased the K uptake of rice plant this may be due to increased absorption of Ca and Mg. (Islam and Saha, 1969). Takijima *et al.* (1959) reported the application of silicon enhances potassium uptake, this might be possible due to increased uptake of Ca and Mg ion.

Work conducted by Cachorro *et al.* (1994) reported the application of silicon improved the Ca uptake thus partially restoring membrane integrity and improving the survival of the crop. Researches conducted on rice reported that uptake of N, P, K, S and Si was increased when Si was applied at rate of 120 Kg/ha (Jawahar and Vaiyapuri, 2008).

2.5.4 Effect on iron, manganese and aluminium toxicity

According to Watanabe *et al.* (1997) application of Si alleviates Al toxicity in *Melastoma malabathricum L* and improves the nutrient uptake.

Work conducted by Okuda and Takahashi (1962); Qiang *et al.* (2012) reported the application of silicon in rice reduces uptake of Mn by enhancing Mn oxidizing power of roots, enhancing the root oxidation power of root and converts ferrous iron to insoluble ferric iron. Thus preventing excess iron absorption. Silicon addition alleviates iron toxicity in acid soil by converting ferrous iron to insoluble ferric iron thus decreasing Fe uptake (Wang *et al.*, 1994).

Work conducted by Wallace, 1992 reported that Si application reduces iron toxicity in acid soil as silicon provided an alkaline rizhosphere thus decreases Fe uptake in plants .He concluded that aluminium toxicity in acid soil is reduced due to increased uptake of silicon.

According to Marschner (1995) Mn distribution in the leaf tissue increases to toxic level when silicon concentration is low. Application of silicon deceases Mn^{2+}

toxicity in leaf tissues. He also concluded silicon application mitigates the toxicity of Al^{3+} in leaf tissue. Application of silicon alleviated the aluminium concentration in rice leaves. (Barbosa *et al.*, 2012)

Work conducted by Cocker *et al.* (1998) on the effect of Si on Al toxicity in maize, barley, sorghum, rice showed that application of silicon in the form of silicic acid reduced the concentration of toxic aluminium. This is possible either due to formation of nontoxic Al-Si complexes. Other possible mechanisms included the co deposition off Al with Si within the plant, by various enzymatic activities in the cytoplasm. Silicon application mitigates aluminium, zinc, manganese, cadmium toxicity in metal contaminated soils. (Song *et al.*, 2009)

2.5.5 Effect on yield, rooting parameters and biotic and abiotic stress

Work conducted by Murillo *et al.* (2007) on the effect of calcium silicate on growth parameters of cowpea and kidney bean grown under salt stress. It was reported that application of calcium silicate improved the net photosynthesis, chlorophyll content, stomatal conductance and transpiration rate. It maintained membrane integrity and increased the intercellular CO_2 content in plants. It increased the calcium and potassium concentration and reduced the sodium and chlorine content in shoot and roots of plant under salt stress.

A field experiment conducted by Hanumanthaiah *et al.* (2015) on the effect of silica on fruit yield and quality of banana c.v Neypoovan. It was reported that basal application of calcium silicate at rate of 1000 g /plant and foliar application of potassium silicate at rate of 2-4 ml/l per plant increased the quality parameters like days for full ripening of the fruit, acidity, shelf life, total soluble solids, reducing and non-reducing sugar, pulp to peel ratio. Hence concluded that silicon application improves fruit quality of banana var Neypoovan.

A field experiment was conducted by Anderson *et al.* (1987) on rice-sugarcane ratton system showed that the application of calcium silicate slag increased the SI concentration in rice and sugarcane. Slag application improves the rice grain yield by 50%, sugarcane yield by 25% and sugar yield by 25%.Work conducted on effect of calcium silicate on foliar development of disease and yield of sugarcane reported that application of calcium silicate at rate of 6.7 t ha^{-1} caused an increase in the total sugar yield and decreased the incidence of ringspot disease caused by *Leptosphaeria sacchari* Breda de Hann) of sugarcane (Raid *et al.*, 1992).

Research conducted by Padmaja and Verghese (1966) on the addition of sodium silicate to lateritic soil increased the plant height, tillering, depth of penetration of root system and proportion of thicker to thinner root of rice. Si application enhanced the potassium content in grain and straw of rice. Sadanandan and Verghese (1968) conducted work on rice reported that the tillering capacity and root growth was increased by the application of silicon in laterite soil. They also concluded that sodium silicate application caused an increase in the number of tillers in the initial stage while the addition of calcium magnesium silicate improves during the later stages.

According to Ma *et al.* (1989) silicon application increased the plant height and root dry weight at different growth stages of rice. Work conducted by Yamaguchi and Winslow (1989) in highly weathered and leached ultisols of Nigeria, it was reported that sodium silicate application improved the dry matter production in rice.

Work conducted by Ma *et al.* (1989) in rice concluded that when silicon was removed during the reproductive stage, the grain yield and dry weight of straw was reduced by 20-50 %. Hence concluded that silicon is important in reproductive stage of the crop. According to Singh (2003) one of the possible reason for low rice yield when rice was intensively cultivated is the low plant available Si in the soil. Application of silicon enhanced the number of spikelets per panicle, spikelet fertility of rice. (Takahashi, 1995).

Silicon accumulation increases photosynthesis rate by improving the erectness of the leaves, improved the light interception. They reported Si application reduced the chance of lodging and disease infestation due to excess nitrogen fertilization (Ma and Takahashi, 2002). Agarie *et al.* (1992), reported the application of silicon enhances the photosynthetic activity, thus increasing the dry matter production. Si application in plants under water stress leads to decrease in transpiration rate by forming silicon cuticle double layer in the plant leaves. Transpiration reduced to 30% by the application of silicon in rice. (Ma *et al.*, 2001a).

Work conducted on rice by Gholami and Falah (2013) and Ahmad *et al.* (2013) reported increase in the plant growth, yield, and quality of rice by the application of silicon. Work conducted by Ahmad *et al.* (2013) in rice reported increase in the number of productive tillers and number of tiller per m^2 is increased by the application of silicon. In rice the kernel weight, biological yield, protein content and starch content is increased by application of silicon and boron (Ahmad *et al.*, 2013).

Experiment conducted by Takahashi (1966) on the effect of Si on radiation stress in rice, reported that silicon application increases the resistance towards radiation. Climatic stresses like low temperature, typhoons, insufficient sunlight during summer months can be mitigated by application of Silicon. Silicon application decreased the chance of electrolytic leakage in leaves (Agarie *et al.*, 1998). Si application enhanced the plant resistance toward chemical stresses by enhancing the strength and rigidity of cell wall, due to deposition of silica (Ma *et al.*, 2004). Eneji *et al.* (2005) reported the application of calcium silicate improves resistance against drought stress in rodes grass (*Chloris gayana Kunth*) and sudan grass (*Sorghum sudanense Piper*).

2.6 IMPORTANCE OF SOIL AMELIORENTS IN BANANA PRODUCTION

Banana requires sufficient quantity of major and micro nutrients at various stages of its growth to have a profitable production. . According to Twyford and

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Walmnsley (1974) for obtaining a production of 50t/ha/year about 1500 kg K_2O/ha/year may be extracted from the soil. At harvest (in kg/ha/year) about N-420, P-60,Ca-215,Mg-140,B-1.25 was absorbed from the soil. Fertilizer application recommended for Tissue culture nendran is N: P_2O_5: K_2O @ 300:115:450 g per plant. Farm yard manure @ 15-20 kg/plant and lime @1 kg/plant was also applied at the time of planting to obtain higher yield (KAU POP, 2016). The soil related constraints as expressed above and the importance of ameliorants in addressing these issues have clearly revealed that the addition of ameliorants to improve the nutrient use efficiency is absolutely essential to improve farmer's income. Hence the present study "Performance of non-conventional soil ameliorants in banana (*Musa spp*) var. Nendran" was carried out.

Materials and Methods

3. MATERIALS AND METHODS

An investigation entitled "Performance of non-conventional soil ameliorants in banana (*Musa spp)* var. Nendran" was carried out at Regional Agricultural Research Station (RARS) farm Nileshwar during 2017 to 2019. The study consisted of 2 experiments, a pot culture experiment to study the performance of soil ameliorants and a subsequent field experiment.

3.1 POT CULTURE EXPERIMENT

Pot experiment was conducted in Regional Agricultural Research Station (RARS) farm, Nileshwar during February 2018 to April 2018. The objective was to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health with respect to availability of nutrients. The experiment was conducted in completely Randomized Design (CRD) consisting of 5 treatments and 4 replications with 5 plants in each replication. Each pot was prepared by filling 20 kg of soil. Fertilizer recommendation was done as per KAU POP 2016 and 1 week old suckers produced by micropopagation were planted.

3.1.1 Initial soil analysis

Initial soil samples were collected randomly from 2 to 3 sites in the field at a depth of 0-15 cm. The samples were air dried, ground, sieved using 2mm sieve and is analyzed for its particle density, pH, EC, CEC, organic carbon, available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, Si and exchangeable Al as per the standard procedures given in table 3.

3.1.2 Soil ameliorants

Soil ameliorants used for the study are calcium silicate ($CaSiO_3$), lime ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), gypsum($CaSO_4.2H_2O$) and silica (SiO_2) are arranged from the instructional farm of College of Agriculture, Padanakkad.

3.1.3 Planting materials

Tissue culture seedlings produced by micropropagation were collected from the instructional farm of College of Agriculture Padannakkad were used for the pot culture study as well as for the field trials.

3.1.4 Design and layout

Crop : Tissue culture banana

Variety : Nendran

Design : CRD

Treatments : 5

Replication : 4

3.1.5 Treatments

T_1: Basal application of Calcium silicate.

T_2: Basal application of lime + silica.

T_3: Basal application of dolomite + silica.

T_4: Basal application of Gypsum + silica.

T_5: Basal application of lime as per KAU POP 2016 (Control)

Details of the soil ameliorants used were lime ($CaCO_3$) at the rate of 20 g/plant, dolomite ($CaMg(CO_3)_2$) at the rate of 33 g/plant, gypsum ($CaSO_4.2H_2O$) at the rate of 33 g/plant, calcium silicate ($CaSiO_3$)at the rate of 36 g/plant, silica (SiO_2) at the rate of 10 g/plant. In control lime ($CaCO_3$) applied at the rate of 20 g/plant

Fig 1. Layout of the pot culture experiment

R_1T_1	R_2T_2	R_3T_3	R_4T_4
R_1T_3	R_2T_5	R_3T_4	R_4T_2
R_1T_2	R_2T_4	R_3T_1	R_4T_5
R_1T_5	R_2T_1	R_3T_5	R_4T_3
R_1T_4	R_2T_3	R_3T_2	R_4T_1

3.1.6 Biometric observations

Biometric observations viz number of leaves, pseudostem height, pseudostem girth, root length, root thickness, root diameter, root CEC, root section study were recorded at monthly interval for a period of 3 months.

3.1.6.1 Number of leaves

Number of leaves were recorded at monthly interval for a period of 3 months.

3.1.6.2 Pseudostem Height (cm)

Height of the pseudostem was measured from the base of the pseudostem to the petiole of the younger leaf.

3.1.6.3 Pseudostem Girth (cm)

Pseudostem girth at 45 cm height from the base of the pseudostem were recorded at monthly interval for a period of 3 months

3.1.6.4 Root length (cm)

Root length of individual treatments was measured at monthly interval for a period of 3 months and was averaged.

3.2.6.5 Root thickness (cm)

Root thickness of each roots of individual treatments at monthly interval for a period of 3 months were measured and averaged

3.2.6.6 Root diameter (cm)

Root diameter of each roots of individual treatments were measured at monthly interval for a period of 3 months and was averaged

3.2.6.7 Root CEC ($cmol_c$/kg)

According to Mitsui and Ueda (1963) the cation exchange capacity of the root was determined by washing the roots in distilled water and shaking with KCl and titrating against NaOH solution.

3.2.6.8 Root section study

The cross section of the root for treatments and control was taken and observed under microscope using 'Zen' image analyzer.

3.2 FIELD EXPERIMENT

The field experiment was carried out at Regional Agricultural Research Station (RARS) farm Nileshwar to study the effect of ameliorants on yield and quality of tissue culture banana var Nendran based on the inference obtained from the pot culture study for entailed results with more number of treatments. The field experiment was conducted in randomized block design comprising of 11 treatments and 3 replications. Fertilizer recommendation and cultural practices were followed as per KAU POP 2016 to the crops.

3.2.1 Design and Layout

Crop : Tissue culture banana

Variety : Nendran

Design : RBD

Treatment : 11

Replication : 3

3.2.2 Treatment combinations

T_1: Basal application of Calcium silicate.

T_2: Basal application of lime + silica.

T_3: Basal application of dolomite +silica.

T_4: Basal application of Gypsum + silica.

T_5: Lime+ silica in 2 splits at 1st and 2nd month after planting.

T_6: Dolomite + silica in 2 splits at 1st and 2nd month after planting.

T_7: Gypsum + silica in 2 splits at 1st and 2nd month after planting.

T_8: Lime+ silica in 3 split doses at 1st month, 2nd month and 4th month after planting.

T_9: Dolomite + silica in 3 split doses at 1st month, 2nd month and 4th month after planting.

T_{10}: Gypsum + silica in 3 split doses at 1st month, 2nd month and 4th month after planting.

T_{11}: Application of lime as per KAU POP 2016 (Control)

Details of the soil ameliorants used: lime ($CaCO_3$) at the rate of 1kg /plant, dolomite ($CaMg(CO_3)_2$) at the rate of 1.47 kg/plant, gypsum ($CaSO_4.2H_2O$) at the rate of 1.45 kg/plant, calcium silicate ($CaSiO_3$) at the rate of 1.16 kg/ plant and silica (SiO_2) at the rate of 500 g/plant In control lime ($CaCO_3$) at the rate of 1kg /plant. Lime was used as the standard and the quantity of the ameliorants were worked out on the basis of the neutralizing value of each ameliorants.

Fig 2. Layout of field experiment

BLOCK 1	BLOCK 2	BLOCK 3
T_8	T_5	T_2
T_1	T_7	T_4
T_{10}	T_{11}	T_3
T_7	T_3	T_7
T_2	T_6	T_6
T_{11}	T_9	T_9
T_6	T_8	T_{11}
T_9	T_{10}	T_{10}
T_5	T_1	T_5
T_4	T_2	T_1
T_3	T_4	T_8

3.2.3 Biometric Observation

Biometric observations recorded were number of leaves, number of functional leaves, pseudostem height, pseudostem girth at 90 cm, days to bunch emergence, days to harvest, days to ripening, bunch weight, number of hands per bunch, number of fingers per hand, average weight of fingers, finger length, finger breadth during the different stages of crop.

3.2.3.1 Number of leaves

Number of leaves at 1 month after planting, 3 month after planting, 5 month after planting and at harvest was recorded.

3.2.3.2 Number of Functional leaves

Number of fully opened leaves from the top of the plant is recorded at the time of harvest.

3.2.3.3 Pseudostem Height (cm)

Height of the pseudostem was measured from the base of the pseudostem to the base of the younger leaf at 1 month after planting, 3 month after planting, 5 month after planting and to the emerging point of peduncle at harvest and expressed in meter.

3.2.3.4 Pseudostem Girth (cm)

Pseudostem girth at 90 cm height from the base of the pseudostem was recorded at the time of harvest.

3.2.3.5 Days to bunch emergence

Number of days from planting to bunch emergence was recorded for individual treatments.

3.2.3.6 Days to harvest

The duration in days from planting to harvest was recorded for every treatments

3.2.3.7 Days to ripening

Days for ripening of the individual treatment was recorded from time of harvest to the stage were the fruit completely changes its color from green to yellow.

3.2.3.8 Bunch weight (Kg)

Bunch weight of individual treatments was recorded at the time of harvest.

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3.2.3.9 Number of hands per bunch

Number of hands in each bunch was recorded at the time of harvest.

3.2.3.10 Number of fingers per hand

Number of fingers in each bunch was counted at the time of harvest for individual treatments.

3.2.3.11 Average weight of fingers (g)

Average weight of the fingers were calculated by measuring the weight of the fingers top, middle and bottom of the bunch and average is taken and recorded.

3.2.3.12 Finger Length (cm)

Average length of fingers was recorded by measuring the length of fingers from the top, middle and bottom of the bunch and average is taken and recorded.

3.2.3.13 Finger Breadth (cm)

Average breadth of fingers was recorded by measuring the breadth of fingers from the top, middle and bottom of the bunch and average is taken and recorded.

3.2.4 Number of Suckers at harvest

Number of suckers produced by individual treatment was recorded at the time of harvest

3.2.5 Incidence of pest and diseases

Incidence of pest and disease was recorded during the whole crop growing period.

3.2.6 Fruit Analysis

The harvested bunches were kept at ambient temperature to read the shelf life. Other quality parameters observed were total soluble solids, titrable acidity, reducing and non-reducing sugar were analyzed using standard procedures.

3.2.6.1 Total Soluble Solids (TSS)

Using a hand refractometer total soluble solids of ripened banana was analyzed and expressed in terms of ^{0}brix.

3.1.6.2 Titrable Acidity (%)

Titrable acidity of a fully ripened banana was analyzed by grinding 50 g of banana from which 25 g of pulped material is transferred to 250 ml beaker. Add 100 ml distilled water to the pulped material and boil for 30 minutes. After cooling the content was transferred to 250 ml volumetric flask. An Aliquot of 50 ml was taken and diluted using equal quantity of hot water. Titrate it against 0.1 N NaOH using phenolphthalein as the indicator. The end point was demarcated by the appearance of pink colour and the result was expressed in percentage.

$$\text{Titrable acidty (\%)} = \text{Vol of aliquot} \times \text{N of alkali} \times 0.064 \times \frac{250 \times 100}{50 \times \text{Wt of the sample}}$$

3.1.6.3 Reducing Sugar (%)

Reducing sugar was determined by titrating the fruit juice against mixture of Fehlings solution A and B as per procedure given by Ranganna (1986).

$$\text{Reducing sugars (\%)} = \frac{\text{Factor(0.052)} \times \text{dilution} \times 100}{\text{titre value} \times \text{wt of sample}} = \text{X (say)}$$

3.1.6.4 Non reducing sugar (%)

Non reducing sugar was calculated by subtracting reducing sugar from total sugar and expressed in percentage.

$$\text{Total sugar (\%)} = \frac{\text{Factor(0.052)} \times \text{dilution} \times 100}{\text{Titre value} \times \text{wt of sample}} = \text{Y (say)}$$

$$\text{Non reducing sugar} = \text{Total sugar(Y)} - \text{Reducing sugar (X)}$$

3.1.6.5 Keeping Quality

Keeping quality was determined by calculating the number of days from the day of onset of ripening to the end of edible life.

3.1.7 SOIL ANALYSIS

Soil samples for the analysis was taken from the field at a depth of 0-15 cm for individual treatments at an interval of 3 month, 6 month after planting and at harvest. The samples were air dried, ground, sieved using 2mm sieve and stored in air tight containers. They were analyzed for particle density, pH, EC, CEC, organic carbon, available nutrients N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, Si and exchangeable Al as per the standard procedures given in table 1.

3.1.8 LEAF ANALYSIS

Index leaf (third fully opened leaf from the top) was collected at the bunching stage and harvest of the crop. Leaf sample was oven dried and analyzed for various micro and macro nutrients using standard procedures given in table 2.

Table 1: Analytical method followed for Soil analysis

SI NO	Parameters	Method	Reference
1	pH	pH meter	Jackson (1958)
2	EC	Conductivity meter	Jackson (1958)
3	Organic carbon	Chromic acid wet digestion	Walkley and Black (1934)
4	Particle Density	Pyconometer	Black *et al.* (1965)
5	Available Nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
6	Available P	Bray extraction and photoelectric colorimetry	Jackson (1958)

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7	Available K	Flame photometry	Pratt (1965)
8	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
9	Available Mg	Atomic absorption spectroscopy	Jackson (1958)
10	Available S	Photoelectric colorimetry	Massouni and Comfield (1963)
11	Available Fe	Atomic absorption spectroscopy	Sims and Johnson (1991)
12	Available Mn	Atomic absorption spectroscopy	Sims and Johnson (1991)
13	Available Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
14	Available Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
15	Exchangable Al	Atomic absorption spectroscopy	Ciesielski *et al.*(1997)
16	Total Silicon	Photoelectric Colorimetry	Gupta (1967)

Table 2: Analytical Method for Plant analysis

SI NO.	Parameter	Method	Reference
1	Total N	Modified Kheldhal digestion method	Jackson (1958)
2	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3	Total K	Flame photometry	Jackson (1958)

4	Total Ca	Atomic absorption spectroscopy	Issac and Kerber (1971)
5	Total Mg	Atomic absorption spectroscopy	Issac and Kerber (1971)
6	Total S	Turbidimetric method	Bhargava and Ragupathi (1995)
7	Total Fe	Atomic absorption spectroscopy	Piper (1966)
8	Total Mn	Atomic absorption spectroscopy	Piper (1966)
9	Total Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
10	Total Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
11	Total Si	Blue silicomolybdous acid method	Ma *et al.* (2002)

Table 3: Properties of the initial soil sample

Sl.No	Parameter	Value
I. Physical properties		
1	Bulk density (g cm^{-3})	1.34
2.	Particle density (g cm^{-3})	2.55
II. Mechanical composition		
1.	Sand (%)	77.40
2.	Silt (%)	19.60
3.	Clay (%)	3.75
4.	Textural class	Loamy sand

III. Chemical properties		
1.	pH	4.72
2.	EC (dS/m)	0.29
3.	Organic carbon (%)	0.65
5.	CEC (meq/100g)	2.41
6.	Available N (kg/ha)	188.16
7.	Available P (kg/ha)	139.00
8.	Available K (kg/ha)	121.45
9.	Available Ca (mg/kg)	220.00
10.	Available Mg (mg/kg)	84.00
11.	Available S (mg/kg)	34.20
12.	Available Zn (mg/kg)	1.82
13.	Exchangable Al (mg/kg)	10.62
14.	Available Fe (mg/kg)	34.20
15.	Available Cu (mg/kg)	1.62
16.	Available Mn (mg/kg)	12.30
17.	Available Si (mg/kg)	24.20

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3.3 STATISTICAL ANALYSIS

The data obtained from the field and pot culture was statistically analyzed and statistically tested using WASP 2.0 software given by ICARGOA.

Plate 1. View of the pot experiment at RARS farm, Nileshwar

Plate 2a. Field view—three month after planting

Plate 2b. Field view—after bunch emergence

Plate 2. Field view of the experimental plot at RARS farm, Nileshwar

Results

4. RESULT

An investigation was conducted to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health of banana with respect to availability of nutrients. The biometric observations were recorded periodically from the pot culture study and field experiment. The results of various soil, plant and yield parameters were statistically analyzed and presented below.

4.1 POT CULTURE EXPERIMENT

The pot culture experiment was carried out at Regional Agricultural Research Station (RARS) Nileshwar during February 2018 to April 2018 to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health with respect to availability of nutrients. The biometric observations were periodically recorded. The important findings are presented below.

4.1.1 Vegetative characters

4.1.1.1 Number of leaves

Number of leaves were recorded periodically at one month, two months and three months after planting and presented in the table 4. Data revealed that all the treatments were significantly over the control at all stages. At 1 MAP T_4 (gypsum and silica basally) produced the maximum number of leaves (6.79) followed by T_2 (6.78) and T_5 (6.49) were on par and minimum was recorded in T_1 (5.99). Similar results were recorded at 2 MAP with T_4 (7.24) while T_2 (6.24) recorded minimum number of leaves. At 3 MAP T_4 (7.24) and T_1 (6.99) were on par with highest leaves produced in T_4 (gypsum and silica basally) and it was 38 % over control.

4.1.1.2 Pseudostem height

Pseudostem height was recorded from the collar region to the petiole of the younger leaf at 1 MAP, 2 MAP, 3 MAP and were presented in the table 4. Application

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of soil ameliorants showed significantly superior results over the control. At 1 MAP T_4 (gypsum and silica basally) recorded highest plant height of 34.49 cm followed by T_2 (34.37) and were on par. Similar results were observed at 2 MAP with T_4 (60.74 cm) T_2 (59.49 cm) on par. At 3 MAP T_4 (gypsum + silica basally) recorded the maximum plant height of 83.61 cm followed by T_2 (82.49 cm) and were on par, which was 23 % and 22% respectively over control.

4.1.1.3 Pseudostem girth

Pseudostem girth was recorded at 3 MAP and were recorded in the table 4. Application of soil ameliorants showed significantly superior results over control in all treatments. Highest pseudostem girth was recorded in T_4 (Basal application of gypsum + silica) with 24.25 cm followed by T_2 (23.35) which was 18 % and 14 % respectively superior over control.

Table 4: Effect of soil ameliorants on the plant height and number of leaves of banana in the pot culture

Treatments	Number of leaves			Plant height (cm)			Plant girth (45cm)
	1 MAP	2 MAP	3 MAP	1 MAP	2 MAP	3 MAP	3 MAP
T_1	5.99	6.99	6.99	27.74	52.47	78.49	21.89
T_2	6.78	6.24	6.49	34.37	59.49	82.49	23.35
T_3	5.99	6.74	5.99	31.49	57.49	77.24	22.65
T_4	6.79	7.24	7.24	34.49	60.74	83.61	24.25
T_5	6.49	6.99	5.24	28.24	53.21	67.49	20.45
SEm (±)	0.12	0.04	0.09	0.34	0.65	0.64	0.09
CD(0.05)	0.36	0.13	0.27	1.04	1.97	1.93	0.63

MAP- Months after Planting

T_1: Basal application of calcium silicate; T_2: Basal application of lime and silica ; T_3: Basal application of dolomite and silica; T_4: Basal application of gypsum and silica; T_5: Basal application of lime as per KAU POP 2016 (control)

4.1.1.4 Root length

Root length was recorded at 1 MAP, 2 MAP, 3 MAP and presented in the table 5 .Soil ameliorants showed significant influence on root length over control at all the stages. At 1 MAP T_4 (gypsum and silica basally) recorded the higher root length of 33.63 cm followed by T_1 (33.26 cm) and were on par. Similar result was observed at 2 MAP with T_4 (38.39 cm). At 3 MAP also similar results were recorded with T_4 (gypsum

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and silica basal) with maximum root length of 48.18 cm which was 36 % superior over control.

4.1.1.5 Root thickness/root diameter

Root thickness or root diameter was recorded at 1 MAP, 2 MAP, 3 MAP. Data from table 5 revealed that all treatments showed significantly better results over control at all the 3 stages. At 1 MAP treatments T_4, T_2 and T_3 were on par. Among them T_4 (gypsum and silica basal) recorded the maximum root diameter of 0.18 cm followed by T_2 (0.14 cm) and T_3 (0.14 cm). Similar results were recorded at 2 MAP with T_4 (0.20 cm) followed by T_3 (0.18 cm) and were on par. At 3 MAP T_4 (gypsum and silica basally) recorded the highest root thickness of 0.39 cm.

4.1.1.6 Root CEC and Root section study

Root CEC was recorded at 3 MAP and presented in the table 5. Increased root CEC was recorded in all treatments. Among the treatments T_4 (basal application of gypsum + silica) recorded the highest root CEC of 24.6 $cmol_c/kg$ followed by T_1(23.80) and T_3 (21.60) which was 47 %, 42% and 29 % respectively superior over control. The treatment application did not show any significant influence on the root section study of the roots done at 3 MAP. Root cross sections of different treatments were depicted in plate 4.

Table 5: Effect of soil ameliorants on the root length, root diameter and root CEC of banana in the pot culture

Treatments	Root length (cm)			Root thickness/ Root diameter (cm)			Root CEC ($cmol_c/kg$) 3rd month of planting
	1 MAP	2 MAP	3 MAP	1 MAP	2 MAP	3 MAP	
T_1	33.26	34.11	41.16	0.09	0.13	0.19	23.80
T_2	26.94	34.20	39.79	0.14	0.13	0.24	20.50
T_3	30.49	34.54	41.92	0.14	0.18	0.29	21.60
T_4	33.63	38.39	48.18	0.18	0.20	0.39	24.60
T_5	26.38	28.41	35.42	0.09	0.12	0.13	16.70
SEm (±)	0.29	0.18	0.40	0.01	0.01	0.003	0.21
CD(0.05)	0.88	0.55	1.20	0.05	0.03	0.002	0.66

MAP- Months after Planting

T_1: Basal application of calcium silicate; T_2: Basal application of lime and silica; T_3: Basal application of dolomite and silica; T_4: Basal application of gypsum and silica; T_5: Basal application of lime as per KAU POP 2016 (control)

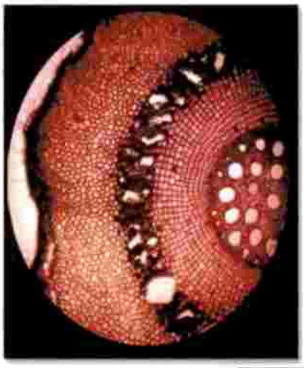
Plate 3a. Best Treatment T_4

Plate 3b. Control (T_5)

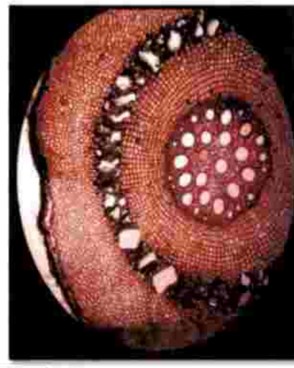
Plate 3c. Best Treatment T_4

Plate 3d. Control (T_5)

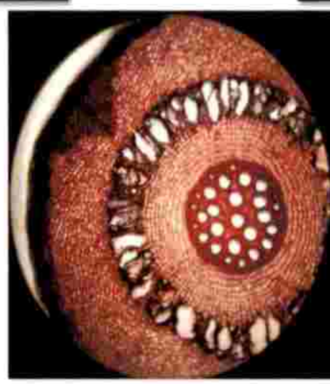
Plate 3. Effect of soil ameliorants on root growth in pot experiment



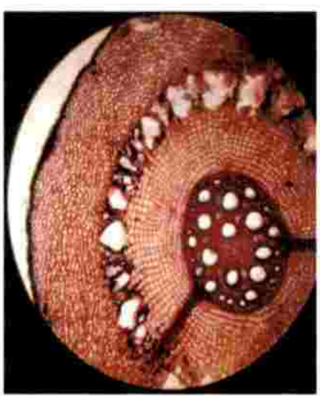
T1



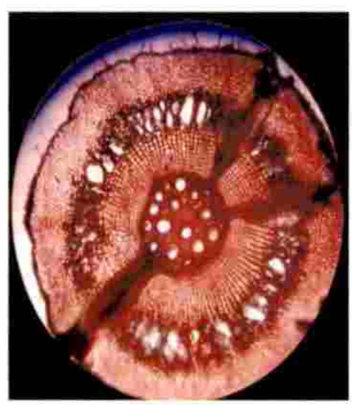
T2



T3



T4



T5 (Control)

Plate 4. Cross section of banana roots

4.2 FIELD EXPERIMENT

The field experiment was carried out at Regional Agricultural Research Station (RARS) Nileshwar to study the effect of various non-conventional soil ameliorants on yield and quality of tissue culture banana var Nendran. The biometric observations were periodically recorded and the various soil, plant and fruit characteristics were analyzed. The important findings are presented below.

4.2.1 Vegetative characters

4.2.1.1 Number of leaves

Number of leaves were recorded at 1 MAP, 3 MAP, 5 MAP and at harvest and was presented in the table 6. All the treatments produced significantly superior number of leaves than control at all stages. At 1 MAP T_{10} (gypsum + silica in 3 splits) produced highest number of leaves of 7.33 followed by T_8 (7.23) and were on par. At 3 MAP T_{10} (7.66), T_1 (7.63) and T_8 (7.33) were on par with highest number of leaves observed in T_{10} (7.66). Similar results were recorded at 5 MAP with T_{10} (12.00) followed by T_6 (11.70), T_1 (11.66) and T_8 (11.63). At harvest treatments T_{10} (12.30) recorded the maximum number of leaves followed by T_5 (12.20), T_1 (12.00) and T_7 (12.00). Treatments T_{10} (gypsum + silica 3 splits) and T_5 (gypsum +silica 2 splits) produced 23 % and 22 % more number of leaves respectively over control.

Table 6: Effect of soil ameliorants on the number of leaves of banana

Treatments	1 MAP	3 MAP	5 MAP	At Harvest
T_1	7.00	7.63	11.66	12.00
T_2	6.66	7.00	11.30	11.00
T_3	7.03	7.00	10.70	11.00
T_4	6.63	6.00	10.66	11.33
T_5	6.70	6.30	11.33	12.20
T_6	6.00	6.66	11.70	11.66
T_7	6.36	6.66	11.00	12.00
T_8	7.23	7.33	11.63	11.66
T_9	6.33	6.00	11.33	11.66
T_{10}	7.33	7.66	12.00	12.30
T_{11}	7.00	6.33	9.70	10.00
SEm (±)	0.55	0.45	0.45	0.44
CD (0.05)	0.25	0.36	0.52	0.47

MAP- Months after Planting

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st. 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.1.2 Pseudostem height

Pseudostem height was recorded from the base of the pseudostem to the base of the younger leaf at 1 MAP, 3 MAP, 5 MAP and to the emerging point of the peduncle at harvest and recorded in table 7. Data revealed that in all treatments showed significantly superior results over control. At 1 MAP T_{10} (gypsum + silica in 3 split) recorded the maximum pseudostem height of 28.26 cm followed by T_3 (28.06 cm) and T_2 (27.06 cm) and were on par. Lowest pseudostem height was recorded in T_8 (19.06 cm). At 3 MAP treatments T_{10} (151.75), T_6 (150.96), T_7 (150.63), T_5 (148.98) were on par with T_{10} recording maximum pseudostem height of 151.75 cm. Similar results were observed at 5 MAP with T_{10} (230.66 cm) followed by T_7 (227.33), T_6 (225.33) and T_5 (225.00). At harvest T_{10} (297.00 cm) recorded the maximum pseudostem height followed by T_7 (295.00 cm). Treatments T_{10} (gypsum + silica 3 splits) and T_7 (gypsum + silica 2 splits) were on par and recorded 23 % and 22 % superior height respectively over control.

4.2.1.3 Pseudostem Girth

Pseudostem girth at 90 cm from the collar region was recorded at the time of bunching and represented in the table 7. The soil ameliorants showed significant superior results over control. Among the treatments T_{10} (43.26 cm), T_5 (42.66 cm), T_9 (42.00 cm), T_4 (42.00 cm), T_7 (41.66 cm), T_1 (41.66 cm) were on par. Among the treatments maximum pseudostem girth of 43.26 cm was observed in T_{10} (gypsum +silica in 3 splits) followed by T_5 (42.66 cm). T_{10} (gypsum +silica in 3 splits) and T_5 (lime +silica in 2 splits) showed 11 % and 10% higher pseudostem girth over control respectively. While comparing the pseudostem girth of treatments T_{10} (43.26 cm) produced 7% higher pseudostem girth over T_2 (40.33 cm) and T_8 (40.33 cm).

Table 7: Effect of soil ameliorants on pseudostem height and pseudostem girth of banana

Treatments	Pseudostem height (cm)				Pseudostem girth at (90cm)
	1 MAP	3 MAP	5 MAP	At Harvest	
T_1	24.43	121.76	195.33	258.33	41.66
T_2	27.06	138.46	216.00	277.00	40.33
T_3	28.06	137.10	208.33	272.66	41.00
T_4	26.16	127.90	212.66	271.00	42.00
T_5	25.93	148.98	225.20	290.16	42.66
T_6	25.36	150.96	225.33	288.00	41.00
T_7	23.40	150.63	227.66	295.00	41.66
T_8	19.06	132.40	204.16	274.00	40.33
T_9	26.16	123.70	196.33	271.00	42.00
T_{10}	28.26	151.75	230.66	297.00	43.26
T_{11}	24.06	123.00	211.00	241.00	38.66
SEm (±)	0.67	1.85	3.10	2.16	1.40
CD (0.05)	2.00	5.45	10.48	6.39	1.97

MAP- Months after Planting

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at

1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st. 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control).

4.2.1.4 Number of Functional leaves

Number of functional leaves were recorded at harvest and presented in table 8. Significant increase in the number of functional leaves were recorded in all treatments were ameliorants added than in control. Among the treatments T_{10} (gypsum + silica in 3 splits) recorded the maximum number of leaves of 10.03 followed by T_7 (8.66), T_8 (8.66), T_9 (8.33) which was 58 % and 31 % respectively superior over control.

4.2.1.5 Number of suckers at harvest

Number of suckers were recorded at harvest and presented in table 8. There were no significant difference between the treatments. Still T_{10} (gypsum +silica in 3 split), T_1 (Basal application of calcium silicate), T_5 (lime +silica in 2 splits), T_9 (dolomite + silica in 3 splits) recorded the maximum of 3.66 suckers which was 9 % superior over control.

Table 8: Effect of soil ameliorants on the number of functional leaves and number of suckers of banana

Treatments	Number of functional leaves (At Harvest)	No of suckers (At Harvest)
T_1	8.00	3.66
T_2	7.33	2.66
T_3	9.00	3.33
T_4	7.66	3.00
T_5	8.00	3.66
T_6	7.00	3.33
T_7	8.66	3.63
T_8	8.66	3.00
T_9	8.33	3.66
T_{10}	10.03	3.66
T_{11}	6.33	3.33
SEm (±)	0.73	0.53
CD (0.05)	0.36	NS

NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at

1^{st}, 2^{nd} and 4^{th} month after planting; T_{10}: gypsum + silica in 3 split at 1^{st}. 2^{nd} and 4^{th}month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.2 Yield attributes

4.2.2.1 Number of hands per bunch

Number of hands per bunch was presented in the table 9. Data revealed that treatments produced significantly superior results over control. Among the treatments T_{10} (6.33), T_7 (6.33), T_4 (6.00), T_6 (5.66), T_3 (5.66) were on par with treatments T_{10} (gypsum and silica 3 splits) and T_7 (gypsum and silica 2 splits) producing maximum number of hands per bunch of 6.33 which was 26 % more than control. Minimum number of hands were produced in T_9 (5.00) and T_5 (5.00). Treatment T_{10} (6.33) produced 26 % more number of hands than in T_9 (5.00) and T_5 (5.00).

4.2.2.2 Number of fingers per hand

Number of fingers per hand were presented in the table 9. With respect to fingers per hands treatments produced significantly superior results over control. Among treatments T_{10} (8.66), T_9 (8.33), T_1 (8.00), T_5 (8.00) were on par with T_{10} (gypsum and silica in 3 splits) producing maximum fingers per hand of 8.66 followed by T_9 (8.33) and T_1 (8.00). Treatments T_{10} (gypsum and silica in 3 splits), T_9 (dolomite and silica in 3 splits), T_1 (Basal application of calcium silicate) and T_5 (lime and silica 2 splits) showed 53 %, 26 % and 24 % higher finger production respectively over control. Moreover T_{10} (8.66) reported 44 % increase in finger production over T_4 (6.00).

4.2.2.3 Bunch weight

Bunch weight is an important economic factor in banana cultivation. Application of soil ameliorants showed significant increase in the bunch weight in treatments over control. Among treatments gypsum + silica in 3 splits, T_{10} recorded highest weight of 11.24 kg followed by T_7 (9.46 kg), T_9 (9.23) and T_5 (8.86) which was

97%, 66 %, 62 % and 55 % respectively superior over control. Considering the treatments T_{10} (11.24 kg) produced a yield increment of 56 % over T_4 (7.20 kg). Bunch weight was represented in table 9.

Table 9: Effect of soil ameliorants on the number of hands per bunch, no of fingers per hand and Bunch weight of banana

Treatments	No of hands per bunch	No of fingers per hand	Bunch weight (kg)
T_1	5.33	8.00	8.79
T_2	5.33	7.66	7.90
T_3	5.66	7.00	8.27
T_4	6.00	6.00	7.20
T_5	5.00	8.00	8.86
T_6	5.66	7.00	7.81
T_7	6.33	7.66	9.46
T_8	5.33	7.66	7.99
T_9	5.00	8.00	9.23
T_{10}	6.33	8.66	11.24
T_{11}	5.00	5.66	5.69
SEm (±)	0.273	0.876	0.23
CD (0.05)	0.387	0.295	0.40

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st. 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

Plate 5a. Best Treatment T_{10} Plate 5b. Control

Plate 5. Best Treatment Bunch vs control

4.2.2.4 Average Length of Fingers

Application of soil ameliorants showed significant superior effect on the finger length of treatments over control. Treatments T_{10} (21.30 cm) T_3 (20.00 cm), T_5 (19.86 cm), T_7 (19.50 cm), T_9 (19.50 cm), T_4 (19.16 cm) were on par with highest finger length recorded in T_{10} (gypsum and silica 3 splits) with 21.30 cm followed by T_3 (20.00 cm). T_{10} (gypsum and silica 3 splits) and T_3 (dolomite and silica basal) produced 25 % and 17 % superior results over control. Among the treatments T_{10} (21.30 cm) produced 18 % increase in the finger length in comparison with T_3 (18.00 cm). Average length of fingers was represented in the table 10.

4.2.2.5 Average breadth of Fingers

Treatment showed significant superior result over the control with respect to finger breadth. Treatments T_9 (16.00), T_2 (15.96), T_5 (15.80), T_3 (15.33), T_4 (15.03), T_{10} (15.00), T_6 (14.86) were on par. Highest finger breadth of 16.00 cm was recorded in T_9 (dolomite and silica basal 3 splits) followed by T_2 (15.96), T_5 (15.80). Treatments T_9 (dolomite and silica basal 3 splits), T_2 (lime and silica basal), T_5 (lime and silica 2 splits) showed 13.79 %, 13.51 % and 12 % superior finger breadth respectively over control. Among the treatments T_9 (16.00 cm) produced 11 % superior finger breadth in comparison with T_7 (14.33 cm). Average breadth of fingers was represented in the table 10.

4.2.2.6 Average weight of fingers

Application of soil ameliorants showed superior results in the treatments over control with respect to the finger weight. Among the treatments T_9 (dolomite + silica 3 splits) recorded the maximum finger weight of 225.00 g followed by T_5 (219.00) and T_3 (203.36 g). Treatments T_9 (dolomite + silica 3 splits), T_5 (lime and silica 2 splits) and T_3 (dolomite and silica basal) produce 20 %, 17 % and 8 % superior results respectively over control. It was also observed that with in the treatments T_9 (225.00)

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produce fingers which were 17 % heavier than those in T_2 (191.00). It was represented in the table 10.

Table 10: Effect of soil ameliorants on length, breadth and average weight of banana fingers

Treatments	Finger length (cm)	Finger breath (cm)	Average weight of fingers (g)
T_1	18.03	14.66	195.93
T_2	18.00	15.96	191.00
T_3	20.00	15.33	203.36
T_4	19.16	15.03	194.50
T_5	19.86	15.80	219.00
T_6	18.00	14.86	194.46
T_7	19.50	14.33	190.90
T_8	14.86	14.66	195.53
T_9	19.50	16.00	225.00
T_{10}	21.30	15.00	204.83
T_{11}	17.00	14.06	186.73
SEm (±)	0.745	1.247	16.23
CD (0.05)	2.213	0.420	9.06

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8:

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Lime + silica in 3 split at 1^{st}, 2^{nd} and 4^{th} month after planting; T_9: dolomite + silica in 3 split at 1^{st}, 2^{nd} and 4^{th} month after planting; T_{10}: gypsum + silica in 3 split at 1^{st}. 2^{nd} and 4^{th}month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

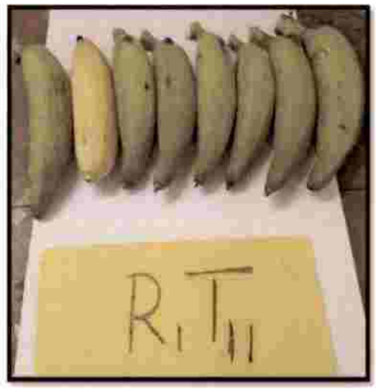

Plate 6a. Highest finger length (T_{10})

Plate 6b. Control

Plate 6c. Highest finger breadth (T_9)

Plate 6. Finger characteristics of treatment and Control

4.2.2.7 Days to bunch emergence

Data in table 11 revealed that application of soil ameliorants showed significantly effect on the days to bunch emergence. All treatments showed early bunch emergence compared to control. Among the treatments T_{10} (gypsum + silica in 3 splits) produced earliest bunches in 186 days whereas the control T_{11} produced bunches in 199.33 days indicating that in T_{10} days for bunch emergence was reduced to 13 days.

4.2.2.8 Days for ripening

Days to ripening was presented in table 11. All treatment showed significant superior results over control with respect to days for ripening. Among the treatments, T_{10} (gypsum + silica in 3 splits) takes shorter days for ripening (4.33) whereas the control T_{11} ripe within 6.666 days. Thus in T_{10} the days for complete ripening of the fruit ripening was shortened to 2 days.

4.2.2.9 Days to harvest

The number of days from planting to harvest was recorded and all treatments were superior over control. 302 days was needed by the control to attain harvest stage where as all treatments harvested within 283 days. Among the treatments T_{10} (gypsum + silica in 3 splits) recorded the minimum days to harvest (277 days) indicating that the duration of crop was reduced to 25 days in T_{10} (gypsum + silica in 3 splits). Days to harvest is presented in table 11.

Table 11: Effect of soil ameliorants on days to bunch emergence, days to harvest, days to ripening

Treatments	Days to bunch emergence	Days to harvest	Days to ripening
T_1	193.00	285.66	5.66
T_2	192.00	283.33	5.30
T_3	189.00	283.33	4.66
T_4	189.00	281.00	5.03
T_5	189.66	282.33	5.33
T_6	190.33	283.00	5.66
T_7	188.00	281.33	5.33
T_8	188.66	282.00	5.63
T_9	188.00	281.33	5.63
T_{10}	186.00	277.00	4.33
T_{11}	199.33	302.00	6.66
SEm (±)	0.51	0.77	0.46
CD (0.05)	1.52	2.27	0.22

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at

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1^{st}, 2^{nd} and 4^{th} month after planting; T_{10}: gypsum + silica in 3 split at 1^{st}. 2^{nd} and 4^{th}month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.3 Fruit characteristics

The effect of soil ameliorants on fruit characteristics of tissue culture banana var. nendran was examined. The various quality parameters observed were titrable acidity, total soluble solids (TSS), reducing sugar, non-reducing sugar, keeping quality of the fruits at ambient condition. These were statistically analyzed and the results were presented below in table 12.

4.2.3.1 Titrable Acidity

Fruit acidity is one of the important factor that determines fruit quality. Fruit quality was enhanced when acid content of the fruit was minimum. Application of soil ameliorants showed a superior effect in reducing titrable acidity than in control. Among the treatments T_{10} (gypsum + silica in 3 splits) produced fruits with the lowest titrable acidity of 0.27 % followed by T_9 (0.28 %). In T_{10} fruit acidity was reduced by 96 % over control.

4.2.3.2 Total Soluble Solids (TSS)

Soil ameliorants showed significant superior effect on TSS content of the fruit. All treatments showed superior results over control. Among the treatments T_{10} (29.90 °brix), T_9 (29.70 °brix), T_4 (29.50 °brix), T_8 (28.80 °brix) were on par. Highest TSS was observed in T_{10} (gypsum and silica 3 splits) with 29.90 °brix followed by T_9 (29.70 °brix), T_4 (29.50 °brix), T_8 (28.80 °brix). In treatments T_{10} (gypsum and silica 3 splits), T_9 (dolomite and silica 3 splits), T_4 (gypsum and silica basal) and T_8 (lime and silica 3 splits) the fruit TSS was increased by 12.92 %, 12.16 % and 9 % respectively over control.

4.2.3.3 Reducing sugar

Higher sugar content increased the economic acceptance of the fruit. In all treatments were ameliorants were added there were significant increase in the reducing sugar content of the fruit over the control. Among the treatment gypsum + silica in 3 splits, T_{10} (19.00 %) recorded the highest reducing sugar followed by T_9 (17.25 %) indicating that fruits produced by T_{10} and T_9 respectively contain 96 % and 78 % more reducing sugars over control.

4.2.3.4 Non reducing sugar

Treatments produce fruits with higher non reducing sugar compared to control. Among the treatments T_{10} (4.89), T_8 (4.85 %), T_3 (4.79 %), T_1 (4.75 %) were on par. Highest quantity of non-reducing sugar was recorded for gypsum +silica in 3 splits T_{10} (4.89 %) followed by T_8 (4.85 %), T_3 (4.79 %), T_1 (4.75 %) and their non reducing content was increased by 36 %, 35 %, 33 %, 32% respectively over control.

4.2.3.5 Shelf Life

Keeping quality of the fruit was determined by calculating the number of days from the day of onset of ripening to the end of edible life of fruit. Shelf life is one of the major quality parameter that determines the marketability of the fruit. Application of soil ameliorants showed significant superior effect on the shelf life of the fruit. All treatments showed a higher shelf life over control. Among the treatments best shelf life was recorded for T_{10} (4.40 days) followed by T_9 (4.08 days). It was observed that fruits of T_{10} (gypsum and silica 3 splits) and T_9 (dolomite and silica 3 splits) showed 33 % and 23 % superior shelf life respectively over control.

Table 12: Effect of soil ameliorants on total soluble sugar, titrable acidity, reducing sugar, non-reducing sugar and shelf life of banana

Treatments	Total soluble sugar (TSS) (^{0}brix)	Titrable acidity (%)	Reducing sugar (%)	Non reducing sugar (%)	Shelf life
T_1	26.6	0.50	9.33	4.75	3.46
T_2	27.3	0.45	12.13	3.88	3.38
T_3	27.7	0.43	12.25	4.79	3.43
T_4	29.5	0.38	15.45	4.25	3.83
T_5	28.2	0.36	12.98	2.25	3.43
T_6	28.7	0.36	14.05	3.75	3.75
T_7	28.4	0.29	13.29	4.17	3.73
T_8	28.8	0.39	13.51	4.85	3.43
T_9	29.7	0.28	17.25	3.70	4.08
T_{10}	29.9	0.27	19.00	4.89	4.40
T_{11}	26.3	0.53	9.68	3.58	3.30
SEm (±)	0.398	0.005	0.187	0.059	0.061
CD (0.05)	1.173	0.010	0.552	0.177	0.185

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1^{st} and 2^{nd} month after planting; T_6: dolomite + silica in 2 splits at 1^{st} and 2^{nd} month after planting. (MAP); T_7: gypsum + silica in 2 split at 1^{st} and 2^{nd} month after planting; T_8: Lime + silica in 3 split at 1^{st}, 2^{nd} and 4^{th} month after planting; T_9: dolomite + silica in 3 split at 1^{st}, 2^{nd} and 4^{th} month after planting; T_{10}: gypsum + silica in 3 split at 1^{st}. 2^{nd} and 4^{th}month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.4 Incidence of pest and diseases

In general incidence of pest and diseases were minimum in treatment plants where as in control incidence of pest and disease was more noticed. Incidence of banana leaf eating caterpillar (*Spodoptera litura*) was prominent during 3 MAP. At 6 MAP there were attack of banana pseudostem weevil (*Odoiporus longicollis).* The major disease noticed was sigatoka leaf spot caused by *Mycosphaerella musicola* at 6 MAP. Necessary control measures were adopted as per KAU POP (2016) uniformly to all the plants.

4.2.5. Influence soil amendments on the nutrient availability in soil

4.2.5.1 pH and Electrical conductivity

Soil pH and electrical conductivity were measured at 3 MAP, 6 MAP and at harvest and was statistically analyzed and presented below in the table 13.

Soil ameliorants had no significant effect on soil pH at 3 MAP and at harvest but it showed significant effect at 6 months after planting. With respect to soil pH all treatments showed superior results over control. Among the treatments T_{10} (Gypsum + silica in 3 splits) reported higher pH. At 3 MAP highest pH was recorded for T_{10} (4.66). At 6 MAP treatments T_{10} (6.61), T_2 (6.58), T_9 (6.57), T_4 (6.46), T_1 (6.32), T_6 (6.29), T_5 (6.16) were on par with highest pH recorded for T_{10} (6.61) followed by T_2 (6.58). Treatments T_{10} (gypsum and silica 3 splits) and T_2 (dolomite and silica 3 splits) showed 12% and 12.28 % higher pH respectively over control. At harvest the soil ameliorants had no significant effect on pH with highest pH recorded for T_{10} (6.46).

With respect to the electrical conductivity the treatments showed significant superior results over control at 6 month after planting and at harvest but there was no significant influence at 3 MAP. At 3 MAP highest EC was recorded for T_{10} (gypsum and silica 3 splits) with 0.27 dS/m. At 6 MAP treatments T_{10} (0.29 dS/m), T_7 (0.27

dS/m), T_8 (0.26 dS/m), T_9 (0.26 dS/m) were at par with T_{10} (gypsum and silica 3 splits) recording highest EC (0.29 dS/m). Similar results were recorded at harvest with T_{10} (0.31 dS/m) followed by T_7 (0.28 dS/m), T_9 (0.27 dS/m) and T_8 (0.27 dS/m). It was also observed that T_{10} (gypsum and silica 3 splits) showed 10 % higher EC over control.

Table 13: Effect of soil ameliorants on the pH and Electrical conductivity of soil

Treatments	pH			Electrical conductivity (dS/m)		
	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	4.46	6.32	6.40	0.26	0.15	0.16
T_2	4.49	6.58	6.51	0.22	0.15	0.17
T_3	4.54	6.00	6.03	0.13	0.25	0.25
T_4	4.53	6.46	6.46	0.11	0.22	0.24
T_5	4.31	6.16	6.28	0.21	0.24	0.26
T_6	4.26	6.29	6.43	0.19	0.23	0.25
T_7	4.32	6.11	6.20	0.25	0.27	0.28
T_8	4.21	6.11	6.40	0.20	0.26	0.27
T_9	4.50	6.57	6.44	0.19	0.26	0.27
T_{10}	4.66	6.61	6.46	0.27	0.29	0.31
T_{11}	4.19	5.86	5.86	0.20	0.13	0.15
SEm (±)	0.11	0.16	0.18	0.06	0.01	0.01
CD (0.05)	NS	0.48	NS	NS	0.04	0.05

MAP- Months after Planting; NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at

1^{st}, 2^{nd} and 4^{th} month after planting; T_{10}:gypsum + silica in 3 split at 1^{st}. 2^{nd} and 4^{th}month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.5.2 Organic Carbon and Cation exchange capacity

Organic carbon content and cation exchange capacity of soil were recorded at 3 MAP, 6 MAP and at harvest and were shown in table 14.

Soil ameliorants did not show any significant effect on the soil organic carbon at 3 MAP and 6 MAP but it showed significant effect at harvest. At 3 MAP there were no significant influence on organic carbon content with highest organic carbon recorded in T_{10} (0.94 %). Similar results were recorded at 6 MAP with T_{10} (1.11 %). At harvest soil ameliorants showed significant superior effect on organic carbon content with higher organic carbon recorded in all the treatments over control. Highest organic carbon was observed in T_{10} (gypsum +silica 3 splits) with 1.64 % followed by T_5 (1.62 %). Treatments T_{10} (gypsum +silica 3 splits) and T_5 (lime and silica 2 splits) respectively reported with 115 % and 113% higher organic carbon content than in control.

Statistically analyzed data revealed that the treatments showed significantly superior CEC over the control at all the three stages. At 3 MAP treatments T_{10} (3.29), T_5 (3.19), T_3 (3.09), T_7 (3.07), T_9 (3.01), T_6 (3.01), T_4 (2.89), T_1 (2.84) and T_8 (2.82) were on par with T_{10} (3.29) recorded the highest cation exchange capacity followed by T_5 (3.19). Similarly at 6 MAP treatments T_{10} (5.33) followed by T_9 (5.31) and T_6 (4.88). At harvest T_{10} (3.33) and T_8 (3.00) were on par with highest CEC was recorded in gypsum + silica in 3 splits T_{10} with 3.33 Cmolkg^{-1} followed by T_8 (3.00). Treatments T_{10} (gypsum and silica 3 splits) and T_8 (lime and silica 2 splits) produced 90 % and 71% superior results respectively over control.

4.2.5.3 Particle size distribution in soil

Application of soil ameliorants showed no significant effect on the particle size at 3 month after planting, 6 month after planting and at harvest. Particle size was analyzed and presented in the table 15.

Table 14: Effect of soil ameliorants on the organic carbon and Cation exchange capacity of soil

Treatments	Organic carbon (%)			CEC (C mol kg^{-1})		
	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	0.88	0.99	1.06	2.84	3.85	1.76
T_2	0.84	0.96	1.06	2.43	3.57	2.07
T_3	0.93	1.01	1.22	3.09	3.73	2.00
T_4	0.92	0.90	1.21	2.89	4.19	2.09
T_5	0.92	1.08	1.62	3.19	3.86	2.49
T_6	0.91	1.00	0.79	3.01	4.88	2.42
T_7	0.92	1.09	1.15	3.07	4.10	2.07
T_8	0.73	0.99	1.08	2.82	4.47	3.00
T_9	0.85	0.95	1.02	3.01	5.31	2.67
T_{10}	0.94	1.11	1.64	3.29	5.33	3.33
T_{11}	0.76	0.83	0.76	2.27	2.79	1.75
SEm (±)	0.09	0.11	0.10	0.16	0.21	0.16
CD (0.05)	NS	NS	0.296	0.49	0.62	0.47

MAP- Months after Planting; NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}:gypsum + silica in 3 split at 1st. 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

Table 15: Effect of soil ameliorants on sand, slit and clay percentage of soil

Treatments	3 MAP			6 MAP			At harvest		
	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)
T_1	77.22	19.15	3.68	77.21	18.95	3.68	77.21	19.01	3.68
T_2	77.15	19.36	3.71	77.15	19.36	3.71	77.15	19.36	3.71
T_3	76.24	19.45	3.65	76.22	19.22	3.65	76.24	19.32	3.65
T_4	76.96	18.75	3.72	76.97	18.61	3.72	76.97	18.69	3.71
T_5	77.14	18.78	2.98	77.03	18.77	2.98	77.03	18.77	2.98
T_6	76.86	19.06	3.52	76.84	19.1	3.52	76.85	19.08	3.51
T_7	77.21	19.12	3.75	77.21	19.14	3.70	77.21	19.14	3.712
T_8	77.24	18.79	3.71	77.23	18.77	3.71	77.23	18.77	3.70
T_9	76.65	18.88	3.70	76.64	18.84	3.70	76.64	18.84	3.71
T_{10}	77.26	19.46	3.72	77.24	19.48	3.72	77.25	19.48	3.72
T_{11}	77.25	19.01	3.70	77.27	19.05	3.70	77.26	19.02	3.70
SEm (±)	0.95	0.26	0.06	1.19	0.18	0.05	1.15	0.26	0.05
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

MAP- Months after Planting; NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8:

Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}:gypsum + silica in 3 split at 1st. 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.5.4 Available Nitrogen, Potassium, Phosphorus

Available nitrogen, potassium and phosphorus status of the soil was analyzed and presented below in table 16.

The treatment showed significant superior results on the available nitrogen status of soil over control at all stages of the crop. At 3 MAP treatments T_{10} (282.24 kg/ha), T_4 (250.88 kg/ha), T_6 (219.52 kg/ha), T_5 (250.88 kg/ha) and T_3 (219.50 kg/ha) were on par with T_{10} (gypsum and silica 3 splits) reported highest available nitrogen in soil (282.24 kg/ha). Similar results were recorded at 6 MAP with T_{10} (313.60 kg/ha) followed by T_6 (282.24 kg/ha), T_7 (250.88 kg/ha) and T_2 (225.88 kg/ha). At harvest T_{10} (433.11 kg/ha) recorded the highest nitrogen content in the soil followed by T_7 (433.11 kg/ha). It was also observed that T_{10} (gypsum and silica 3 splits) and T_7 (gypsum and silica 2 splits) showed 130 % and 113 % higher nitrogen content in soil respectively over control.

At 3 MAP and at 6 MAP ameliorants had no significant influence on the available potassium content in soil. But at harvest potassium content in the treatments was significant increased over control. At 3 MAP T_{10} (gypsum and silica 3 splits) recorded highest potassium content of 255.05 kg/ha. Similar results were recorded at 6 MAP with T_{10} (348.90 kg/ha). At harvest treatments T_{10} (401.65), T_5 (358.10), T_8 (349.45), T_7 (301.37) were on par with highest potassium content reported in T_{10} (348.90) indicating that potassium availability in T_{10} (gypsum and silica 3 splits) was increased by 119 % over control.

Soil ameliorants showed significant influence on the phosphorus availability in soil at 6 MAP and at harvest but it was non-significant at 3 MAP. At 3 MAP T_{10}

(gypsum and silica 3 splits) recorded higher phosphorus availability (98.93 kg/ha). At 6 MAP T_{10} (576.708 kg/ha), T_9 (527.63 kg/ha), T_4 (522.45 kg/ha), T_2 (495.54 kg/ha), T_7 (489.11 kg/ha) were on par with highest phosphorus availability reported in T_{10} (576.708 kg/ha). Similar results were recorded at harvest with T_{10} (169.51 kg/ha) followed by T_9 (138.11 kg/ha) and T_1 (132.99 kg/ha).

Table 16: Effect of soil ameliorants on available nitrogen, potassium and phosphorous status of soil

	Nitrogen (kg/ha)			Potassium (kg/ha)			Phosphorus(kg/ha)		
Treatment	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	156.78	219.52	319.87	217.50	278.96	206.10	84.84	423.92	132.99
T_2	188.16	225.88	226.23	176.11	243.58	206.97	93.72	495.54	67.80
T_3	219.50	188.16	298.51	232.71	261.11	226.07	91.21	407.17	112.30
T_4	250.88	190.16	283.08	198.43	237.48	212.70	90.46	522.45	91.46
T_5	250.88	156.80	284.66	225.93	262.36	358.10	82.67	443.14	83.88
T_6	219.52	282.24	278.60	216.26	220.38	195.70	92.41	434.63	62.26
T_7	156.80	250.88	401.21	126.08	241.15	301.37	92.39	489.11	60.36
T_8	156.80	188.16	282.24	242.98	286.61	349.45	86.95	419.96	54.58
T_9	188.16	188.16	313.80	161.30	233.85	216.85	85.96	527.63	138.11
T_{10}	282.24	313.60	433.11	255.05	348.90	401.65	98.93	576.70	169.51
T_{11}	125.44	125.44	188.16	149.76	200.92	182.75	78.10	350.91	36.67
SEm (±)	21.97	30.735	30.2	52.16	31.64	35.13	8.39	31.12	13.94
CD (0.05)	65.28	91.308	89.972	NS	NS	103.65	NS	91.81	41.12

MAP- Months after Planting; NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}:gypsum + silica in 3 split at 1st. 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

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4.2.5.5 Available Calcium, Magnesium, sulphur

With respect to the available calcium content in the soil treatments showed significant superior results over control at all the 3 stages and are presented in table 17. At 3 MAP T_{10} (286.66 mg/kg), T_4 (280.00 mg/kg), T_8 (266.60 mg/kg), T_7 (266.60 mg/kg), T_5 (266.60 mg/kg), T_1 (260.00 mg/kg) and T_3 (260.00 mg/kg) were on par. Among the treatments T_{10} (gypsum and silica 3 splits) recorded the highest calcium content of 286.66 mg/kg. Similar results were recorded at 6 MAP with T_{10} (506.66 mg/kg) showing highest calcium content. At harvest T_{10} (280.00 mg/kg) recorded highest calcium followed by T_7 (260.00 mg/kg) and T_9 (250.00 mg/kg). 86% higher calcium availability was reported in T_{10} (gypsum and silica 3 splits) over control.

At 3 MAP, 6 MAP and at harvest the ameliorants showed significant superior effect on magnesium status of the soil over control. At 3 MAP treatments T_9 (207.96 mg/kg), T_6 (205.92 mg/kg), T_1 (192.00 mg/kg) T_5 (192.00 mg/kg), T_7 (192.00 mg/kg), T_4 (192.00 mg/kg), T_3 (183.96 mg/kg) were on par with T_9 (dolomite and silica in 3 splits) showing highest magnesium content of 207.96 mg/kg. Similar results were recorded at 6 MAP with T_9 (390.000 mg/kg) showing highest magnesium content. At harvest the treatment T_9 (219.60 mg/kg and T_8 (198.00 mg/kg) were on par. Highest magnesium content was recorded in T_9 (219.60 mg/kg followed by T_8 (198.00 mg/kg). Available magnesium content in the soil was represented in table 17.

Treatments showed significant superior results over the control with respect to sulphur availability in the soil at all the 3 stages of the crop and were presented in table 17. At 3 MAP treatments T_{10} (8.47 mg/kg), T_7 (7.00 mg/kg), T_9 (6.90 mg/kg), T_1 (5.60 mg/kg) were on par with T_{10} (gypsum + silica in 3 splits,) reported highest sulphur content in soil (8.47 mg/kg). Similar results were recorded at 6 MAP with T_{10} (43.39 mg/kg) followed by T_7 (39.38 mg/kg). At harvest treatment T_{10} (65.75), T_6 (65.09 mg/kg), T_9 (64.41 mg/kg), T_1 (64.00 mg/kg), T_8 (63.12 mg/kg), T_5 (61.27 mg/kg), T_3 (60.79 mg/kg), T_7 (60.60 mg/kg) and T_2 (60.45 mg/kg) were on par. Among the

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treatments T_{10} (65.75) recorded higher sulphur availability in soil which was 18 % superior over control.

Table 17: Effect of soil ameliorants on calcium, magnesium and sulphur status of soil

Treatments	Calcium ($mg\ kg^{-1}$)			Magnesium ($mg\ kg^{-1}$)			Sulphur ($mg\ kg^{-1}$)		
	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	260.00	260.00	220.00	192.00	267.96	51.96	5.60	10.31	64.00
T_2	220.00	260.00	160.00	135.96	240.00	123.96	3.92	18.92	60.45
T_3	260.00	300.00	190.00	183.90	231.96	96.00	3.85	22.03	60.79
T_4	280.00	340.00	160.00	192.00	252.00	99.96	2.57	8.42	59.45
T_5	266.60	306.60	170.00	192.00	243.96	147.96	4.44	13.69	61.27
T_6	210.00	440.00	200.00	205.92	291.96	144.00	4.07	26.48	65.09
T_7	266.60	420.00	260.00	192.00	207.96	96.00	7.00	39.38	60.60
T_8	266.60	310.00	190.00	145.92	312.00	198.00	4.64	11.89	63.12
T_9	220.00	360.00	250.00	207.96	390.00	219.96	6.90	16.40	64.41
T_{10}	286.60	506.60	280.00	147.96	303.96	123.96	8.47	43.39	65.75
T_{11}	200.00	246.60	150.00	96.00	159.96	51.96	1.76	5.23	55.33
SEm (±)	11.11	7.05	13.86	16.14	24.256	23.53	1.09	5.48	1.86
CD (0.05)	33.00	20.94	41.17	47.95	72.060	69.90	3.21	16.16	5.50

MAP- Months after Planting

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st, 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

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4.2.5.6 Available Iron and Manganese

Soil ameliorants reduce soil acidity by reducing iron toxicity in acid soils. Ameliorants did not show any significant effect on iron content at 3 MAP and at 6 MAP but it showed significant effect at harvest and all treatments showed significant reduction in soil iron content over control. Among the treatments T_{10} (gypsum + silica in 3 splits) recorded the lowest iron content in the soil at all stages. At 3 MAP T_{10} (11.13 mg/kg) recorded the lowest iron content. Similar results were recorded at 6 MAP with T_{10} (4.48 mg/kg). Ameliorants showed significantly superior effect on the iron content in the treatments over control at harvest. Among the treatments lowest iron content was recorded in T_{10} (48.16 mg/kg) followed by T_7 (48.16 mg/kg). Moreover T_{10} (gypsum and silica 3 splits) reduced iron availability to almost 200 % over control. Available iron content in the soil at different stages were represented in the table 18.

Manganese toxicity in acid soil was effectively mitigated by the application of soil ameliorants. Application of soil ameliorants showed no significant effect on the manganese availability in soil at 3 MAP and 6 MAP but it showed significant effect at harvest. Treatments showed noticeable reduction in manganese content over control at all stages. Among the treatments lowest manganese content was reported in T_{10} (gypsum+ silica in 3 split). At 3 MAP T_{10} (17.00) recorded the lowest manganese content. Similar results were observed at 6 MAP with T_{10} (12.77 mg/kg). At harvest Treatments T_{10} (2.56 mg/kg), T_4 (4.64 mg/kg), T_3 (4.79 mg/kg), T_8 (4.86 mg/kg), T_9 (5.94 mg/kg) were on par with T_{10} (2.56 mg/kg) showing lowest manganese availability in soil. Data regarding the manganese availability in soil was presented in table 18.

Table 18: Effect of soil ameliorants on available iron and manganese status of soil

Treatment	Iron(mg kg^{-1})			Manganese (mg kg^{-1})		
	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	26.00	23.77	142.03	24.63	13.13	9.26
T_2	21.86	19.43	115.23	28.13	15.92	9.24
T_3	18.71	15.50	126.33	22.16	15.10	4.79
T_4	16.46	10.63	85.66	22.16	14.10	4.64
T_5	16.16	19.43	123.66	22.80	21.86	10.35
T_6	16.13	10.88	119.06	26.40	13.26	6.76
T_7	14.56	5.68	51.06	22.60	14.26	8.35
T_8	22.03	5.49	125.53	23.70	14.26	4.86
T_9	18.70	18.54	119.06	22.66	16.13	5.94
T_{10}	11.13	4.48	48.16	17.00	12.77	2.56
T_{11}	32.06	24.60	148.50	36.60	22.53	10.38
SEm (±)	4.91	6.43	12.59	3.83	3.26	1.31
CD (0.05)	NS	NS	37.14	NS	NS	3.87

MAP- Months after Planting; NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st, 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.5.7 Available Zinc and Copper

Available zinc and copper content in the soil at 3 MAP, 6 MAP and at harvest were statistically analyzed and presented in the table 19.

Soil ameliorants had no significant impact on the zinc availability in soil. Addition of soil ameliorants showed an increase in zinc availability in all treatments over control. Among the treatments T_{10} (gypsum and silica in 3 spits) recorded the highest zinc availability at all 3 stages of the crop. At 3 MAP T_{10} (3.04 mg/kg) recorded highest zinc content in soil. Similar trend was recorded At 6 MAP with T_{10} (2.45 mg/kg). At harvest T_{10} (1.87 mg/kg) recorded highest zinc content in soil. T_{10} (gypsum and silica 3 splits) showed 66 % superior zinc availability over control.

With respect to the copper availability in the soil, ameliorants showed significant effect at 3 MAP but at 6 MAP and at harvest ameliorants had no significant impact on copper availability. All treatments in which ameliorants were added showed higher copper availability over control at all stages of the crop. At 3 MAP T_{10} (gypsum and silica 3 splits) recorded the highest copper content of 1.10 mg/kg followed by T_7 (0.88 mg/kg). Similar results were observed at 6 MAP with T_{10} (1.15 mg/kg) and at harvest T_{10} (gypsum and silica 3 splits) recorded highest copper content of 1.90 mg/kg in the soil.

Table 19: Effect of soil ameliorants on the available zinc and copper status of soil

Treatments	Zinc (mg/kg)			Copper (mg/kg)		
	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	2.50	1.77	1.16	0.52	0.99	1.69
T_2	2.21	2.08	1.30	0.21	1.06	1.69
T_3	2.37	1.89	1.81	0.12	0.79	0.76
T_4	1.99	1.74	1.14	0.40	0.81	1.58
T_5	2.10	1.87	1.40	0.17	1.05	1.41
T_6	2.21	1.78	1.39	0.17	1.11	1.45
T_7	1.81	2.32	1.67	0.88	0.80	1.86
T_8	2.46	1.92	1.75	0.65	0.99	1.23
T_9	2.39	1.95	1.65	0.02	1.09	1.43
T_{10}	3.04	2.45	1.87	1.10	1.15	1.90
T_{11}	1.59	1.43	1.12	0.01	0.70	0.59
SEm (±)	0.28	0.28	0.28	0.09	0.24	0.36
CD (0.05)	NS	NS	NS	0.28	NS	NS

MAP- Months after Planting; NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st. 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.5.8 Exchangeable Aluminium and Silicon

The results of exchangeable aluminium and silicon in the soil were statistically analyzed and presented in table 20.

Aluminium toxicity is one of the major reason contributing to higher acidity in lateritic soils. Application of soil ameliorants showed significant effect on aluminium concentration in soil. In all treatments were ameliorants were added there was a superior reduction in the aluminium concentration over control at all the stages of the crop. At 3 MAP T_{10} (gypsum and silica 3 splits) recorded the lowest aluminium concentration of 4.44 mg/kg followed by T_7 (5.06 mg/kg). Similar results were observed at 6 MAP with T_{10} (2.67 mg/kg) followed by T_9 (3.30 mg/kg). At harvest treatments T_{10} (6.19 mg/kg) recorded the lowest aluminium availability followed by T_8 (6.20 mg/kg) and T_9 (6.28 mg/kg). Aluminium concentration in T_{10} (gypsum and silica 3 splits) was reduced by 114 % over control.

The results on silicon availability revealed that application of soil ameliorants showed significant superior results in treatment plants rather than in control at all the 3 stages. Among the treatment T_{10} (gypsum + silica in 3 split) recorded the highest silicon availability at all stages of the crop. At 3 MAP treatment T_{10} (30.40 mg/kg) recorded highest silicon content followed by T_4 (26.40 mg/kg). Similar results were reported at 6 MAP with T_{10} (33.20 mg/kg) followed by T_7 (32.60 mg/kg). Similarly at harvest T_{10} (36.00 mg/kg) recorded highest silicon content followed by T_7 (30.20 mg/kg) indicating that in T_{10} (gypsum and silica) silicon availability was increased by 136 % over control.

Table 20: Effect of soil ameliorants on the exchangeable aluminium and silicon status of soil

Treatments	Exchangable Aluminium (mg kg^{-1})			Silicon (mg kg^{-1})		
	3 MAP	6 MAP	At harvest	3 MAP	6 MAP	At harvest
T_1	8.67	10.29	11.42	21.00	20.00	22.40
T_2	6.56	9.53	9.40	21.00	23.00	22.20
T_3	5.95	10.95	9.91	16.00	26.00	22.80
T_4	6.66	10.91	8.92	26.40	20.60	22.40
T_5	7.41	12.22	8.38	21.00	23.00	23.60
T_6	7.10	11.86	7.99	17.20	18.80	26.20
T_7	5.06	11.51	7.93	26.20	32.60	30.20
T_8	7.57	3.99	6.20	23.20	19.00	20.00
T_9	8.18	3.30	6.28	15.00	22.40	21.80
T_{10}	4.44	2.67	6.19	30.40	33.20	36.00
T_{11}	9.42	13.04	13.25	14.80	14.00	15.20
SEm (±)	0.06	0.11	0.13	0.25	.0.99	1.15
CD (0.05)	0.18	0.34	0.39	0.77	0.33	0.38

MAP- Months after Planting

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st. 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control).

4.2.6 Influence soil amendments on the nutrient content of the leaves

Leaf samples were collected at the bunching stage and at harvest. Leaf samples were collected, oven dried and powdered and analyzed for macro and micro nutrients using standard procedures.

4.2.6.1 Nitrogen, Potassium and Phosphorous

Nitrogen, potassium and phosphorous status of the leaf at bunching stage and at harvest was statistically analyzed and depicted in the table 21.

Soil ameliorants showed significant superior effect on the nitrogen content in the leaf with superior nitrogen content reported in all treatments over control both at bunching stage and harvest of the crop. Among the treatments T_{10} (gypsum + silica in 3 splits) recorded the maximum nitrogen content at both stages. At bunching stage T_{10} (4.62 %) showed the highest nitrogen content followed by T_6 (3.50 %). At harvest T_{10} (gypsum and silica in 3 splits) reported highest nitrogen content (4.06 %) which was 163 % superior over the nitrogen content in control.

With respect to the leaf potassium content treatments showed significantly superior results over control at bunching stage and harvest of the crop. Considering the various treatments, T_{10} (gypsum and silica 3 splits) reported with maximum potassium content at both stages. At bunching the treatments T_{10} (2.33 %), T_9 (2.32 %), T_6 (2.25 %), T_8 (2.24 %), T_3 (2.21 %), T_7 (2.17 %), T_4 (2.16 %), T_1 (2.14 %) were on par with T_{10} (2.33 %) recorded highest potassium content in the leaves. Similar results were recorded at harvest with T_{10} (1.45 %) followed by T_9 (1.31 %). Treatments T_{10} (gypsum and silica 3 splits) and T_9 (dolomite and silica 3 splits) showed 85 % and 65 % higher potassium content in the leaves respectively over control.

Soil ameliorants showed significant effect on phosphorous content in the leaf at bunching stage of the crop. All treatments showed higher phosphorus content over control. At bunching treatments T_{10} (0.22 %), T_9 (0.20 %), T_4 (0.20 %), T_1 (0.20 %), T_6 (0.19 %) were on par. Highest phosphorus content of 0.22 % was reported in T_{10} (gypsum and silica in 3 splits). Leaf phosphorus content in T_{10} was increased by 83 % over control. At harvest the treatments found to be non-significant with respect to phosphorus content. However highest phosphorus content was recorded in T_{10} (0.183 %).

Table 21: Effect of soil ameliorants on the nitrogen, phosphorous and potassium content of banana leaves

Treatments	Nitrogen (%)		Potassium (%)		Phosphorus (%)	
	At Bunching	At harvest	At Bunching	At harvest	At Bunching	At harvest
T_1	2.10	2.10	2.14	1.18	0.20	0.15
T_2	1.54	1.82	2.05	0.94	0.16	0.14
T_3	1.82	1.96	2.21	0.86	0.19	0.12
T_4	2.66	2.38	2.16	0.85	0.20	0.13
T_5	3.08	2.24	1.77	1.18	0.17	0.13
T_6	3.50	2.52	2.25	1.00	0.19	0.13
T_7	3.22	2.66	2.17	1.02	0.13	0.13
T_8	3.08	2.54	2.24	0.98	0.15	0.13
T_9	2.52	2.38	2.32	1.31	0.20	0.12
T_{10}	4.62	4.06	2.33	1.45	0.22	0.18
T_{11}	1.40	1.54	1.45	0.79	0.12	0.11
SEm (±)	0.09	0.07	0.07	0.06	0.01	0.01
CD (0.05)	0.28	0.22	0.22	0.20	0.03	NS

NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st, 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.6.2 Calcium, Magnesium and Sulphur

The leaf samples were collected at bunching stage and at harvest of the crop. The leaves were analyzed for calcium, magnesium and sulphur content in the leaves. The obtained values were statistically analyzed and presented below in table no 22.

It was observed that in all treatments were ameliorants were added showed significantly superior calcium content over control both at bunching stage and at harvest. Among the treatments T_{10} (gypsum and silica 3 splits) recorded highest calcium content at both the stages. At bunching treatments T_{10} (0.0286 %), T_4 (0.0282 %), T_3 (0.0260 %), T_7 (0.0250 %), T_8 (0.0240 %), T_2 (0.0230 %), T_6 (0.0220 %), T_9 (0.0210 %) were on par with T_{10} (0.0286 %) showing highest calcium content. Similarly at harvest T_{10} (0.0380 %) reported highest calcium content followed by T_2 (0.0300 %). It was observed that treatments T_{10} (gypsum and silica 3 splits) and T_2 (lime and silica basal) showed 128 % and 80 % more calcium content respectively over control.

At bunching stage soil ameliorants did not show any significant influence on magnesium content of the leaves. However T_9 (dolomite and silica 3 splits) reported highest magnesium content of 0.022 %. At harvest the treatment showed significant superior results on magnesium content in the leaves over control. Among the treatments T_9 (0.022 %), T_8 (0.016%) and T_2 (0.012%) were on par. Highest magnesium was reported in T_9 (0.022 %) followed by T_8 (0.016%) and T_2 (0.012%).

At bunching stage and at harvest ameliorants showed significant effect on the leaf sulphur content at bunching and harvest of the crop. All treatments showed significantly superior results over control. Among the various treatments, treatment containing gypsum and silica in 3 splits, T_{10} recorded highest sulphur content at both stages. At bunching stage T_{10} (0.240 %) T_7 (0.215%), T_5 (0.195 %), T_3 (0.195 %) were on par with T_{10} (0.204 %) showing higher sulphur content Similar results were recorded at harvest with T_{10} (0.360 %) recorded with highest sulphur content followed by T_6 (0.250 %).

Table 22: Effect of soil ameliorants on calcium, magnesium and sulphur content of banana leaves

Treatments	Calcium (%)		Magnesium (%)		Sulphur (%)	
	At Bunching	At harvest	At Bunching	At harvest	At Bunching	At harvest
T_1	0.0210	0.0200	0.019	0.010	0.175	0.150
T_2	0.0230	0.0300	0.021	0.016	0.176	0.125
T_3	0.0260	0.0246	0.021	0.012	0.195	0.125
T_4	0.0282	0.0266	0.015	0.007	0.165	0.171
T_5	0.0200	0.0220	0.019	0.008	0.195	0.125
T_6	0.0220	0.0180	0.019	0.011	0.181	0.250
T_7	0.0250	0.0260	0.018	0.010	0.215	0.133
T_8	0.0240	0.0240	0.017	0.018	0.160	0.110
T_9	0.0210	0.0240	0.022	0.022	0.173	0.065
T_{10}	0.0286	0.0380	0.015	0.012	0.240	0.360
T_{11}	0.0200	0.0166	0.007	0.001	0.115	0.085
SEm (±)	0.0010	0.0020	0.003	0.001	0.017	0.045
CD (0.05)	0.0070	0.0060	NS	0.003	0.055	0.136

NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st, 2nd and 4thmonth after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.6.3 Iron, Manganese and Zinc

Iron, manganese and zinc content in leaves was recorded at bunching stage and at harvest and was presented in the table 23.

In acid soils higher iron availability forces the plant to absorb more iron which leads to iron toxicity. Addition of soil ameliorants reduced the iron toxicity by reducing iron uptake in plants. With respect to the iron content in leaves the concentration decreased from bunching stage to harvest except in the control. All treatments showed significantly lower iron content over control. Among the treatments T_{10} (gypsum + silica 3 splits) showed the lowest iron content at all stages. At bunching stage there was no significant effect on the iron content with T_{10} (508.00 mg/kg) recorded the lowest iron content in the leaves. At harvest the treatments showed significant effect on iron content with T_{10} (164.82 mg/kg), T_4 (260.00 mg/kg), T_6 (266.300 mg/kg) were on par with T_{10} (gypsum and silica 3 splits) recorded lowest iron content of 164.82 mg/kg in the leaves.

Addition of soil ameliorants in acid soils mitigated manganese toxicity in leaves by reducing the uptake of manganese ion from soil. Manganese concentration in the leaves increased from bunching to harvest. At bunching stage ameliorants did not show any significant effect on manganese concentration in leaves. All treatments were ameliorants were added showed lower manganese content over control. Among the treatments lowest manganese content was recorded in T_{10} (gypsum + silica in 3 splits) with 1297.50 mg/kg. At harvest ameliorants showed significant effect with lower manganese content reported in all treatments over control. Among the treatments T_{10} (1616.10 mg/kg), T_3 (1791.95 mg/kg), T_8 (1918.20 mg/kg) T_9 (2145.90 mg/kg) T_7 (2357.50 mg/kg) T_6 (2402.10 mg/kg) were on par with T_{10} (gypsum + silica 3 splits) recorded lowest manganese content of 1616.10 mg/kg in the leaves.

Data revealed that treatments showed significantly superior result on the zinc concentration in the leaves over control at bunching stage and harvest of the crop. Zinc concentration significantly decreased from bunching stage to harvest.

Among the treatments T_{10} (gypsum +silica in 3 splits) recorded highest zinc content. At bunching stage T_{10} (61.20 mg/kg), T_5 (58.63 mg/kg), T_9 (56.80 mg/kg) T_8 (56.20 mg/kg), T_7 (52.30 mg/kg) T_6 (51.90 mg/kg) were on par with highest zinc content recorded in T_{10} (61.20 mg/kg). Similarly at harvest T_{10} (17.57 mg/kg) recorded highest zinc content followed by T_3 (17.51 mg/kg), T_5 (16.94 mg/kg), T_7 (16.02 mg/kg) and T_9 (14.24 mg/kg).

Table 23: Effect of soil ameliorants on iron, manganese and zinc content of banana leaves

Treatments	Iron (mg/kg)		Manganese (mg/kg)		Zinc (mg/kg)	
	At Bunching	At harvest	At Bunching	At harvest	At Bunching	At harvest
T_1	636.00	414.30	1692.00	2785.00	50.50	7.89
T_2	836.00	566.30	1873.00	2815.20	45.90	11.65
T_3	650.00	586.20	1713.00	1791.95	50.10	17.51
T_4	825.00	260.00	1943.00	2861.00	39.80	9.94
T_5	658.00	490.80	2015.00	2843.00	58.63	16.94
T_6	745.00	266.30	1695.00	2402.10	51.90	11.79
T_7	793.00	444.80	1702.00	2357.50	52.30	16.02
T_8	648.00	366.50	1345.00	1918.20	56.20	7.11
T_9	751.00	600.30	1635.00	2145.90	56.80	14.24
T_{10}	508.00	164.82	1297.50	1616.10	61.20	17.57
T_{11}	918.00	1230.70	2072.00	2879.80	36.80	4.70
SEm (±)	84.80	67.24	326.27	290.89	3.62	1.57
CD (0.05)	NS	201.30	NS	858.16	10.68	4.63

NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite +

silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st, 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

4.2.6.4 Copper and Silicon

Copper and silicon content of the leaf was recorded at bunching stage and at harvest of the crop and were presented in the table 24.

Addition of soil ameliorants showed significantly influence on the leaf copper content both at bunching and at harvest. All treatments showed higher copper content over control. Among the treatments highest copper content was reported in T_{10} (gypsum and silica 3 splits) both at bunching and at harvest. At bunching stage T_{10} (129.71 mg/kg) recorded highest copper content in the leaves followed by T_9 (61.44 mg/kg). Similarly at harvest T_{10} (105.25 mg/kg) showing highest copper content which was 479 % superior over control.

Statistically analyzed data revealed that treatments showed significantly higher silicon content in the leaves over control. Among the treatments T_{10} (gypsum and silica 3 splits) recorded highest silicon content both at bunching and harvest of the crop. At bunching stage T_{10} (0.185 %) recorded highest leaf silicon content followed by T_7 (0.183 %) and T_3 (0.177). Similarly at harvest T_{10} (0.235 %) recorded highest silicon content followed by T_6 (0.182 mg/kg). It was observed that T_{10} (gypsum and silica 3 splits) showed 475 % higher silicon content over control.

Table 24: Effect of soil ameliorants on copper and silicon content of banana leaves

	Copper (ppm)		Silicon (%)	
Treatments	At Bunching	At harvest	At Bunching	At harvest
T_1	23.60	21.75	0.147	0.100
T_2	24.50	22.75	0.155	0.135
T_3	29.00	23.65	0.177	0.060
T_4	26.60	82.65	0.172	0.067
T_5	32.70	61.85	0.130	0.075
T_6	34.00	31.13	0.127	0.182
T_7	45.28	41.15	0.183	0.115
T_8	54.12	47.89	0.171	0.105
T_9	61.44	50.38	0.135	0.055
T_{10}	129.71	105.25	0.185	0.235
T_{11}	22.20	18.15	0.102	0.040
SEm (±)	1.15	0.65	0.003	0.002
CD (0.05)	2.33	1.92	0.005	0.004

NS- Non Significant

T_1: Basal application of calcium silicate; T_2: Basal application of lime + silica; T_3: Basal application of dolomite + silica; T_4: Basal application of gypsum + silica; T_5: Lime + silica in 2 splits at 1st and 2nd month after planting; T_6: dolomite + silica in 2 splits at 1st and 2nd month after planting. (MAP); T_7: gypsum + silica in 2 split at 1st and 2nd month after planting; T_8: Lime + silica in 3 split at 1st, 2nd and 4th month after planting; T_9: dolomite + silica in 3 split at 1st, 2nd and 4th month after planting; T_{10}: gypsum + silica in 3 split at 1st. 2nd and 4th month after planting; T_{11}: Application of lime as per KAU POP 2016. (Control)

Discussion

5. DISCUSSION

An Investigation entitled "Performance of non-conventional soil ameliorants in banana var. Nendran" was conducted to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health of banana with respect to availability of nutrients. The results obtained from the pot culture study and field experiment was discussed below

5.1 POT CULTURE EXPERIMENT

Pot culture experiment was conducted in Regional Agricultural Research Station (RARS) farm, Nileshwar. The objective was to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health with respect to availability of nutrients. The experiment was conducted in completely randomized design (CRD) consisting of 5 treatments and 4 replications in such a way that each replication constituted 4 plants. 20 kg soil was filled in each pot and 0.5g Nitrogen, 0.7g phosphorus and 0.25g potash were added. Then one week old suckers produced by micropropagation were planted. The treatments were T_1(basal application of Calcium silicate), T_2(Basal application of lime+ silica), T_3(Basal application of dolomite+silica), T_4(Basal application of Gypsum + silica) and a control maintained with basal application of lime as per KAU POP 2016. The biometric observations recorded were the plant height, number of leaves, root length, root diameter and root CEC were periodically recorded.

5.1.1 Influence of soil ameliorants on plant growth parameters

5.1.1.1 Pseudostem height and pseudostem girth

Application of soil ameliorants showed significant influence on the pseudostem height over the control. Among the treatments T_4 (gypsum and silica basal) recorded the highest plant height at all the 3 stages. At 1 MAP application of gypsum and silica recorded superior results followed by the addition of lime + silica and dolomite + silica. This might be due to the immediate action of lime and dolomite in neutralizing the surface acidity. Similar findings were reported by Sun *et al.* (2000). At 2 MAP action of dolomite decreases as solubility of dolomite was low over other ameliorants. At 3 MAP gypsum and silica got highest result which might be due to the action of gypsum in neutralizing the subsoil acidity which was not done by other ameliorants (Alva *et al.,* 1990; McLay and Ritchie, 1994). This might increases the availability and uptake of nutrients by plants and thus increases cell growth and cell division. Similar findings were reported by Aloka (2016) in black pepper that the application of gypsum increased the uptake of nutrients which enhanced the plant height. Silicon addition might also enhanced the growth of the plant similar findings were reported in rice by Padmaja and Verghese (1966)

Pseudostem girth at 45 cm showed significant difference among the treatments. Treatment T_4 (basal application of gypsum + silica) showed the highest pseudostem girth at 3 MAP followed by T_2 (lime and silica basal) because of the increased solubility of gypsum over other liming materials which helped in reducing subsoil acidy. The findings were in harmony with that of Shainberg *et al.* (1989). This might promotes increased uptake of N, P, K, Ca, S which inturn promoted cell growth and development. Similar findings were reported by Nasreen *et al.* (2007) in which he reported that application of gypsum increase the uptake of N,P,K, Ca, S which helped in enhancing the cell growth and cell division. This might contribute to increased pseudostem girth in plants.

5.1.1.2 Number of leaves

Numbers of leaves at different intervals were significantly superior with all treatments over control at all the 3 stages. It was observed that the basal application of gypsum and silica (T_4) recorded the higher number of leaves over the other treatments at all the 3 stages. At 1 MAP application of gypsum and silica basally (T_4) recorded superior number of leaves followed by treatments T_2 and T_3 respectively. Immediate action of lime and dolomite in ameliorating surface acidity in the initial stages might contribute to the increased leaf production in T_2 (lime + silica basal) and T_3(dolomite +silica basal) Similar results were reported by Sun *et al.* (2000) that application of lime helped in increasing pH in the surface soil. At 2 MAP action of dolomite in ameliorating soil acidity increased over lime as dolomite was less soluble which increased its action in later stages of the crop. At 3 MAP T_4

(addition of gypsum and silica basally) recorded superior results over the others. This might be because of the efficiency of gypsum in reducing subsoil acidity as gypsum was more soluble over other ameliorants. More over gypsum helped in improving the availability of Ca in soil (Jacob and Venugopal, 1993). Cachorro *et al.* (1994) reported that silicon addition improved the Ca uptake by the plant. Increased uptake of Ca by Si might promote the uptake of Ca by plants. Higher uptake of these Ca might contribute to the increased leaf production. It was in correlation with the findings of Chapman *et al.* (1965) that Ca was required for foliage production in sweet orange.

5.1.1.3 Root length and Root thickness/ Root diameter

Treatment showed significance increased root length and root diameter over control at 1 MAP, 2 MAP and 3 MAP. Among the treatments addition of gypsum and silica basal (T_4) recorded higher results in all the 3 stages. At 1 MAP T_4 (basal application of gypsum + silica) showed the highest root length and root diameter followed byT_2 and T_3. This could be due to the immediate ameliorating effect of lime and dolomite in mitigating surface acidity. At 2 MAP action of T_3 (dolomite+silica basal) increased over T_2 (lime +silica basal) this may be due to the low solubility of dolomite over lime which helped in increasing pH in later stages. But at 3 MAP T_4 (gypsum and silica basal) recorded superior results as gypsum was more soluble and helped in reducing sub soil acidity. Gypsum helped in increasing the soluble Ca^{2+} and hence reducing Al^{3+} toxicity (Jacob and Venugopal, 1993). This promoted wider coverage by the root in the soil. Increased calcium uptake helps in promoting cell growth and cell division which in turn promoted root growth (Reeve and Sumner 1972; Radcliffe *et al.,* 1986). Gypsum helped in increasing the plant available SO_4^{2-}ion in the soil which helped in reducing phosphorous fixation by exchangeable Al and increased P availability, which helped in increasing the root length and diameter. Thus gypsum addition might contributes to the increased root characters. Similar finding were reported by Farina *et al.*(2000a) that rooting environment was improved by the application of gypsum. Silicon addition might also influence the root growth. The findings were in harmony with the studies conducted by Sadanandan and Verghese (1968) in rice in which they reported that application of silicon in laterite soil increased the root growth in rice

5.1.1.4 Root CEC

Root CEC observed significantly higher for the treatments with respect to the control. At 3 MAP T_4 (basal application of gypsum + silica) reported the highest root CEC. This could be due to the addition of gypsum which helped in ameliorating subsoil acidy and thus increasing nutrient availability. Gypsum addition increased the availability and uptake of phosphorous and potassium by the plants (Nakayama *et al.,* 1987). More over silicon addition also helped in increasing the uptake of phosphorous and potassium (Ma and Takahashi, 1990 and Ling, 1999). The increased uptake of these nutrients might contribute to the increased cation exchange capacity of the roots. Similar findings were reported by Ram (1980) that increased uptake of potassium and phosphorus showed positive impact on the root CEC of crops like paddy and wheat.

5.2 FIELD EXPERIMENT

The field experiment was conducted out at Regional Agricultural Research Station (RARS) farm Nileshwar to study the effect of various non-conventional soil ameliorants on yield and quality of tissue culture banana var Nendran. The biometric observations were periodically recorded and the various soil, plant and fruit characteristics were analyzed. The experiment consisted of 11 treatments of which T_1 to T_4 was the basal application of calcium silicate, lime, dolomite, gypsum along with silica respectively, T_5 to T_7 was the application of lime, dolomite, gypsum along with silica in respectively in 2 splits at first and second month after planting and T_8 to T_{10} was the application of lime, dolomite, gypsum along with silica in respectively in 3 splits at first, second and fourth month after planting along with T_{11} application of lime as per KAU POP (2016) as the control.

5.2.1 Pseudostem height and Pseudostem girth

Soil ameliorants showed a positive influence on the vegetative characters of the crop. Pseudostem height and pesudostem girth was significantly affected by treatment application at 1 MAP, 3 MAP, 5 MAP and at harvest. Among the treatments T_{10} (gypsum and silica 3 splits) recorded higher plant height and plant girth at all the stages). At 1 MAP highest plant height was recorded in T_{10} (gypsum and silica in 3 splits) followed by T_3 (dolomite and silica basal) and T_2 (lime and silica basal). This could be due the spontaneous action of lime and dolomite in ameliorating surface acidity. At 3 MAP and at 5 MAP the action of dolomite increased over lime this could be due to low solubility of dolomite. At harvest T_{10} (gypsum and silica 3 splits) recorded the highest plant height followed by T_7 (gypsum and silica 2 splits).This could be due to presence of gypsum. Gypsum helped in ameliorating subsoil acidity by promoting deeper penetration of Ca ions into deeper layers. O' Brien and Sumner, (1988) similarly reported that phosphogypsum application reduced soil acidity by increasing calcium absorption. Moreover gypsum addition might increase the availability and uptake of nutrients like N, P, K and Ca which lead to the higher plant height. The study was in line with the conclusions of Aloka (2015) in which he reported that gypsum addition increased the uptake of N, P, K and Ca which enhanced the plant height in black pepper. Silicon addition also enhanced the uptake of N, P, K (Jawahar and Vaiyapuri 2008) which might have positively influenced the pseudostem height. With respect to the pseudostem girth at 90 cm T_{10} recorded higher pseudostem girth with respect to other treatments. Application of gypsum might have helped in acidity correction by which enhanced the uptake of N, P, K, Ca which in turn promoted cell growth and development. Similar findings were reported Nasreen *et al.* (2007) in which he reported that application of gypsum increased the uptake of N, P, K, Ca which helped in enhancing the cell growth and cell division. This might contribute to increased pseudostem girth at 90 cm

5.2.2 Number of leaves, Number of Functional leaves and number of suckers at harvest

Application of soil ameliorants showed significant effect on the number of leaves and number of functional leaves at all the stages. At 1 MAP T_{10} (gypsum + silica in 3 split) recorded the maximum number of leaves followed by T_8 (Lime and silica 2 splits). This might be due to the high solubility of lime which favored the immediate action of lime in reducing soil acidity. At 3 MAP and 5 MAP action of lime decreased and action of calcium silicate and dolomite increase respectively as both of them showed less solubility hence showed ameliorating action in later stages of the crop. Watanabe *et al.*(1997) reported that application of calcium silicate reduced soil acidity and improved nutrient uptake. At harvest T_{10} (gypsum + silica in 3 split) showed highest number of leaves followed by T_7 (gypsum and silica in 2 splits). It was in correlation with the findings of Chapman *et al.* (1965) in sweet orange. It was also observed that T_{10} (gypsum + silica in 3 split) recorded the maximum number of functional leaves. This could be due to the application of gypsum. Gypsum was more soluble and it helped in mitigating subsoil acidity by deeper penetration of calcium in soil. Similar findings were reported by Jacob and Venugopal (1993) that gypsum increased Ca availability in soil. Another possible reason was the addition of Si. Cachorro *et al.* (1994) also reported that Si addition improved the Ca uptake by the plant. Higher uptake of these Ca might contribute to the increased leaf production. . It was in correlation with the findings of Chapman *et al.* (1965) that Ca is required for foliage production in sweet orange. Soil ameliorants did not produce any significant effect on sucker production at harvest.

5.2.3 Yield attributes

Yield in bananas is a function of bunch weight and number of plants per hectare. Hence, any nutrient management study should aim at producing maximum bunch weight, so that, the productivity could be enhanced reasonably (Kumar and Kumar, 2008).

In the present study the application of ameliorants showed positive and significant influence on the yield character like bunch weight, number of hands per bunch number of fingers per hand.

Number of hands per bunch, number of fingers per hand, average weight of the bunch, were significantly affected by application of soil ameliorants and treatments obtained superior yield over control. Among the treatments T_{10} (gypsum

+ silica in 3 split) produced the maximum results in each of the parameters with a yield increment of 97 % over the control. Among the treatments higher yield attributes were produced in plants applied with gypsum followed by plants applied with dolomite. It might be the higher solubility of gypsum over dolomite which helped in mitigating subsoil acidity. By increasing the pH of the soil gypsum might enhance the availability of various nutrients in the soil. Gypsum positively influenced sulphur availability in soil (Summer *et al.*,1986 and Shainberg *et al.*, 1989).Increased uptake of sulphur might also contributes to higher number of hands per bunch and higher number of fingers per hand. Similar results were reported in banana by Mostafa and Kader (2006) that increased uptake of sulphur showed positive impact on the number of hands and finger number. Which might result in the increased bunch weight in T_{10} (gypsum and silica in 3 splits).

Gypsum addition also improved the Ca availability in soil as gypsum was soluble in soil (Shainberg *et al.*, 1989). This might help in higher uptake of Ca which might create a favorable soil environment by reducing acidity and it might have helped in protecting the root plasma membrane from the deleterious effects of H^+ (Epstein and Bloom, 2005). Besides, the role played by Ca as a regulator ion in the translocation of carbohydrates through its effect on cells and cell wall (Bennett, 1993) might have led to the higher fruit yield. Nambiar *et al.* (1978) also reported on the effect of graded doses of lime on growth and yield of banana var. Zanzibar at Kannara also reported that number of hands per bunch, number of fingers per hand and bunch weight was increased by lime application in grades dosses.

Yield attributes of banana might also be influenced by the increased absorption of micronutrients. T_{10} (gypsum and silica 3 splits) recorded with higher uptake of Zn and Cu. Which might be due to the ameliorating action of gypsum in acid soil. Increased uptake of these micronutrients might increase the bunch weight of banana by enhancing the accumulation and mobilization of photo assimilates into the fruits which might increase the cell growth and expansion. This might contribute to higher bunch weight. The findings were in line with the conclusions of Premalatha (2016) in nendran banana.

Moreover increased absorption of N, P, K nutrients produced higher number of leaves in T_{10} (gypsum +silica 3 splits). As the leaf number increased the photosynthesis activity also increased which might resulted in the highest yield in $T_{10}$by producing higher number of hands per bunch and higher number of finger per hand. This might contribute to increased bunch weight in T_{10}. Silica addition might also increase the bunch weight of banana. The findings were in harmony with the conclusions of Hanumanthaiah *et al.* (2015) that silica addition increased the fruit yield and quality of banana c.v Neypoovan.

While considering the finger characters like finger length, finger breadth and average weight of the fingers, the soil ameliorants produced significant effect on treatments. Among the treatments T_{10} (gypsum +silica in 3 splits) recorded highest finger length. It might be due to the increased supply of sulphur by gypsum. Due to the higher solubility of gypsum over other liming materials it helped in mitigating subsoil acidity by enhancing the availability of Ca and SO_4^- in the soil (Sumner *et al.*,1986; Shainberg *et al.*, 1989). This might favored higher sulphur uptake. This might help in increasing the cell elongation and formation of intercellular space in fruits. Similar findings were reported by Kumar and Kumar (2007) that sulphur addition increased finger length of banana. With respect to the finger breadth and average weight of the fingers treatments applied with gypsum showed superior results followed by dolomite treated plants. Among the treatments, T_9 (dolomite + silica in 3 splits) recorded the maximum finger breath and finger weight. This could be due to the increased availability of K in soil. Dolomite addition helped in increasing pH of the soil there by increasing K availability in soil. Blaszcyk *et al.* (1986) also reported that liming increased potassium availability in topsoil.Silicon addition improved the uptake of K by promoting H-ATPase in the membrane (Liang 1999).Higher K uptake might help in promoting cell enlargement thus increasing finger breath and weight of the fruit. The findings were in harmony with studies of Bhargava *et al.* (1995). He reported that potassium helped in activating various enzymes that promoted cell enlargement. Another possible reason for increased fruit weight might be due to the decreased finger number and yield which might result in the assimilation of nutrients to the available fruits thus increasing in the average fruit weight.

Treatments showed significantly superior results on the days to bunch emergence, days to harvest and days to ripening over control. It was observed that gypsum applied treatments showed superior results followed by dolomite applied treatments. Among the treatments T_{10} recorded the minimum days for bunch emergence, days to harvest and days for ripening. It could be due to the increased Zn uptake in T_{10} (gypsum +silica 3 splits). Mitigation of subsoil acidity by gypsum as gypsum showed higher solubility over dolomite, which might enhance the Zn availability. Curcunrr(1988) also reported that gypsum application enhanced the zinc content in the leaves of brussels sprout. Moreover Zn content might be increased by silicon addition. It was reported that zinc content in the root and shoot of rice was enhanced by silicon application (Bridgit, 1999). Zinc might have helped in enhancing the enzymatic reaction involved in cell growth and division which promoted faster growth and maturity of the crop. Similar findings were reported by Supriya and Bhattacharyya (1993), Yadav and Patel(2013), Ghanta and Mitra (1993) in banana cv. Giant Governor, Yadav *et al.* (2010) in banana cv. Grand Naine, Babu and Singh (2002) in mandarin orange and Yadlod and Kadam (2008c) in banana cv. Ardhapuri.

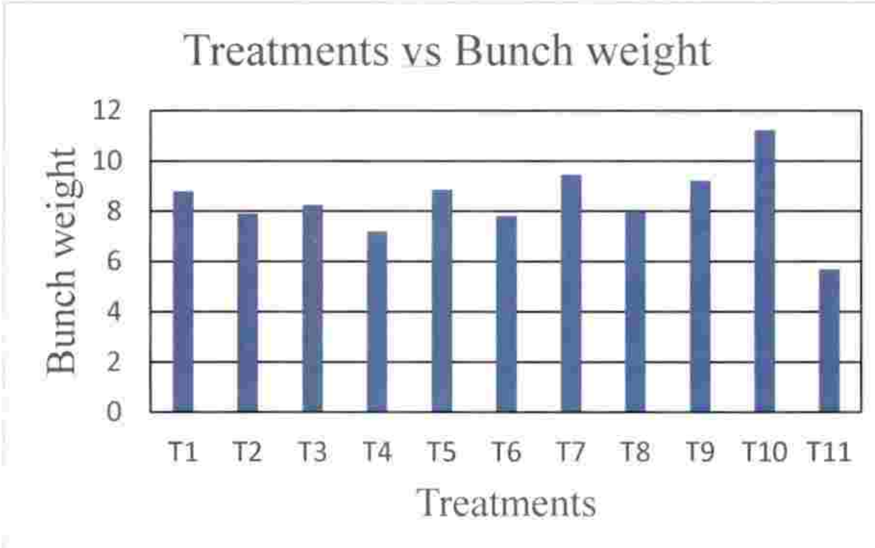

Fig 3: Effect of soil ameliorants on bunch weight of banana

5.2.4 Fruit characteristics

In fact, in high value crops like banana, quality standards have become the most important factor influencing monetary yield and farmers income. Any management system should aim to produce quality fruits, besides maximizing productivity (Kumar and Kumar, 2007).

In the present study on effect of soil ameliorants on fruit characteristics of tissue culture banana var. Nendran was examined. The various quality parameters like titrable acidity, total soluble sugar (TSS), reducing sugar, non-reducing sugar, keeping quality of the fruits at ambient condition were significantly influenced by the treatments.

Soil ameliorants showed significant effect on the titrable acidity percentage of the fruits. Usually fruits with lesser acidity are preferred and the treatments showed a reduction in titrable acidity in comparison with the control T_{11}. Among the treatments T_{10}(gypsum + silica in 3 split) recorded the lowest tirtrable acidity. Application of gypsum showed a better reduction in fruit acidity followed by dolomite and lime as gypsum was highly soluble which helped in ameliorating soil acidy. Moreover the Ca uptake was more observed in T_{10} (gypsum + silica in 3 split) as gypsum increased Ca availability in soil. Rampim and Lana (2015) similarly reported that gypsum caused an increase in the uptake of calcium This calcium might have reduced the acidity of the fruit as it neutralizes or precipitates the organic acids present in the fruit and utilizing it as a substrate for the respiratory and other metabolic activities. Similar results were reported in aonla by Tripati and Shukla (2011).

Application of soil ameliorants showed significant effect on the TSS content. T_{10}(gypsum + silica in 3 split) recorded the maximum TSS content followed by T_9 which could be due to the increased sugar production in the fruit. In T_{10} the uptake of potassium was higher due to the subsoil acidity correction by gypsum which enhanced the K availability in soil. This potassium uptake might enhanced the sugar production in fruits. The results were in harmony with findings of Bhavya (2010) in grapes.

Treatments showed significant effect on the reducing and non reducing sugar content. Among the treatments T_{10} (gypsum + silica in 3 split) recorded the maximum sugar contents. The increased reducing sugar might be due to formation and translocation of carbohydrates which helped in improving fruit quality. Similar findings were reported by Pathak and Mitra, (2008). Gypsum helped in mitigating subsoil acidity thereby increasing the availability of calcium and sulphur (Sumner *et al.*, 1986; Shainberg *et al.*, 1989). Increased Ca and S uptake was observed in T_{10} (gypsum + silica 3 splits). Calcium played an important role in the activation of amylase enzyme thereby helping in converting starch to sugar on ripening, thus helped in improving the sugar content (Tripathi and Shukla, 2011). Sulphur helped in the activation of anabolic enzymes which help in polymerization of carbohydrate to starch and on ripening these starch get converted to sugar (Kumar and Kumar, 2008). Since the reducing sugar constituted the major portion of the total soluble solids the maximum non reducing sugar was reported for the treatment T_{10} (gypsum + silica in 3 split). Similar finding were reported by Bhavya (2010) in blue grapes.

Application of soil ameliorants showed significant effect on the keeping quality of the fruit. Among the treatments T_{10}(gypsum + silica in 3 split) recorded the highest shelf life this might be due to the action of gypsum and silica in decreasing the rate of respiration and transpiration, restricting ethylene production and accumulation during fruit production. Gypsum application improved the potassium availability in the soil (Brien and Sumner, 1988). Among the treatments, T_{10} (gypsum +silica 3 splits showed highest K uptake. the potassium might improve the fruit quality by decreasing the respiration and restricting ethylene accumulation. Similar results were obtained by Kaluwa *etal.* (2010). Silicon also helped in restricting ethylene formation by forming complexes with the organic compounds in the cell wall and restricts the action of degrading enzymes (Babak and Majid, 2011).

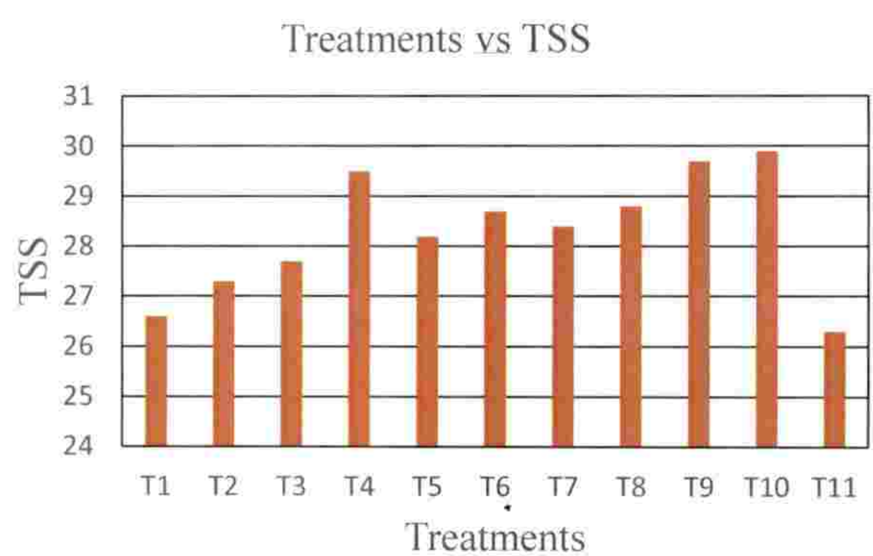

Fig 4: Effect of soil ameliorants on fruit TSS content of ripened banana

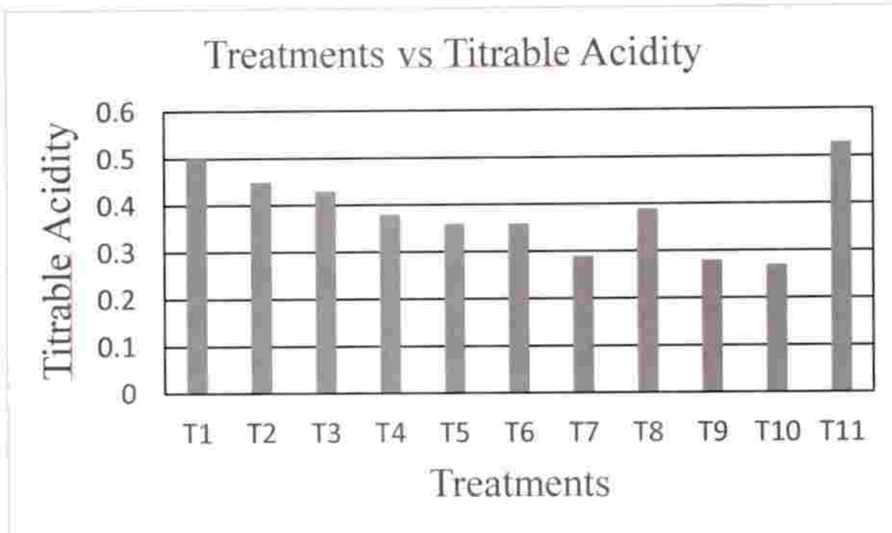

Fig 5: Effect of soil ameliorants on titrable acidity of ripened banana fruit

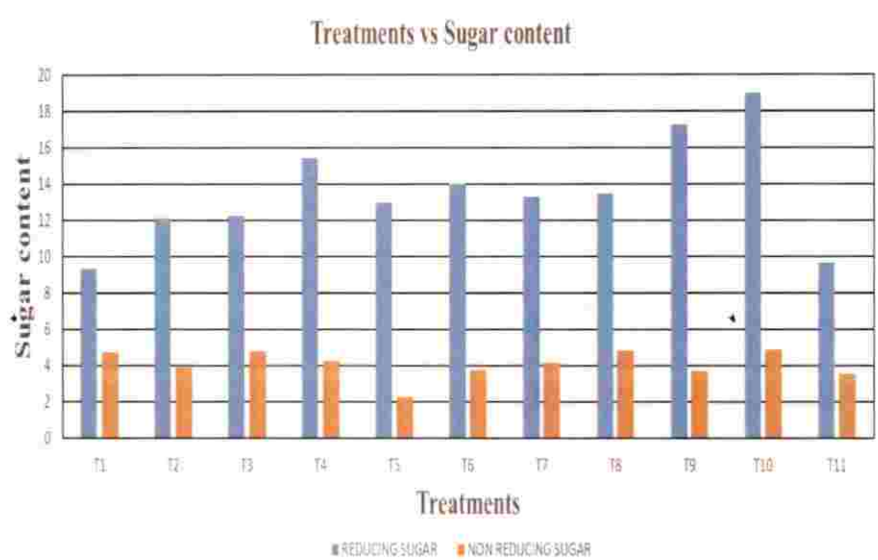

Fig 6: Effect of soil ameliorants on reducing and non-reducing content of ripened banana fruit

5.2.5 Effect of soil ameliorants on soil characteristics

5.2.5.1 pH and Electrical conductivity

Data given on the table showed there was a significant increase in the soil pH in the treatments than in control at 6 MAP with respect to the initial soil analysis. Among the treatments T_{10} (gypsum + silica in 3 split) recorded the highest pH followed by T_2 (lime and silica basal) and T_9 (Dolomite and silica in 3 splits). This might be due to addition of gypsum. Addition of lime and dolomite helped in ameliorating surface acidity but it had limited role in mitigating subsoil acidity as it was less soluble (Sun *et al.*, 2000). As gypsum was more soluble it might help in increasing the subsoil pH by precipitating toxic aluminium in soil by promoting the movement of Ca into the deeper layers (Sumner *et al.*, 1986 and shainberg *et al.*, 1989). Moreover gypsum addition might decreases the soil acidity by decreasing the activity of Al by increasing the concentration of $AlSO_4^+$ in the soil. The findings were in harmony with the findings of Sun *et al.* (2000).

Application of soil ameliorants showed significant increase in the EC than in control at 6 MAP and at harvest. Among the treatments T_{10} (gypsum + silica in 3 split) recorded the highest EC followed by T_7 (gypsum and silica 2 splits). This could be due to correction of soil acidity by ameliorants. Addition of gypsum showed higher results over others due to the low solubility of lime and dolomite in soil. Shainberg *et al.* (1989) reported that gypsum was more soluble than lime. Moreover addition of lime and dolomite helped in ameliorating topsoil acidity only gypsum showed greater impact on reducing subsoil acidity.It was in line with the studies of Sun *et al.*(2000). Thus gypsum addition increased the availability of soluble salts in the later stages of the crop. The findings were in harmony with the conclusions of Rampim and Lana (2015). He reported that application of gypsum increased the Ca^{2+}, basic exchangeable cations in the soil which might helped in increasing the electrical conductivity of soil.

5.2.5.2 Cation exchange capacity and Organic matter

The initial CEC of soil was very low with a CEC of 2.413 $Cmolkg^{-1}$ and at 3 MAP, 6 MAP and at harvest CEC increased significantly. Among the treatments T_{10} (gypsum + silica 3 splits) recorded highest CEC. At 3MAP the treatments were on par of which T_{10} (gypsum + silica in 3 splits) showed highest cation exchange capacity. This might be due to the immediate action of the soil ameliorates in reducing topsoil acidy But at 6 MAP the action of dolomite increased over lime and calcium silicate this might be due to the lesser solubility of dolomite thus showing its ameliorating activity in the later stage of the crop. At harvest T_{10} (gypsum and silica in 3 splits) recorded the highest CEC followed by T_8 (dolomite and silica in 3 split). The increased solubility of gypsum might helped in reducing subsoil acidity by deeper movement of Ca and SO_4^{2-} ions. The findings were in line with research done by Ismail *et al.* (1993) and Toma *et al.* (1999). Moreover gypsum addition might increase the sum of basic cations in the soil. Hence improving the CEC of soil. Similar findings were reported by Rampim and Lana (2015) that the application of gypsum cause an increase in the CEC of soil.

At harvest of the crop organic carbon content significantly increased over control with T_{10}(gypsum +silica in 3 spit) recorded the highest value this might be due to the increased production of So_4^{2-}ions in the soil by the addition of gypsum. Similar finding were reported by Da Costa *et al.* (2016) that phosphogypsum improved the carbon content in the soil profile.

5.2.5.3 Available Nitrogen, Phosphorus and Potassium

Treatments showed significant higher available nitrogen content than control at all the 3 stages of the crop. At 3 MAP treatmentsT_{10}, T_4, T_6, T_5, T_3were on par. Application of gypsum recorded higher results followed by lime addition this could be due to the immediate action of lime in mitigating topsoil acidity as lime was soluble in soil. At 6 MAP dolomite showed superior results over lime due to the low solubility of dolomite which might reduce its action in the early stages. Finally at harvest T_{10} (gypsum + silica 3 splits) showed superior result. Due to the increased solubility of gypsum over other liming materials, addition of gypsum might reduce the subsoil acidity by enhanced by the leaching of Ca in the soil. This increased pH might contribute to increased available nitrogen in soil. Similar findings were reported by Aloka (2015) that the sole application of gypsum increases nitrogen content by enhancing the leaching of Ca in the soil. Another possible reason might be the addition of silica. Ma and Takahashi (2002) also reported that application of silicon increased nitrogen availability in soil

Soil ameliorants showed significant effect at 6 MAP and at harvest with respect to the available phosphorous in soil. At 6 MAP T_{10} (gypsum and silica in 3 splits) recorded higher phosphorous availability followed by T_9 (dolomite and silica 3 splits). This could be due to the increased activity of dolomite in neutralizing soil acidity as dolomite was less soluble it starts its ameliorating action in the later growth stages of the crop. At harvest of the crop, T_{10} (gypsum and silica in 3 splits) recorded higher phosphorous availability. It could be due to the reduction in subsoil acidity by gypsum. Addition of gypsum might reduce the fixation of P with Fe and Al instead it promotes the precipitation of P with Ca, resulting in the formation of calcium phosphate. This calcium phosphates disintegrates by the microbial action to release plant available phosphorous into the soil. Similar finding was reported by Phillips *et al.* (2000). Increased phosphorous availability might also be due to the addition of silica to the soil.This might be due to the replacement ofphosphate anion $[HPO_4]^{2-}$from aluminum and iron phosphates by the anion monosilicic acid $[Si(OH)^3]^-$ thereby increasing the solubility of phosphorus. Similar finding were reported by Subramanian and Gopalswamy (1990).

With respect to the available potassium content there were significant superior results in treatments than in control at harvest of the crop. Treatment T_{10} (gypsum+ silica in 3 splits) recorded the highest potassium content. This might be due to the efficiency of gypsum in ameliorating subsoil acidity in the harvest stage of the crop. Sumner (1970) similarly reported that gypsum was more soluble than lime and was used in neutralizing subsoil acidity. Increased pH might enhance the availability of potassium in the soil. Brien and Sumner (1988) also reported that addition of phosphogypsum increased potassium availability in soil. Silicon addition might also influences the potassium availability as silicon addition enhanced the reduction of Fe and Al in acid soils, resulting in the production of hydrogen ions. These hydrogen ions helped in releasing the potassium from the exchangeable sites to the soil solution. Similar findings were reported by Patrick and Mikkelsen (1971).

5.2.5.4 Available Calcium, Magnesium and Sulphur

Application of soil ameliorants caused an increase in the available calcium content in soil. Calcium content of the treatments was significantly increased over control at all stages. At 3 MAP, 6 MAP and at harvest T_{10} (gypsum + silica in 3 splits) recorded the highest calcium content. At 3 MAP treatments with lime and silica showed greater calcium content over dolomite and silica this could be due to the increased solubility of lime over dolomite. Moreover lime showed immediate action in mitigating topsoil acidity (Sun *et al.,* 2000). At 6 MAP and at harvest treatment with gypsum and silica in 3 splits (T_{10}) recorded higher calcium availability. This could be due to the incorporation of Ca^{2+} by gypsum which helped in reducing Al^{3+} toxicity. The findings were in line with that of Toma *et al.* (1999). Moreover increased solubility of gypsum enhanced the availability of calcium in the soil. The findings were in line with the conclusions of Ismail *et al.*,(1993). He reported that gypsum application improved the calcium concentration in the soil. Silicon addition might be one of the other reason which enhanced the calcium content in the soil. Work conducted by Takijima *et al.* (1959) in rice also reported that application of silicon enhanced the calcium uptake in soil.

Soil available magnesium was significantly influenced by the application of the ameliorants. T_9 (dolomite+ silica in 3 splits) recorded the highest magnesium content at all the 3 stages of the crop. At 3 MAP treatments with dolomite and silica in 3 splits recorded higher magnesium availability in soil which was on par with T_1, T_3, T_4 T_5, T_6. This might be due to the increase in the availability of Mg in the soil as dolomite is a good source of Mg. Similar findings were reported by Cristancho *et al.*(2014) in oil palm. Silicon addition might also enhanced the available magnesium in the soil. Takijima *et al.* (1959) in rice reported that application of silicon increases Mg uptake in rice.

Statistically analyzed data showed that there were significant effect on the treatment with respect to available sulphur content in the soil at 3 MAP, 6 MAP and at harvest. At 3 MAP application of gypsum and silica in 3 splits (T_{10}) recorded the highest available sulphur followed by T_7,T_9 and T_1 and were on par Dolomite applied treatments (T_3,T_6,T_9)showed lesser sulphur availability compared to gypsum applied treatments (T_4,T_7,T_{10}) as dolomite showed low ameliorating power as it was less soluble. Similar trend was observed at 6 MAP. At harvest T_{10} (gypsum and silica in 3splits) recorded higher sulphur content which was on par with T_1,T_2,T_3,T_5,T_6,T_7,T_8 and T_9 This might be due to high solubility of gypsum which promoted the movement of S into the deeper layers.These finding were in harmony with the findings of Sumner *et al.* (1986) and Shainberg *et al.* (1989) that gypsum was more soluble than lime and enables faster movement of $S0_4^{2-}$ in the soil.

5.2.5.5 Available Iron, Manganese and Zinc

Application of soil ameliorants helped in significantly reducing iron toxicity at harvest of the crop. Among the treatments T_{10} (gypsum + silica in 3 splits) recorded the lowest available iron content at harvest. It was observed that gypsum applied treatments T_{10} and T_7 showed better results than dolomite applied treatment. Higher solubility of gypsum might have promoted the lateral migration of calcium and magnesium in the subsoil region thus decreasing the exchangeable and total acidity in the soil. The findings were supported by Moralli *et al.* (1971).Bertic *et al.* (1988) also reported that liming at higher rate help in mitigating iron toxicity. Silicon addition might have also helped in alleviating iron toxicity by increasing the oxidizing power of the root and convert ferrous iron to insoluble ferric iron. Similar findings were reported by Wang *et al.* (1994) that silicon addition convert ferrous form of iron into insoluble ferric form and helped in decreasing Fe uptake thus reducing soil acidity.

Manganese toxicity was highly prevailed in lateritic soils. Application of treatments helped in reducing the manganese toxicity. Treatments showed significant effect at harvest of the crop. Among the treatments T_{10} (gypsum + silica in 3 splits) recorded the lowest manganese availability at harvest. Treatments T_{10}, T_3, T_4, T_8 and T_9 were on par. It was observed that gypsum applied treatments showed superior influence in reducing manganese toxicity than dolomite applied treatments. This could be due to better liming action of gypsum. Gypsum was highly soluble and it releases Ca in to the deeper layers of soil which in turn elevated the soil pH (Sun *et al.*, 2000). This might contributed to reduction in manganese toxicity in soil. Similar findings were reported by Hue *et al.* (2001) that increase in soil pH decreased the Mn solubility in soil. Another possible reason might be the addition of silica as silica addition mitigated Mn toxicity in soil. Song *et al.* (2009) also reported that silicon addition reduced manganese toxicity in metal contaminated soils.

Zinc availability in the soil did not show any significance at 3 MAP, 6 MAP and at harvest. Still there was an increase in the zinc availability from the initial level. Addition of the treatments T_{10} (gypsum + silica in 3 splits) recorded the highest zinc content in soil. This might be due to the ameliorating action of gypsum which increased the pH of the soil this might have enhanced the availability of zinc in the soil.

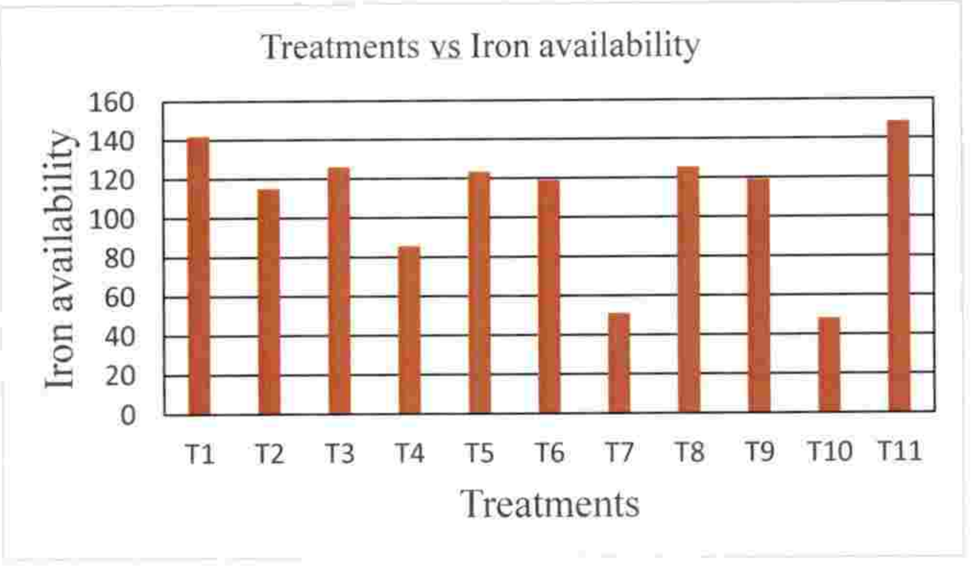

Fig 7: Effect of soil ameliorants on the available iron status of soil at various stages of field experiment

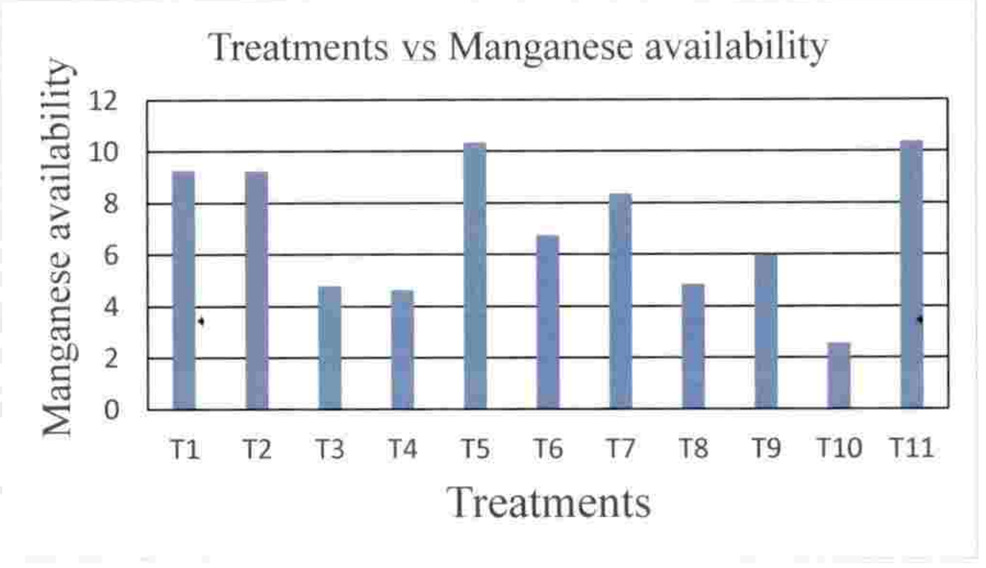

Fig 8: Effect of soil ameliorants on the available manganese status of soil at various stages of field experiment

5.2.5.6 Copper, Exchangeable Aluminium and Silicon

At 3 MAP soil ameliorants showed significant effect on availability of copper in soil. Application of treatment T_{10} (gypsum + silica in 3 split) showed the highest copper content. Addition of gypsum helped in mitigating soil acidity more over gypsum increased the availability of calcium (Ismail *et al.*, 1993). This increased calcium might increase the availability of copper in the soil. Similar finding were reported by Neethu (2015) that increasing level of Ca slightly increases the Cu availability in soil

Aluminium concentration in the soil was significantly influenced by the ameliorants. Treatments showed significantly superior results over control at 3 MAP, 6 MAP and at harvest. Among the treatments T_{10} (gypsum + silica in 3 split) recorded the lowest aluminium content at 1 MAP,2 MAP and 3 MAP. At 1 MAP treatments containing gypsum and silica ($T_{10,}$ T_7 and T_4) showed superior results followed by lime treated and dolomite treated soil. Decreased activity of dolomite might be because of the low solubility of dolomite over lime. Moreover the lime showed immediate response in neutralizing surface acidity. At 6 MAP dolomite treated soil showed better reduction in aluminium toxicity compared to lime treated ones. This might have contributed to the low solubility of dolomite which showed its ameliorating action in the later stages of the crop. Similar trend was observed at harvest with T_{10} (gypsum + silica in 3 split) recorded the lowest aluminium content. Treatments T_{10}, T_8 and T_9 were on par. Increasing solubility of gypsum might help in the reduction of exchangeable aluminium by the incorporation of Ca and SO_4^{2-} ions. These findings were in harmony with the conclusions of Sun *et al.* (2000). He reported that application of gypsum increased the activity of Ca and decreased Al toxicity.

With respect to the silicon concentration the treatment significantly increased silicon over control at 3 MAP, 6 MAP and at harvest. At 3 MAP soil treated with gypsum and silica showed higher silicon availability compared to lime and dolomite. Increased action of lime might helped in correcting the surface acidity as lime was soluble over dolomite. At 6 MAP dolomite treated soil showed better results over lime this might be due to better acidity correction as dolomite was less soluble thus showing its ameliorating activity in the later stages. At 6 MAP and at harvest T_{10} (gypsum and silica 3 splits) recorded higher Si content. Gypsum treatments showed better results because of the better action of gypsum in reducing subsoil acidity as gypsum was soluble in soil. Similar finding were reported by Sumner *et al.* (1986). This might increase the availability of silicon in the soil. Brien and Summer (1988) also reported that gypsum addition enhanced silicon availability in soil. Silica added might prevail in the soil as monosilicic acid (H_4SiO_4) and enhanced the silicon availability in soil. Similar finding were reported by Jawahar and Vaiyapuri (2008) that the Si content in soil was increased when Si was applied at the rate of 120 kg/ha.

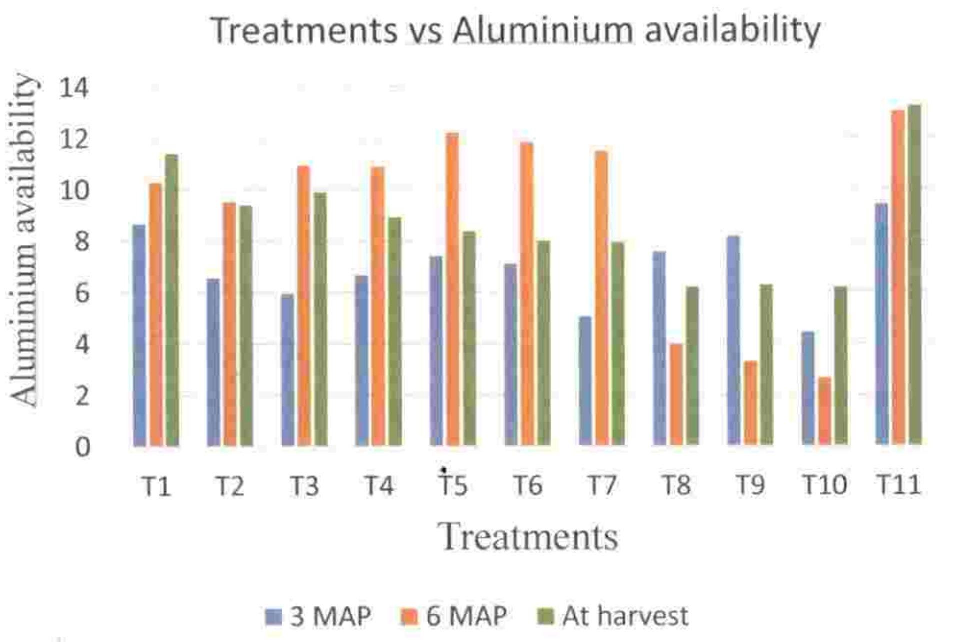

Fig 9: Effect of soil ameliorants on the exchangeable aluminium status of soil at various stages of field experiment

5.2.6 Influence of soil amendments on plant nutrients

5.2.6.1 Nitrogen, Phosphorus and Potassium

The nitrogen content of the leaf was significant increased with the application of the soil ameliorants. Among the treatments T_{10} (gypsum and silica 3 splits) recorded higher nitrogen content in the leaves both at bunching stage and at harvest. At bunching and harvest it was observed that gypsum added plants showed higher nitrogen uptake followed by the dolomite applied plants. From the soil analysis conducted at 6 MAP and harvest it was concluded that the gypsum applied treatments showed an increase in the availability of nitrogen in soil, due to the increased solubility and subsoil acidity correction by gypsum. Thus gypsum increased the leaching of nitrogen in the form of $N\text{-}NO_3$. Similar findings were reported by Belkacem and Nys(1997) that gypsum application enhanced the availability of nitrogen. Which might have contributed to greater uptake of nitrogen by plants. Another possible reason was addition of silica. Silica addition might also influenced the nitrogen uptake in plants. Jawahar and Vaiyapuri (2008) also reported that Si applied at the rate of 120 kg/ha increased the uptake of nitrogen by rice.

Treatment showed significantly higher phosphorus content in the leaves compared to control results than the control at bunching stage of the crop. Considering the treatments T_{10} (gypsum+ silica in 3 split) recorded the highest phosphorous content at bunching and at harvest. Addition of gypsum helped in ameliorating sub soil acidy this might be due to the solubility of gypsum over dolomite. This caused an increase in the soil available phosphorus in T_{10}. These finding were in harmony with the findings of Brien and Sumner (1988). They reported that application of phosphogypsum increased the phosphorus availability that might contribute to higher uptake of phosphorous by the crop. Moreover Silica addition might also enhanced the phosphorous uptake of the plant. Similar findings were reported by Jawahar and Vaiyapuri (2008) in rice that Si applied at the rate of 120 kg/ha increased the uptake of phosphorus by rice.

Banana consumes high amount of potassium. Treatments showed significant superior effect on the potassium content of the leaves both at bunching stage and at harvest. At bunching stage treatments were almost at par but at harvest T_{10} (gypsum+ silica in 3 split) recorded the highest potassium content followed by T_9 (dolomite and silica in 3 splits). Studies conducted on the potassium availability in the soil, T_{10} recorded the highest plant available potassium in soil. This might be due to the increased solubility of gypsum which promoted subsoil acidity correction which enhanced the plant available potassium in soil. Similar finding were reported by Brien and Sumner (1988) that application of phosphogypsum enhanced the potassium content in the soil. This might have contributed to higher potassium absorption by the plants Moreover silica addition enhanced the uptake of potassium by promoting action of H-ATPase in the membranes. Similar findings were reported by Liang(1999).

5.2.6.2 Calcium, Magnesium and Sulphur

The calcium content in the leaf at bunching and harvest showed significant effect by the application of treatments. At bunching stage almost all treatments were on par but at harvest T_{10} (gypsum + silica in 3 split) recorded the maximum calcium content. Soil analysis conducted at 6 MAP showed higher availability of Ca in T_{10}. Addition of gypsum decreased subsoil acidity by improving the downward movement of Ca ions (Sun *et al.*, 2000 and Jacob and Venugopal, 1993). This in turn might have helped the plant to absorb more calcium from the soil. Silica addition might also help in increasing the Ca uptake of plants. Similar findings were reported by Cachorro *et al.* (1994) that Ca uptake by the plant was increased by the application of Si.

Similarly magnesium content in the leaf was significant increased at bunching and harvest by treatment application. Considering the treatments, T_9 (dolomite+ silica in 3 split) recorded the highest magnesium content in leaves. It was observed that magnesium availability was higher in T_9. Dolomitic lime was a rich source of Mg. Moreover it enhanced the availability of Mg in the soil by alleviating soil pH (Cristancho *et al.*, 2014). Higher Mg availability might promote the plant to absorb more amount of Mg from the soil. Another possibility was by the addition of silicon. Silicon addition might enhance the uptake of Mg by the plants. The findings were in harmony with the conclusions of Takijima *et al.* (1959) in rice that silicon application increases the uptake of Mg ion.

Application of soil ameliorants increased the sulphur content in the leaf both at bunching and harvest of the crop. At both stages treatments applied with gypsum showed higher uptake of sulphur followed by dolomite applied treatment. This was due to the increased availability of sulphur in T_{10} (gypsum and silica 3 splits) than in other treatments as gypsum was highly soluble and its addition alleviates subsoil acidity. This might help in increasing the uptake of sulphur by the plants. Similar finding were reported by the Soratto and Crusciol (2008) in bean and rice that phosphogypsum increased the uptake of sulphur by rice. Silicon addition might also enhances the sulphur uptake of the plant. Similar findings were reported by Jawahar and Vaiyapuri (2008) in rice that Si addition at the rate of 120 kg/ha increased the sulphur uptake by rice.

5.2.6.3 Iron, Manganese and zinc

Iron content of the leaf shoed significant effect only at harvest stage of the crop. Among the treatmentsT_{10} (gypsum + silica in 3 split) recorded the minimum iron content and the control recorded with highest iron content in the leaves. Among the treatments, gypsum and silica in 3 splits (T_{10}) recorded the lowest iron availability in soil. Which could be due to the action of gypsum in ameliorating subsoil acidy as gypsum was more soluble than dolomite. The findings were in line with the studies of Bertic *et al.* (2008). Thus gypsum application reduced iron toxicity and thus reducing the iron uptake by the plants. Similar findings were reported by Moralli *et al.* (1971). Another possible reason might be due to the action of silicon as silicon addition by increasing the oxidizing power of the root and converts ferrous iron to insoluble ferric iron. Thus reducing the uptake of iron by the plants. The findings were in harmony with the findings of Wang *et al.*(1994).

Similarly soil ameliorant showed significant influence on the leaf manganese content at harvest. There was a decrease in the manganese content in the treatments with respect to control. Lowest manganese content in soil was recorded for T_{10} (gypsum + silica in 3 split). Gypsum addition might release soluble Ca which in turn elevated the pH of the soil thus helped in reducing manganese toxicity.Abruna *et al.* (1964) also reported that liming elevate the pH of humid topics by decreasing the exchangeable aluminum and manganese in the soil that might prevent the manganese uptake. Silicon addition might also helped in reducing manganese toxicity as silicon enhanced the manganese oxidizing power of the root and thus preventing the manganese uptake. Similar findings were reported by Okuda and Takahashi (1962) and Qiang *et al.* (2012) in rice.

Zinc content in the leaves varied significantly with the treatments at bunching stage and at harvest. Among the treatments T_{10} (gypsum + silica in 3 split) recorded the maximum zinc content in the leaves. It was observed that treatments containing gypsum showed higher zinc availability followed by dolomite. Which could be due to the increased solubility of gypsum over dolomite and ameliorating action of gypsum in correcting subsoil acidity which might increase the Zn availability in T_{10}. This might enhanced the zinc uptake by the plant. Similar findings were reported by Cutcliffe (1988) in Brussels sprouts. Moreover silicon addition might also enhanced the zinc uptake in plants. These findings were in harmony with findings of Epstain (1994); Marshner (1995) and Bridgit (1999) in rice.

5.2.6.4 Copper and silicon

The effect of soil ameliorants on copper content of the leaves showed significant increase at bunching and harvest. The treatment T_{10} (gypsum + silica in 3 split) recorded the highest copper content in the leaves at both stages. Which could be due to the increased availability of copper in T_{10}. Addition of gypsum alleviated subsoil acidity by increasing Ca content in the soil. Increased level of Ca in soil might enhanced the availability of copper. Similar findings were reported by

Neethu (2015) in nendran banana that the application of Ca increased the Cu availability in soil this might have enhanced the uptake of Cu by plants.

Soil ameliorants showed significant effect on the silicon content of the leaf. Among the treatments T_{10} (gypsum + silica in 3 split) and T_7 (gypsum + silica 2 splits) recorded the highest silicon content this might be due to increased availability of silicon in T_{10} and T_7 respectively. Acidity correction by gypsum might increase the silicon availability in soil. Brien and Summer (1988) also reported that gypsum addition enhanced silicon availability in soil thus making it more available to plants. Silica added might prevail in the soil as monosilicic acid (H_4SiO_4) and enhanced the silicon availability in soil. Similar finding were reported by Singh *et al.*(2006) and Jawahar and Vaiyapuri (2008) in rice.

5.2.7 Incidence of pest and diseases

Pest and disease incidence was recorded higher in control with respect to the treatments Lower incidence of pest and disease in treatments might be due to the balanced uptake of nutrients by plants which might increase the metabolic activities of the plant. Similar findings were reported by Vincente (2012). Application of silica along with the ameliorants might also helped the plants to show resistance against pest and diseases. Increased uptake of silica by the plants might contribute to better resistance against pest and diseases. Silica helped the plant to get adapted to different biotic and abiotic stresses. Similar findings were reported by Ma and Takahashi (2002) that Si application reduced the chance of pest and disease incidence in rice.

Summary

6. SUMMARY

The salient findings of the study entitled "Performance of non-conventional soil ameliorants in banana (*Musa spp)* var. Nendran" are summarized in this chapter.

An investigation was carried out at Regional Agricultural Research Station (RARS) farm Nileshwar during 2017 to 2019. The objective was to study the performance of banana in initial period with respect to the different non-conventional ameliorants and a subsequent field trial to confirm the importance of these ameliorants throughout the growing period in improving plant health and yield

The pot culture study was carried out to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health with respect to availability of nutrients upto 4 months. The experiment was conducted in Completely Randomized Design (CRD) consisting of 5 treatments with 4 replications. Treatment were T_1 (basal application of Calcium silicate), T_2 (Basal application of lime+ silica), T_3 (Basal application of dolomite + silica), T_4 (Basal application of Gypsum+ silica), control T_5 (Basal application of lime as per KAU POP, 2016). The biometric observations like the plant height, number of leaves, root length, root diameter and root CEC were periodically recorded. The results revealed that the plant growth was increased in treatments were non conventional soil ameliorants were added. Among the treatments plant characters like plant height, pseudostem girth and number of leaves were found superior in T_4 were gypsum and silica was added basally. The root characters like root length, root thickness and root CEC showed similar results with gypsum and silica in 3.3:1 ratio.

The field experiment was carried out at Regional Agricultural Research Station (RARS) farm Nileshwar to study the effect of ameliorants on yield and quality of tissue culture banana var Nendran. It was conducted in randomized block design comprising of 11 treatments and 3 replications. The treatments used in pot culture experiment were used in split doses to manage the soil acidity throughout the growing period of crop. Treatments were T_1(Basal application of Calcium silicate), T_2 (Basal application of lime + silica), T_3 (Basal application of dolomite +silica), T_4 (Basal application of Gypsum + silica), T_5 (Lime+ silica in 2 splits at 1st and 2nd month after planting), T_6 (Dolomite + silica in 2 splits at 1st and 2nd month after planting), T_7 (Gypsum + silica in 2 splits at 1st and 2nd month after planting, T_8 (Lime+ silica in 3 split doses at 1st month, 2nd month and 4th month after planting),T_9 (Dolomite + silica in 3 split doses at 1st month, 2nd month and 4th month after planting), T_{10} (Gypsum + silica in 3 split doses at 1st month, 2nd month and 4th month after planting), T_{11} (Application of lime as per KAU POP 2016) as the control. Manures and fertilizers application and other cultural practices were followed as per POP, KAU (2016) for all the treatments uniformly.

The results of the field experiment revealed that the yield characters were found to be superior in all treatments where ameliorants were added. Among the treatments highest yield (11.24 kg) was recorded with gypsum and silica in 3 splits (T_{10}). Higher number of hands per bunch (6.33) and higher number of fingers per hand (8.66) were also recorded in T_{10}. Vegetative characters like Pseudostem height, Pseudostem girth at 45 cm, number of leaves and number of functional leaves were found superior when plants were applied with gypsum and silica in 3 splits (T_{10}). Soil ameliorants showed superior finger characters in all treatments over control. It was observed that plants applied with gypsum and silica in 3 splits (T_{10}) recorded higher finger length while plants applied with dolomite and silica in 3 splits recorded the highest finger breadth and finger weight. Plants supplied with gypsum and silica in 3 splits took minimum days to bunch emergence (186 days), days to harvest (277 days) and days to ripening (4.33 days). Application of silica along with the ameliorants showed decreased incidence of pseudostem weevils and sigatoka disease compared to control.

Studies regarding the quality parameters of the fruit revealed that plants applied with soil ameliorants produced beter quality fruits with respect to the control. Different quality parameters like TSS, titrable acidity, reducing sugar content, non reducing sugar content and keeping quality were studied. It was found that the application of gypsum and silica in 3 splits produced significantly superior results.

Application of soil ameliorants increased the yield and vegetative character of banana by increasing the uptake of macro and micro nutrients. Results revealed that plants treated with non conventional soil ameliorants showed a higher uptake of nutrients than control.

Leaf analysis at bunching stage and at harvest of the crop was also studied. Application of non conventional soil ameliorants showed significant influence on the N and K content of the leaf both at bunching and harvest whereas the P content was significantly influenced only at bunching stage of the crop. Highest uptake of N, P and K content was reported in plants treated with gypsum and silica in 3 splits (T_{10}).

Regarding the secondary nutrient content in the leaf, all treatments showed significantly higher content than control. The concentration of Ca, Mg and S content was high in all treatments over control. Application of gypsum and silica significantly increased the Ca content both at bunching stage and at harvest. Highest Ca was seen in plants supplied with 3 splits doses of gypsum and silica (T_{10}). Similarly Mg content was significantly increased by the application of dolomite and silica at harvest and those plants applied with dolomite and silica 3 split doses recorded the highest Mg content in the leaves. Sulphur content in the leaves was significantly higher at bunching and harvest of the crop. Highest S content was reported when gypsum and silica in 3 doses was applied (T_{10}).

Soil ameliorants helped in decreasing the Fe and Mn uptake by plants thereby reducing the Fe and Mn concentration in the leaves. Application of soil ameliorants significantly decreased the Fe and Mn uptake at harvest than in control. Plants supplied with gypsum and silica in 3 split doses recorded the lowest Fe and Mn content in the leaf. Soil ameliorants showed significant influence on the Cu, Zn and Si content in the leaf at bunching stage and at harvest. Split application of gypsum and silica in 3 doses (T_{10}) showed a highest Cu, Zn, Si content in the leaves.

Soil ameliorants increased the plant nutrient uptake by increasing the nutrient status of soil throughout the growing period. Results revealed that in all the treatments applied with the soil ameliorants showed a greater increase in availability of nutrients in the soil than in the control. Soil ameliorants enhances the soil properties like pH, EC, CEC. Moreover it increases the available N, P, K, Ca, Mg, S, Zn, Cu and Si content in soil at the same time it decreased the Fe, Mn and Al toxicity in the soil.

Soil analysis conducted at 3 MAP, 6 MAP and harvest of the crop revealed that application of soil ameliorants significantly influenced the pH at 6 MAP with gypsum and silica in 3 splits recorded highest pH (6.61). Electrical conductivity of the soil exhibited significant difference among the treatments at 6 MAP and at harvest of the crop. Highest EC was observed in T_{10} which received 3 splits of gypsum and silica while lowest EC was observed in the control. Organic carbon content of the soil was significantly increased by the soil ameliorants at harvest with gypsum and silica in 3 splits doses recorded the highest organic carbon content. Cation exchange capacity of the soil was significantly influenced by the addition of soil ameliorants at 3 MAP, 6 MAP and at harvest. Highest CEC was found in T_{10} receiving gypsum and silica in 3 splits.

Available N content showed significant superior results in the treatments at all the 3 stages of the crop. Plants supplied with gypsum and silica in 3 split doses (T_{10}) recorded the highest available N in the soil. Available K content in the soil was significantly influenced by the application of soil amelorents at 6 MAP whereas Available P content was significantly increased at 6 MAP and at harvest. Application of gypsum and silica in 3 split doses recorded the highest P and K availability in soil.

Ca, Mg and S status of the soil was found superior in soil treated with non conventional ameliorants than in the control at 3 MAP, 6 MAP and at harvest. Gypsum and silica in 3 split doses reported highest calcium and sulphur content while the Mg content was superior for T_9 which received 3 splits of dolomite and

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silica. Application of soil ameliorants showed significant increase on the available Cu content in soil but it did not show any significant effect on the Zn content. Application of gypsum and silica in 3 splits recorded the highest Cu availability in soil.

Non conventional soil ameliorants helped in mitigating Fe, Mn and Al toxicity in acid soils. Treatment application showed significant effect on the Fe and Mn content at harvest of the crop.T_{10} (gypsum and silica in 3 splits) recorded the lowest Fe and Mn content in the soil while the highest was recorded in T_{11} (control). Addition of gypsum and silica in 3 splits (T_{10}) showed the lowest Al content at all the 3 stages while the control T_{11} recorded the highest Al content in the soil. With respect to the available silicon content in the soil, ameliorants showed significant influence at all the 3 stages of the crop with gypsum and silica in 3 split doses (T_{10}) showed the highest Si availability in soil.

The results from the investigation revealed that the application of non-conventional soil ameliorants increased the nutrient availability in soil thereby increasing the yield and quality of banana. Among them application of gypsum + silica in 3 splits dosses performed well and produced superior results. The study could identify the potentiality of application of gypsum and silica in 3 split doses in Kerala conditions were the soils are mostly dominated by low activity clays to produce higher yield and premium quality banana thereby improving the financial status of the farmers.

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PERFORMANCE OF NON-CONVENTIONAL SOIL AMELIORANTS IN BANANA (*Musa spp*) var. Nendran

by

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Abstract of the thesis

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ABSTRACT

An investigation entitled "Performance of non-conventional soil ameliorants in banana (*Musa spp*) var. Nendran" was carried out at College of Agriculture Padannakad and Regional Agricultural Research Station (RARS) farm Nileshwar from 2017 to 2019. The objective was to study the performance of banana (*Musa spp*) var. Nendran in initial period with respect to the different non-conventional ameliorants and a subsequent field trial to confirm the importance of these ameliorants throughout the growing period in improving plant health and yield

Pot culture study was carried out to evaluate the efficiency of different soil ameliorants in improving soil health as well as crop health with respect to availability of nutrients upto 4 months. The experiment was conducted in Completely Randomized Design (CRD) consisting of 5 treatments and 4 replications with the following treatments; T_1 (basal application of Calcium silicate), T_2 (Basal application of lime+ silica), T_3 (Basal application of dolomite + silica), T_4 (Basal application of Gypsum+ silica), control T_5 (Basal application of lime as per KAU POP 2016). The biometric observations like the plant height, number of leaves, root length, root diameter and root CEC were periodically recorded. Considering the plant height, pseudostem girth and number of leaves T_4 showed superior results. The root characters like root length, root thickness and root CEC were found superior in T_4.

The field experiment was carried out at Regional Agricultural Research Station (RARS) farm Nileshwar to study the effect of ameliorants on yield and quality of tissue culture banana var. Nendran. It was conducted in randomized block design comprising of 11 treatments and 3 replications. The treatments used in pot culture experiment were used in split doses to manage the soil acidity throughout the growing period of crop. Treatments were T_1(Basal application of Calcium silicate), T_2 (Basal application of lime + silica), T_3 (Basal application of dolomite +silica), T_4 (Basal application of Gypsum + silica), T_5 (Lime+ silica in 2 splits at 1st and 2nd month after planting), T_6 (Dolomite + silica in 2 splits at 1st and 2nd month

after planting), T_7 (Gypsum + silica in 2 splits at 1st and 2nd month after planting, T_8 (Lime+ silica in 3 split doses at 1st month, 2nd month and 4th month after planting),T_9 (Dolomite + silica in 3 split doses at 1st month, 2nd month and 4th month after planting), T_{10} (Gypsum + silica in 3 split doses at 1st month, 2nd month and 4th month after planting), T_{11} (Application of lime as per KAU POP 2016) as the control. Biometric observations were recorded periodically. Soil and leaf analysis were also carried out at specific intervals of the experiment.

The results of the field experiment revealed that among the vegetative characters, plant height, pseudostem girth at 90 cm height, number of leaves, number of functional leaves and number of suckers were superior for T_{10}. Considering the yield attributes like number of hands per bunch (6.33) and number of fingers per hand (8.66) T_{10} recorded superior results. Treatment T_{10} recorded the highest bunch weight of 11.24 kg. Among the finger characteristics, average finger breadth (16.00 cm) and average weight of the fingers (225.00 g) is superior in T_9 and the finger length (21.30 cm) is superior in T_{10}. Among the treatments T_{10} recorded minimum days for bunch emergence (186 days), days to harvest (277 days) and days to ripening (4.33 days). Fruit characters like total soluble solids (29.90 ^{0} brix), titrable acidity (0.27 %), reducing sugar (19.00 %), non reducing sugar (4.89 %), shelf life (4.40 days) were found superior in T_{10}.

Studies on the soil nutrient status was conducted at 3 months after planting, 6 month after planting and at harvest of the crop. It was revealed that T_{10} recorded superior results for soil pH and electrical conductivity. Considering the organic carbon content and cation exchange capacity T_{10} recorded superior results. Available nitrogen, potassium, phosphorus, calcium and sulphur, copper, zinc and silicon was found superior in T_{10} whereas highest available magnesium content was recorded in T_9. In case of available Iron, manganese and exchangeable aluminium T_{10} gave superior results.

Leaf analysis was carried out at bunching and at harvest of the crop and the following results were obtained. Nitrogen, potassium, phosphorus content in the leaf was found superior for T_{10}. The calcium and sulphur content in the leaf was

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superior for T_{10} while treatment T_9 recorded the highest magnesium uptake. Uptake of micronutrients like zinc, copper and silicon were found superior in T_{10}. Lowest concentration of iron and manganese were recorded in T_{10}.

The results from the investigation revealed that the application of non-conventional soil ameliorants increased the nutrient availability in soil thereby increasing the yield and quality of banana. Among them application of gypsum + silica in 3 splits dosses performed well and produced superior results in northern lateritic soils.

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APPENDIX I

Daily average weather parameters of RARS, Pilicode

Date	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	I	II	
01-02-2018	32	16.5	95	53	0
02-02-2018	32.5	17	95	54	0
03-02-2018	31	18	90	63	0
04-02-2018	30.5	19	91	60	0
05-02-2018	31	18	90	53	0
06-02-2018	32.5	21.5	87	52	0
07-02-2018	32	22	96	64	0
08-02-2018	29.5	22	89	57	0
09-02-2018	31.5	22	91	55	0
10-02-2018	32.5	23	96	61	1.6
11-02-2018	32	23	96	68	0
12-02-2018	31	23	96	65	0
13-02-2018	31.5	24.5	88	68	0
14-02-2018	30.5	22	93	63	0
15-02-2018	31	22	95	55	0
16-02-2018	32.2	22	91	58	0
17-02-2018	32	21	91	57	0
18-02-2018	31.8	20.5	91	58	0
19-02-2018	32	20.5	91	60	0
20-02-2018	31.5	22	91	60	0
21-02-2018	32	22	96	61	0
22-02-2018	33	22.5	91	59	0
23-02-2018	32	22	91	63	0
24-02-2018	31.5	21	91	55	0
25-02-2018	32.3	20.5	95	69	0
26-02-2018	32	22	91	63	0
27-02-2018	32	21	91	64	0
28-02-2018	32	21.5	89	51	0
01-03-2018	33.5	21	89	53	0
02-03-2018	32.5	21	91	58	0
03-03-2018	32	21.5	91	66	0
04-03-2018	32	22.5	91	64	0
05-03-2018	32	23.5	91	64	0
06-03-2018	32	23	88	60	0
07-03-2018	32	23	90	66	0
08-03-2018	32	23.5	91	58	0

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09-03-2018	32	23.5	96	61	0
10-03-2018	33	23	93	55	0
11-03-2018	33	22	83	55	0
12-03-2018	33.5	21	94	61	0
13-03-2018	33	23	91	56	0
14-03-2018	33.8	25	96	69	0
15-03-2018	31	24	92	66	7.9
16-03-2018	32	24.5	84	66	3.4
17-03-2018	31	24.5	88	59	0
18-03-2018	33.5	24.5	88	61	0
19-03-2018	33	24.5	89	63	0
20-03-2018	32.8	22.5	91	65	25.6
21-03-2018	32.5	24.5	93	66	0
22-03-2018	32.5	24.5	92	65	0
23-03-2018	32.5	23.5	84	66	0
24-03-2018	32	22	83	58	0
25-03-2018	32.5	24.5	92	64	0
26-03-2018	33	24.5	92	64	0
27-03-2018	33	26.5	95	70	0
28-03-2018	32.5	25.5	92	70	0
29-03-2018	32.5	25	92	64	0
30-03-2018	32	25	88	65	0
31-03-2018	32	26	92	70	0
01-04-2018	32	25	92	64	0
02-04-2018	33	25.5	96	70	0
03-04-2018	32.5	24.5	93	64	2.7
04-04-2018	33	24.5	87	61	0
05-04-2018	33	24.5	92	64	0
06-04-2018	32.8	25	84	61	0
07-04-2018	33	23	84	67	0
08-04-2018	32.5	25	92	64	1.3
09-04-2018	33	24.5	92	66	0
10-04-2018	33	25	88	67	0
11-04-2018	32.5	23.5	92	64	0
12-04-2018	32	24.5	92	64	0
13-04-2018	32.5	25	88	66	0
14-04-2018	32	25	88	70	0
15-04-2018	32	25	88	64	1.5
16-04-2018	32.5	25	88	64	0
17-04-2018	33.5	25	88	64	0

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18-04-2018	33.5	Damaged	75	67	0
19-04-2018	33.5	"	86	63	0
20-04-2018	34	"	86	64	0
21-04-2018	33.5	"	85	65	4.6
22-04-2018	34.5	"	81	64	0
23-04-2018	33	"	92	67	0
24-04-2018	33.5	"	85	62	0
25-04-2018	34.1	"	85	61	0
26-04-2018	34	"	75	62	0
27-04-2018	33.5	"	92	66	0
28-04-2018	34	"	81	61	0
29-04-2018	34	"	85	62	0
30-04-2018	34	"	92	68	0
01-05-2018	33.9	"	86	61	0
02-05-2018	34	"	84	64	0
03-05-2018	33	"	88	67	0
04-05-2018	33.5	"	84	67	2.6
05-05-2018	33.5	"	85	60	0
06-05-2018	34.5	26	85	66	0
07-05-2018	33.5	25.5	85	67	0
08-05-2018	33	25	85	66	0
09-05-2018	33.8	22.5	96	61	0
10-05-2018	33	24.5	88	64	0
11-05-2018	32	25	84	66	0
12-05-2018	32	24	90	68	14.8
13-05-2018	32.2	24	84	64	0
14-05-2018	32.5	25	92	72	11.8
15-05-2018	31	25.5	90	61	0
16-05-2018	33.5	25.5	81	78	0
17-05-2018	32	25	88	68	1
18-05-2018	32.8	25	92	62	0
19-05-2018	32.9	25.5	84	65	0
20-05-2018	33	23	92	63	3
21-05-2018	32.5	24.5	88	66	0
22-05-2018	32	24.5	86	64	0
23-05-2018	32.5	26	81	64	0
24-05-2018	33	26.5	92	66	0
25-05-2018	33.5	21.5	96	71	30.3
26-05-2018	31	22.8	93	79	45
27-05-2018	30.5	24	92	81	12
28-05-2018	30	24	92	82	18.4
29-05-2018	30	23	96	81	7.8

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30-05-2018	28	24	96	72	130.5
31-05-2018	30.5	25.5	88	64	0
01-06-2018	32	25.5	87	68	0
02-06-2018	32	26	92	70	0
03-06-2018	32.2	25	88	70	0
04-06-2018	31.5	23.5	100	96	92.4
05-06-2018	29	23.5	98	87	32.9
06-06-2018	29.5	25	96	82	17.5
07-06-2018	31.5	24.5	96	82	5.8
08-06-2018	30	24	98	89	145
09-06-2018	29	23.5	96	96	36.3
10-06-2018	27	23.9	88	72	120.6
11-06-2018	31	24.5	88	82	4
12-06-2018	31.2	26.5	85	79	5.2
13-06-2018	31	27	85	76	5.3
14-06-2018	31.5	25	89	96	7.4
15-06-2018	27	24	93	81	25.5
16-06-2018	30	25	96	70	5.6
17-06-2018	31.5	24.5	96	78	6.3
18-06-2018	30.5	23.5	92	81	24.2
19-06-2018	30.2	24.5	94	96	19.5
20-06-2018	29.5	23.5	100	100	51.9
21-06-2018	25.5	23.5	100	84	67.4
22-06-2018	27.5	23.5	93	90	5.9
23-06-2018	27.5	23.5	96	90	12.9
24-06-2018	26.5	22.5	96	81	16.6
25-06-2018	29.5	23	96	92	14.1
26-06-2018	29.5	22.5	96	78	32.8
27-06-2018	30.5	23	98	85	13
28-06-2018	30	23	100	92	71.5
29-06-2018	27.5	23	97	96	70.5
30-06-2018	25.5	23.5	93	75	15.2
01-07-2018	30.5	24	92	88	6.2
02-07-2018	30.5	25	92	81	2.8
03-07-2018	30.2	23.5	96	68	9.3
04-07-2018	31	24	92	79	13.2
05-07-2018	30.5	22	88	70	6.6
06-07-2018	31.5	24	96	75	12
07-07-2018	30.5	24	96	92	74.8
08-07-2018	29	22	96	85	35.2
09-07-2018	30	25.5	88	85	13.7
10-07-2018	30	24.5	96	87	19.4

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11-07-2018	30.2	24.5	96	88	33.5
12-07-2018	29.5	23.5	98	75	61.3
13-07-2018	30.3	24	96	96	51
14-07-2018	27.5	24	98	75	48.5
15-07-2018	30.8	24	92	75	17.3
16-07-2018	30.8	24.5	94	87	32.2
17-07-2018	29.5	25	88	73	33.2
18-07-2018	30.5	23.5	96	92	42.2
19-07-2018	30	24.5	100	96	88.4
20-07-2018	29.5	24	96	92	96
21-07-2018	26.8	24	96	85	33.1
22-07-2018	29.8	24.5	95	77	14.2
23-07-2018	30	25	96	70	20.2
24-07-2018	31.5	25	96	75	6.4
25-07-2018	30	25	96	85	4.7
26-07-2018	28.5	24.8	98	78	48.3
27-07-2018	29.5	24.5	96	75	11.8
28-07-2018	30	25.8	94	75	4.4
29-07-2018	30.5	28.5	85	78	2.1
30-07-2018	31	27	96	85	1.4
31-07-2018	30	25	94	71	24.8
01-08-2018	30	25	96	81	7.5
02-08-2018	29	25	96	78	6
03-08-2018	31	23.5	98	82	86.3
04-08-2018	30	24	96	71	26.5
05-08-2018	30	24	96	75	0
06-08-2018	31.5	25	96	73	5.8
07-08-2018	30.5	24.5	92	84	14.3
08-08-2018	28.5	24	95	81	42.5
09-08-2018	29	24	96	78	5.2
10-08-2018	30	24	96	85	9.6
11-08-2018	30	23.5	96	85	36.6
12-08-2018	29.5	23	96	87	24
13-08-2018	28.5	23	95	79	41.2
14-08-2018	29	24.5	96	95	25.7
15-08-2018	26.5	24.8	93	92	85.8
16-08-2018	28.5	24.8	93	100	14
17-08-2018	28	24	96	80	54.3
18-08-2018	28	24.2	95	79	38.5
19-08-2018	29.5	24.5	96	78	21
20-08-2018	29.5	23	92	78	1.2
21-08-2018	29	23.5	96	78	9.1

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22-08-2018	29	24.5	96	78	16.4
23-08-2018	29	23	93	72	14.5
24-08-2018	29.5	23	91	75	2.8
25-08-2018	30	23	90	80	5.3
26-08-2018	30	24	92	78	0
27-08-2018	30	24	96	81	10.9
28-08-2018	29	23.5	98	88	28.1
29-08-2018	29	23	96	77	51.4
30-08-2018	29	24.5	96	83	4.5
31-08-2018	29.5	24	92	78	3.6
01-09-2018	29.5	24	92	78	0
02-09-2018	30	23.5	91	75	0
03-09-2018	31	24	88	70	0
04-09-2018	30	23.5	88	72	0
05-09-2018	30	24	89	74	0
06-09-2018	30	23.5	92	74	0
07-09-2018	29.5	23.2	94	74	1
08-09-2018	29.5	23.5	91	69	4.2
09-09-2018	30	23	91	67	0
10-09-2018	30.5	22	91	69	0
11-09-2018	31	23.5	91	69	0
12-09-2018	31	24.5	92	71	0
13-09-2018	30.2	24.5	92	69	0
14-09-2018	30.5	23.5	86	67	0
15-09-2018	30.3	24	91	71	0
16-09-2018	30	25	84	69	0
17-09-2018	31	25.5	92	70	0
18-09-2018	30.7	24	91	66	0
19-09-2018	30.9	25.5	88	71	4.3
20-09-2018	30.6	23.8	85	69	0
21-09-2018	30.5	24	88	64	0
22-09-2018	31	23.5	84	63	0
23-09-2018	31	26.5	84	69	0
24-09-2018	31.5	24.5	90	60	0
25-09-2018	31.5	25	88	61	0
26-09-2018	31.5	24	87	59	0
27-09-2018	31.8	25.5	84	69	0
28-09-2018	30.5	25	92	71	8.5
29-09-2018	30.7	25	92	75	0
30-09-2018	31	25.5	88	66	0
01-10-2018	32	25.2	91	70	5.1
02-10-2018	31.5	23.5	96	69	20.7

03-10-2018	31.5	26	88	79	0
04-10-2018	29	25.5	92	81	0.8
05-10-2018	30.5	25.5	88	75	6.4
06-10-2018	30	25	96	72	14.5
07-10-2018	31	26	92	64	4.8
08-10-2018	32	25	92	96	6.8
09-10-2018	29.8	24.5	96	70	47.7
10-10-2018	29.5	24.8	92	73	1.7
11-10-2018	31	26	91	69	0
12-10-2018	32	26	92	72	0
13-10-2018	31.5	25	93	72	0
14-10-2018	31.5	25	92	75	5.5
15-10-2018	30.5	25	92	74	1.2
16-10-2018	30.5	25.5	92	78	0
17-10-2018	29	24	88	71	15.7
18-10-2018	30	24.5	96	75	0.8
19-10-2018	30	25	92	70	1.8
20-10-2018	30	24	96	81	21.8
21-10-2018	28.9	23.9	88	69	0
22-10-2018	30.5	24	92	70	0
23-10-2018	30.5	24.5	91	63	0
24-10-2018	31.5	23.5	91	57	0
25-10-2018	32	23.5	88	59	0
26-10-2018	32	24	80	49	0
27-10-2018	33	24	91	56	0
28-10-2018	32.5	22.5	83	47	0
29-10-2018	33	22	91	54	0
30-10-2018	32.5	21	85	48	0
31-10-2018	32	21.5	88	53	0
01-11-2018	32	24	91	64	0
02-11-2018	31.5	25	92	58	0
03-11-2018	32.5	25	93	71	0
04-11-2018	31	25	92	63	8.2
05-11-2018	32	25	95	69	0
06-11-2018	31.5	25	90	58	0
07-11-2018	32.5	25	88	63	0
08-11-2018	32	23	87	54	0
09-11-2018	31.5	23	84	52	0
10-11-2018	32.5	24	87	61	0
11-11-2018	32	23	91	66	0
12-11-2018	31.5	23	87	60	0
13-11-2018	31.5	23.5	86	60	0

14-11-2018	32	21.5	91	56	0
15-11-2018	31.9	19.5	91	47	0
16-11-2018	32.5	23.5	83	63	0
17-11-2018	31.5	23.5	91	58	0
18-11-2018	32	25	88	63	0
19-11-2018	31.5	25.5	96	73	0
20-11-2018	30.9	24.5	92	68	0
21-11-2018	30.5	25.5	92	65	0
22-11-2018	32.5	25.5	88	60	0
23-11-2018	32.5	25	93	63	0
24-11-2018	32	24	94	69	6.8
25-11-2018	31.5	24	92	69	40
26-11-2018	31.5	24	96	66	0
27-11-2018	31.5	24	85	63	0
28-11-2018	32	21.5	87	46	0
29-11-2018	32	20.5	93	55	0
30-11-2018	32.5	25	88	66	0
01-12-2018	32	24	92	67	0
02-12-2018	31.5	24	91	58	0
03-12-2018	32.5	21.5	92	64	0
04-12-2018	31	22	87	63	0
05-12-2018	31	23.5	90	63	0
06-12-2018	31.5	20.5	93	70	0
07-12-2018	31.6	21.8	93	66	0
08-12-2018	32.2	23	91	63	0
09-12-2018	32	23	91	60	0
10-12-2018	32	23.5	91	73	4.2
11-12-2018	30	22	92	66	0
12-12-2018	31.4	23.5	91	66	0
13-12-2018	30.3	21	91	60	0
14-12-2018	31.5	21.2	91	66	0
15-12-2018	31.5	20.5	91	66	0
16-12-2018	32	21	95	66	0
17-12-2018	31	19	90	53	0
18-12-2018	30.5	17.7	93	70	0
19-12-2018	32.5	18.5	89	70	0
20-12-2018	31.5	23	93	61	0
21-12-2018	31	22	93	63	0
22-12-2018	31.2	21.8	88	59	0
23-12-2018	32	23.5	91	60	0
24-12-2018	32	24	96	66	0
25-12-2018	31	22.5	92	63	13.8

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26-12-2018	32	23	91	66	0
27-12-2018	31.5	23	92	66	0
28-12-2018	31	22.5	91	66	0
29-12-2018	31	23	93	69	0
30-12-2018	30.5	23.2	92	66	0
31-12-2018	30.5	21	94	60	0
01-01-2019	31.5	18.8	91	66	0
02-01-2019	31.2	17	90	66	0
03-01-2019	30.5	16	93	64	0
04-01-2019	30.5	15	91	61	0
05-01-2019	32	15.2	89	58	0
06-01-2019	31.5	16.5	90	75	0
07-01-2019	30.5	17	88	53	0
08-01-2019	30	19	91	48	0
09-01-2019	31.5	18.5	95	46	0
10-01-2019	32	18.4	95	52	0
11-01-2019	31	19.5	89	57	0
12-01-2019	31	20.5	91	60	0
13-01-2019	31	20.2	88	63	0
14-01-2019	31	19.2	92	52	0
15-01-2019	31.1	19.4	93	44	0
16-01-2019	32.9	15	87	44	0
17-01-2019	32.5	15.5	94	44	0
18-01-2019	31.9	19	91	57	0
19-01-2019	31	20	93	59	0
20-01-2019	30.5	18.5	95	44	0
21-01-2019	32.5	19	95	59	0
22-01-2019	30.3	20	95	57	0
23-01-2019	30.7	19.5	94	51	0
24-01-2019	31	20	95	59	0
25-01-2019	30.5	21.5	91	58	0
26-01-2019	31	21.5	81	57	0
27-01-2019	30.5	20.3	91	59	0
28-01-2019	30.5	19.2	91	49	0
29-01-2019	31	19	89	54	0
30-01-2019	31	20	92	49	0
31-01-2019	32	20	93	59	0
01-02-2019	30.8	20	92	61	0
02-02-2019	31	20.2	91	50	0
03-02-2019	32	21	88	49	0
04-02-2019	32.5	20.5	91	49	0
05-02-2019	32.5	21	89	59	0

06-02-2019	30.8	23	96	65	0
07-02-2019	32.5	23	92	63	0
08-02-2019	31.5	24	92	66	0
09-02-2019	31	24	93	66	0
10-02-2019	31.5	24	92	66	0
11-02-2019	31	23	91	66	0
12-02-2019	32	21	91	46	0
13-02-2019	32.5	20.5	91	45	0
14-02-2019	33	20	91	47	0
15-02-2019	33	22.5	84	53	0
16-02-2019	32.5	23.2	91	58	0
17-02-2019	32	22.5	91	55	0
18-02-2019	32.5	21	87	55	0
19-02-2019	32.5	19.2	91	57	0
20-02-2019	30.7	22	89	50	0
21-02-2019	33.5	20	91	48	0
22-02-2019	32.5	19.2	86	45	0
23-02-2019	33.2	18	89	47	0
24-02-2019	32.5	18	81	43	0
25-02-2019	33.5	19.4	91	65	0
26-02-2019	31.5	23	91	61	0
27-02-2019	32	23	93	57	0
28-02-2019	31.5	22	86	54	0
01-03-2019	31.5	19.4	87	57	0
02-03-2019	32.0	20.3	83	66	0
03-03-2019	31.5	22.5	91	55	0
04-03-2019	32.5	22.5	91	56	0
05-03-2019	32	23.5	85	55	0
06-03-2019	32.5	23	84	60	0
07-03-2019	31.5	22	88	60	0
08-03-2019	31.5	21	91	60	0
09-03-2019	31	23	87	60	0
10-03-2019	32.3	24	92	64	0
11-03-2019	32	25.4	86	64	0
12-03-2019	32	24.4	88	55	0
13-03-2019	32.5	21.5	91	62	0
14-03-2019	32.5	22	89	56	0
15-03-2019	33	23.3	91	60	0
16-03-2019	32.4	24	92	63	0
17-03-2019	31.5	23	88	63	0
18-03-2019	31.5	23	91	63	0
19-03-2019	32.3	23	88	63	0

20-03-2019	32.7	24	89	59	0
21-03-2019	32.8	24	88	58	0
22-03-2019	32	22.1	87	56	0
23-03-2019	32.3	24	92	64	0
24-03-2019	32	22	92	62	0
25-03-2019	33.5	24	92	62	0
26-03-2019	34	24.5	86	62	0
27-03-2019	33.5	25	84	59	0
28-03-2019	34	24.5	82	64	0
29-03-2019	32.5	25	86	62	0
30-03-2019	33.5	25	86	64	0
31-03-2019	32.8	25	88	65	0

APPENDIX II

Effect of non-conventional soil ameliorants on B : C Ratio

Treatments	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	B:C Ratio
T1	461000	860761.00	1.870
T2	460300	815970.00	1.770
T3	461775	877834.27	1.901
T4	464650	884693.60	1.904
T5	461300	884773.40	1.918
T6	462775	969050.85	2.094
T7	464650	1024088.60	2.204
T8	462300	989784.30	2.141
T9	463775	1015667.25	2.190
T10	465650	1064941.55	2.287
T11	460175	716952.65	1.558

APPENDIX III

Pest and disease incidence in banana (*Musa spp*) var. Nendran

Name of the Pest	**Remarks**	**Name of the disease**	**Remarks**
Banana pseudostem weevil (*Odoiporous longicollis*)	Observed	Bunchy top disease (Banana bunchy top virus)	Not observed
Banana rhizome weevil (*Cosmopolites sordidus*)	Not observed	Panama wilt (*Fusarium oxysporum f. cubense*)	Not observed
Banana aphid (*Pentalonia nigronervosa*)	Not observed	Sigatoka leaf spot (*Mycosphaerella sp.*)	observed
Banana leaf eating catterpiller (*Spodoptera litura*)	Observed	Kokkan disease (Banana bract mosaic virus)	Not observed