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EFFECT OF BONE MEAL COMPOST ON GROWTH AND ION CONTENT IN LEAF SAP OF BANANA CROP

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Abstract

Soil fertility degradation is associated with continued cultivation of crop and without further addition of organic amendments. Improving the productivity of low fertile soils is a key to achieve the target of food production and tackling global food crises. A field study was conducted during 2022 to observe the effect of bone meal compost (BMC) on the growth and ion content of banana crop. The field study was organized at the experimental site of Sindh Agricultural University Tandojam in a three-replicated randomized complete block design. Each block was planted with 36 banana suckers of three months old. The treatments were designed as CK1: BMC=00 + recommended NPK (N=300, P=250 and K=500) kg ha^{-1}, CK2: BMC = 7.0 t ha^{-1} and no chemical fertilizers were used, CK3: BMC = 7.0 t ha^{-1} with recommended NPK (N=300, P=250 and K=500) kg ha^{-1}. Bone meal compost with inorganic fertilizer (BMC+IF) showed remarkable positive effects on banana growth and soil quality. However, the maximum increase in banana pseudo stem height 26.72%, number of leaves 15.74% leaf length 39.65%, leaf area index 36.37%, stem girth 38.47% were observed in CK3. Moreover, the root length was decreased by 8.77% in CK3. The maximum increase in leaf sap ions was observed with the application of bone meal compost with recommended inorganic fertilizer. The maximum increase in sap nitrogen was 38.29%, phosphorus 59.35%, potassium 22.51% and calcium were increased up to 44.92% where plants were treated with bone meal compost along with recommended inorganic fertilizer in compression to other treatments. The improvements in soil macronutrient were observed with the amendment of bone meal compost and inorganic fertilizer. The maximum soil nitrogen content was 23.84%, phosphorus 31.75% and potassium 15.46% at the depths of 0-20 cm with the application of (BMC+IF). The findings of experimental results demonstrate the effectiveness of bone meal compost and inorganic fertilizer for improving the growth and ion uptake in banana plants. Furthermore, amendment also improves the nutrient content in soil at both depths.

Key words: Bone meal compost, Banana growth, Sap ion content, Soil nutrients.

Introduction

Bananas are known as a king of fruits producing industry in the world. The fruit produced by banana plant mostly be liked by children, old age person, and youngster. From the medical point of view physicians mostly suggest to the patients in various health concerns as a vital food source (Singh *et al.*, 2016). Banana crops particularly, grown in tropical and sub-tropical regions. Southeast Asia has been considered the main hub of bananas; hence the countries falling under this region are significant banana fruit producers and exporters in the world (Ray *et al.*, 2021). The "banana" word is derived from the Arabic language that means, "finger" (Ferdous *et al.*, 2021). It is generally grown in more than 130 countries of the world on an area of 10.13 million hectares, producing 121.85 million tons of banana (Mustafa & Kumar 2012). Availability of antioxidants and biologically active additives, banana fruit is a good source of nutrients such as polysaccharides, carbohydrates, vitamins A, C, B6 and other minerals with traces of oil, as well as favorable health properties such as diminished incidence of death, heart attack, stroke, and other chronic illnesses (Jideani *et al.*, 2021). Banana is most valuable food crop of Pakistan, which may produce remarkable quantity, accounting for 87 percent of total region and 89 percent of total production. Sindh province produces 126.14 thousand tons of bananas and cultivated on 32.20 thousand hectares of land (Dahri *et al.*, 2020). The central zone of Sindh Tando Allahyar district contributes a large portion to Sindh's banana production areas, including Khairpur, Badin, Hyderabad, Mirpurkhas, and Sanghar, with an average yield of 36.46 t ha^{-1} reported through small land holder and 49.40 t ha^{-1} from progressive farmers (Dahri *et al.*, 2020). The Indus delta district of Sindh has the majority of banana-growing fields and soils of these districts suit to grow high quality of banana crop. Climate, especially temperature and light intensity, have an impact on the nutritional content of banana fruit and improve the test, quality and size of fruit (Nannyonga *et al.*, 2016).

Composting is one the major site plan on the basis of art and science to invest the organic inputs in to commercial organic fertilizer and reduce the environmental pollution. This is worldwide well-known cheapest source of organic fertilizer, which may improve physical, biochemical, and biological properties of soil. Furthermore, compost-based treatments may shield plants from disease and promote plant physiological status, resulting in increased nutrient uptake and crop yields (Lashari *et al.*, 2015; Liguori *et al.*, 2015). Plant derived organic waste is a significant commercial, financial and

social element in agriculture. Biomass waste, in particular, is a vast pool of materials that can be recovered using various methods and used to make numerous types of compost fertilizers (Chojnacka, 2020). Farmers are forced to look for new supplies of organic substances for the purpose of providing nutrients as industrial farms get more specialized and the production of natural fertilizers from the source of manure and minimize the investment on inorganic fertilizers and reduce the environmental pollution (Rajput *et al.*, 2017; Chen *et al.*, 2018).

Meat and bone meal (MBM) is an agricultural by-product that includes large quantity of phosphate, calcium, microelements, and organic compounds, in addition to protein. Phosphorus is used in MBM in two forms: soluble organic form (meat fraction) that is partially accessible to plants, and apatite (bone fraction) that is not bone fraction. Hydrogen ion is required for the release of phosphorus from apatite (Hu *et al.*, 2018). Phosphates are a poor source of accessible phosphorus for crops. Bone meals are a better source of available phosphorus for crops. Meat and bone meal (MBM) also has a strong calcium level, making it a viable liming alternative (Vamvuka *et al.*, 2018). Bone meal is a high-phosphorus, granulated source of phosphorus that is simple to apply and absorb by plants (Stepien *et al.*, 2021). The use of phosphorus promotes and balanced root systems up to 14%, while the role of calcium is up to 24%. But the use of bone meal compost is still not evaluated as per its benefits and uses in agriculture. In this research the use benefits of bone meal compost have been highlighted, which may not be reported previously in Sindh soils used for banana cultivation.

Materials and Methods

Site descriptions and soil properties: The study was conducted at the field of Bio-saline Agriculture Centre, Department of Soil Science, Faculty of Crop Production, Sindh Agriculture University, Tandojam. The field geographically located ($25^0$26.435'N, $68^0$33.216'E), non saline ECe 0.89 dS m^{-1}, pH 7.84, soil organic carbon 9.63, low in nitrogen 4.37 g kg^{-1}, medium in phosphorus 3.93 g kg^{-1}, potassium 131 mg kg^{-1} and belongs to medium in texture (clay loam) as indicated (Table 1).

Planting of banana plants: Three months old Basri banana variety suckers were initially separated from their mother's plants. After compression of homogeneity of suckers such as age, length, size and weight were transplanted in the field at the distance of (6×6) feet from plants to plants. Moreover, 60 banana plants were raised in the field up to 7 months for recording the observations against treatments.

Preparation and analysis BMC: Bone meal was collected from the slaughterhouse, grinded and composted using 1:1 ration bone meal and fresh soil. The collected material was covered with green fiber net and left it for 45 days for composting periods. Almost after 45 days the bone meal compost became and was ready to use. Prior to use the properties of bone meal compost were analysed using prescribed laboratory techniques and properties composition shown (Table 1). The bone meal compost used in the experiment was slightly alkaline having pH 7.45, low bulk density 0.62 g cm^3, rich in carbon, calcium, nitrogen and other trace elements.

Irrigation water used: The canal water was used for irrigation as flooding basin irrigation to each banana plant under field system. The management practices were done to avoid the loss of added bone meal compost with the addition of irrigation water to other untreated plants available nearby. The chemical properties of irrigation water were suitable for banana crop as shown in table 1.

Table 1. Physical and chemical properties of the soil (0-20 cm), bone meal compost and water used for irrigation purpose to banana plants.

Attribute	Soil	Bone meal compost	Water
Electrical conductivity (dS m^{-1})	0.89 ± 0.17	3.60 ± 0.51	0.93 ± 0.18
pH	7.84 ± 0.13	8.45 ± 0.32	7.21 ± 0.53
Bulk density (g cm^{-3})	1.31 ± 0.12	0.62 ± 0.11	NA
Organic carbon (g kg^{-1})	9.63 ± 0.73	106.32 ± 4.29	NA
Total nitrogen (g kg^{-1})	4.37 ± 0.51	26.30 ± 1.23	NA
Available phosphorus (mg kg^{-1})	3.93 ± 0.19	63.71 ± 3.58	0.84 ± 0.04
Available potassium (mg kg^{-1})	131 ± 6.35	3.47 ± 0.37	35.78 ± 2.61
Sulfur (mg kg^{-1})	2.84 ± 0.13	15.35 ± 1.52	NA
Zinc (mg kg^{-1})	1.93 ± 0.11	0.27 ± 0.03	NA
Iron (mg kg^{-1})	2.14 ± 0.14	6.75 ± 0.51	NA
Calcium carbonate %	9.48 ± 0.42	3.27 ± 0.41	NA
Chlorides (meq L^{-1})	5.93 ± 0.92	NA	7.46 ± 0.63
Calcium (meq L^{-1})	8.47 ± 0.23	153.82 ± 9.46	4.39 ± 0.42
Magnesium (meq L^{-1})	6.58 ± 0.31	7.29 ± 0.33	2.41 ± 0.21
Sodium (meq L^{-1})	18.73 ± 1.43	NA	13.25 ± 0.36
Cation exchange capacity	27.93 ± 2.36	NA	NA
Field capacity	21.57 ± 1.32	NA	NA
Sand (%)	33.60	NA	NA
Silt (%)	28.80	NA	NA
Clay (%)	37.60	NA	NA

Use of Bone meal compost: The bone meal compost was applied to transplanted banana suckers under field situations. The canopies areas of designed plants of each treatment were incorporated with bone meal compost using different treatments. In treatment control (CK1) bone meal compost (BMC) was not applied, only recommended dose of inorganic fertilizer was applied to selected banana plants. In treatment (CK2) bone meal compost (BMC= 7.0 t ha^{-1}) and no chemical fertilizer was added to the banana plants. In treatment three, the bone meal compost was applied (BMC = 7.0 t ha^{-1} with recommended NPK fertilizer ratio). The recommendation of chemical fertilizer was done after the analysis of soil used in the study and followed the recommended rate of fertilizer for banana crop. As per recommendation nitrogen was applied 300 kg ha^{-1}, phosphorus 250 kg ha^{-1} and potassium 500 kg ha^{-1}.

Leaf sampling and analysis: Banana leaves samples were collected after 7 months 10 days of the treated banana plants. The top fully developed central leaves were collected from randomly treated banana plants from each treatment. Collected leaves were washed with distilled water and ambient surface moisture was cleaned with the help of tissue paper. For analysis of banana leaf sap ion content were further processed, crushed and chopped into small pieces. The accurate 6.0 g of chopped leaves of banana were filled in Eppendorf centrifuge tube. The filled Eppendorf centrifuge tubes were placed in Deep Freezer for 2 weeks with adjusted temperature at -20ºC.

The frozen leaf samples were further homogenized using glass rod, centrifuged at 10000 × *g* for 20 mints to obtain the supernatant as the banana leaf sap. For total nitrogen and phosphorus analyses, 5 mL of the supernatant leaf sap was digested with concentrated H_2SO_4: H_2O_2 at 270ºC on an electric hotplate. For determination of Ca^{2+} and K^+, the leaf sap was diluted 1:50 with deionized water and measured directly using methods (Cuin & Shabala 2007; Chen *et al.*, 2007). For all the analytical work, a reference sample was processed with the same procedure in a single batch of measurement.

Soil sampling and analysis: Composite soil samples were collected from the canopy area of the randomly treated banana plants at the depths of 0-20 cm and 20-40 cm. The collected samples were brought to laboratory, processed and analysed for macronutrient in soil after harvest of crop.

Data processing and analysis: All collected data from the field study including soil and plants were expressed as mean ± SD. Observed data were processed using Microsoft Excel 2007 and statistical analysis was done with SPSS, version 16.0, 2001 (SPSS Institute, Chicago, IL, USA). Significance for differences between the treatment means was examined by one-way analysis of variance (ANOVA), with a probability defined at ($p<0.05$).

Results

Banana plant growth and development: The bone meal compost and inorganic fertilizer (BMC+IF) application significantly improve banana growth and development in compression of other treatment included in the study (Table 2). The maximum growth in sense of pseudostem height were increase by 26.73%, number of fully matured leaves of banana plants by 15.82%, leaf sheath lengths by 32.69%, leaf area index by 20.66% and stem girth by 38.47% was comparatively increased in treatment CK3, where BMC =7.0 t ha^{-1} and recommended inorganic fertilizer was added to the plants. However, the root length was decreased by 17.52% in treatment CK3, where BMC was applied with the rate of recommended chemical fertilizers to banana plants.

Soil nutrients availability: Soil samples were collected during the active growth stage of banana plant under field conditions from occupied canopy area of the plants. Composite samples were collected from each selected plants at the depths of 0-20 and 20-40 cm. Soil analysis was done for major nutrients such as NPK for nutritional status of soil. Findings of the results showed that status of the nutrients were improved with the use of bone meal compost (BMC+IF). The maximum availability of nitrogen, phosphorus and potassium were increased by 23.84%, 31.75%, and 43.82% at the depths of 0-20 cm, where the recommended chemical fertilizer (NPK) and bone meal compost (BMC) were applied to banana plants in treatment CK3 (Table 3). However, low nitrogen availability was observed in soil 17.45% in the treatment CK2 where only bone meal compost (BMC = 7.0 t ha^{-1}) was applied to banana plants. Moreover, the maximum soil phosphorus availability in soil was observed in treatment CK3 by 33.16% and potassium content were variable in all treated soil of banana crop. The maximum potassium contents were observed in CK3 followed by CK1 in compression of CK2 treatment at the depths of 0-20 cm. Furthermore, the very low nitrogen content at the depths of 20-40 cm were observed in treatment CK3 by 42.89%. However, the maximum availability of phosphorus by 33.16% and potassium by 40.62% were observed in treatment CK3 in soil at the depths of 20-40 cm.

Sap ion content: The ion availability in soil plays an important role related to the type of functional growth and development of plants. The majority of fruit bearing crop consume a large amount of these ion for metabolic functions and enzymatic activity. The value-added ions or primary food components display an important role related to the nutritional values and improvement of fruit quality. In the experimental findings the addition of bone meal compost and inorganic fertilizer played a prominent role for the improvement of ion content in banana leaves. The remarkable high content of nitrogen in banana leaf sap was observed in treatment CK3 by 38.29% in compression of CK2 and CK1 treatment (Fig. 1). In the case of phosphorus content in leaf sap also showed positive compression with the amendment of bone meal compost. The maximum phosphorus ion increase was observed in CK3 by 59.35% followed by CK2 over the control treatment CK1 (Fig. 2). However, the leaf sap potassium trend was different from the nitrogen and phosphorus content of leaf sap (Fig. 3). The maximum increases in leaf sap potassium were observed by 46.65% and 61.32% in CK1 and CK3 treatments. Banana fruit is also known as a high additive of calcium nutrition to human health for the strongest bones. So, the sap analysis was also performed for calcium content in sap of banana leaf. The study of leaf sap analysis showed that in the sap content calcium was increased in treatment CK3 and CK2 by 44.93% and 29.00% where bone meal compost was added to banana plant under field system.

Table 2. Effect of bone meal compost on growth related activities of banana plant.

Treatments	Pseudostem height	Number of leaves	Leaf length	Leaf area index	Stem girth	Root length
CK1	121.81 ± 4.12	7.87 ± 0.13	86.67 ± 8.43	4.32 ± 0.78	27.61 ± 3.40	26.67 ± 2.04ns
CK2	152.63 ± 12.53	8.42 ± 0.24c	121.72 ± 4.46	5.35 ± 1.62	37.67 ± 2.39	22.98 ± 1.98
CK3	166.23 ± 9.43	9.34 ± 0.51a	143.63 ± 6.42	6.79 ± 0.53	44.87 ± 3.76	24.33 ± 1.89

CK1: BMC=00 + recommended NPK (N=300, P=250 and K=500) kg ha^{-1}, CK2: BMC 7.0 t ha^{-1} and zero use of chemical fertilizer, CK3: BMC 7.0 t ha^{-1} + recommended NPK (N=300, P=250 and K=500) kg ha^{-1}, BMC= Bone Meal Compost, N= Nitrogen, P= Phosphorus, K= Potassium, Pseudostem height (cm), Number of leaves $plant^{-1}$, Leaf lengths (cm), Leaf area index (m^2), Stem girth (cm) and Root length (cm)

Table 3. Effect of bone meal compost on improvement of major nutrient content in soil after seven month.

Treatments details	Attribute	Soil depths (0-20 cm)	Soil depths (20-40 cm)
CK1: BMC=00 + recommended NPK (N=300, P=250 and K=500) kg ha^{-1}	Total nitrogen (mg kg^{-1})	7.25±0.64	3.35±0.11
	Available phosphorus (mg kg^{-1})	7.89±0.13	5.22±0.22
	Available potassium (mg kg^{-1})	267.95±11.53	156.64±7.39
CK2: BMC 7.0 t ha^{-1} and zero use of chemical fertilizer	Total nitrogen (mg kg^{-1})	5.67.37±0.52	3.87±0.31
	Available phosphorus (mg kg^{-1})	8.96±0.45	6.43±0.25
	Available potassium (mg kg^{-1})	178.42±7.49	115.53±5.63
CK3: BMC 7.0 t ha^{-1} + recommended NPK (N=300, P=250 and K=500) kg ha^{-1}	Total nitrogen (mg kg^{-1})	9.52±1.23	2.21±0.36
	Available phosphorus (mg kg^{-1})	11.56±0.84	7.81±0.62
	Available potassium (mg kg^{-1})	317.59±9.69	198.54±9.75

The data was integrated using composite soil samples (n=3) mean data presented in this table after standard deviations for representation of values

Discussion

Bone meal effect on banana growth: For the boasting of crop growth and yield potential many ingredients in the form of organic and inorganic may use as a source of fertilizer in the field. The effective uses of these organic products such as bone meal compost improve soil fertility, increase plant nutrition source in soil and boost an active growth of several beneficial soil organisms. In this study the use effects of bone meal compost were observed highly positive and showed significant effects on the growth and development of banana plants. The maximum pseudostem height, number of leaves, leaf length, leaf area index and stem girth were observed in appreciated amount and were comparatively higher in compression to all other treatments such as CK1, and CK2 (Table 2). The growth of banana plants with the amendment of organic bone meal compost was highly co-related with the findings of (Shi *et al.*, 2017; Luyima *et al.*, 2021). However, the leaf index and stem girth showed contrast activity with the finding of (Maharjan *et al.*, 2022). The finding of (Liu *et al.*, 2019) showed the non-significant effects of bone meal compost in compression of chemical fertilizers at the rate of 250 to 300 kg P_2O_5. In the experimental findings related amendment of bone meal compost integrated with chemical fertilizer showed effective performance related growth and development of banana plant. The single source use of bone meal compost at the rate of 7.0 t ha^{-1} could not prove effective and showed non-significant values.

Bone meal effect on ion uptake: Most of organic products and its amendments have highly positive effects on various plants related yield. However, the use of organic amendments may reduce different types of abiotic stresses, such as ionic toxicity, salt stress and water stress and other field-concerned problems. Moreover, some findings indicate the mechanisms and uses of organic biomolecules and bone meal compost are highly effective to increase the solubility and availability of specific ion in soil medium for plant uptake and reduce the toxic effects (Nogalska & Zalewska, 2013). In present study the effective growth-promoting ion in banana leaf sap were recorded highly significant at ($p>0.05$) with the combined use of bone meal compost with inorganic fertilizer recommended NPK (N=300, P=250 and K=500) kg ha^{-1} plus bone meal compost 7.0 t ha^{-1}. The maximum availability of leaf sap potassium 22.82%, phosphorus 59.35%, calcium 44.92% and nitrogen 38.29% were recorded in treatment CK3 in compression of CK2 and CK1. The finding of experimental results were co-related with the results reported by (Silvasy *et al.*, 2021), who observed high yield potential of sweet corn in clay loam soil with the use of bone meal compost at the rate of 5.0 t ha^{-1} with addition of inorganic fertilizer.

Improvement in soil properties: Bone meal compost is highly reactive in case of soil pH and considered highly effective to improve the soil pH especially in acidic soil when applied in sufficient quantity (Lazarovits *et al.*, 1999). In this experiment soil was slightly alkaline at the time of banana planting and application of bone meal compost. Soil reaction showed increase in soil pH, but non-significant effects were observed on the availability of other major ions. However, it was observed that bone meal compost improved the soil physical condition such as reduction in the hardness of soil that might be due to the compaction of soil layers and increase the absorption of water in soil (Assefa & Tadesse, 2019). The bone meal compost is well known conditioner for soil properties and used for gardening of soil. The soft condition of soil is preferred for the root penetration of plants and increases the area of uptake of available ion for banana plants. Bone meal is known as the richest source of phosphorus nutrition. Solubility of bone meal increases the availability of phosphates in soil medium. At early growing stage and at time of fruiting banana plants mostly require a maximum availability of phosphorus for required growth and development process (Andrade *et al.*, 2014). The addition of bone meal enriched the

availability of phosphorus into the soil may increase root elongation, avoid the banana plant from logging, root disease and increase soil microbial activity in rhizosphere (Mondini *et al.*, 2008). Our results of field study also showed a significant positive response of soil phosphorus. The maximum availability of soil phosphorus was observed in treatment CK3 (Table 3). Bone meal is a slow releasable material, which may avoid the losses of nitrogen in soil from applied fertilizer under extreme soil temperature and climatic conditions (Caldwell *et al.*, 2002). However, the finding of the experiment shows positive correlation of nitrogen in soil and banana leaf sap. The maximum increase in leaf sap nitrogen was observed in treatment CK3 by 38.29%, shown (Fig. 1) where bone meal compost was added 7.0 t ha^{-1} and recommended inorganic fertilizer. However, the positive response of was also observed with the application of bone meal compost plus inorganic fertilizer (Table 3). Our findings clearly demonstrate in reduction and losses of nitrogen, caused by leaching from surfaces (Jadon *et al.*, 2018). Bone meal compost does not contain admissible amount of potassium. But the addition of bone meal compost into the soil it may improve the soil conditions by the uptake of potassium in banana plants through added inorganic components of potassium. The finding of the results showed the great improvement in leaf sap potassium where bone meal compost was applied 7.0 t ha^{-1} compared to control treatment (Fig. 3). Nogalska., 2016 reported the highly positive response with the amendment of bone meal compost and in potassium content in dry matter of barley crop. Furthermore, it's observed that bone meal compost is highly reactive to the soil pH. The high rate of application may prone to increase soil pH and reduce the solubility of some major ions such as phosphorus due to high availability of Calcium hydroxide in soil (Hodson *et al.*, 2001). It was reported that the bone meal available source of phosphates might increase the uptake of phosphorus nutrition in plants (Nogalska *et al.*, 2012; Lashari *et al.*, 2013). Banana crop equally consume calcium as other major nutrients and majority of crops grown in alkaline types of soil (Bourassa *et al.*, 2022). In this experiment, amendment of bone meal compost showed the highly positive effect on the uptake of calcium in banana leaf sap at maturity stage of plants (Fig. 4). Available calcium as a primary nutrient consumed by various plant species and has a highly supporting role on the growth and yield of crops (Pilbeam and Morley, 2016). However, the findings of the experiment showed positive response of the bone meal compost in the availability of calcium in soil as well as in banana leaf sap.

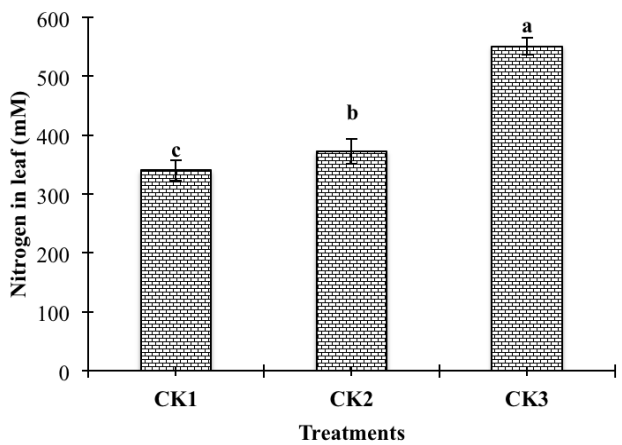

Fig. 1. Effect of bone meal compost on nitrogen content in banana leaf sap extract after seven months of the treated plants.

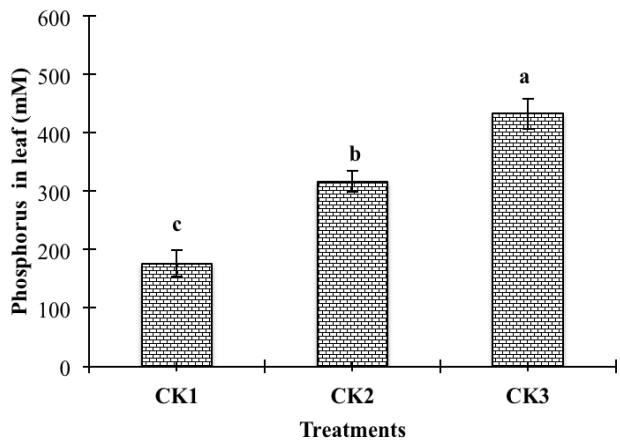

Fig. 2. Effect of bone meal compost on phosphorus content in banana leaf sap extract after seven months of the treated plants.

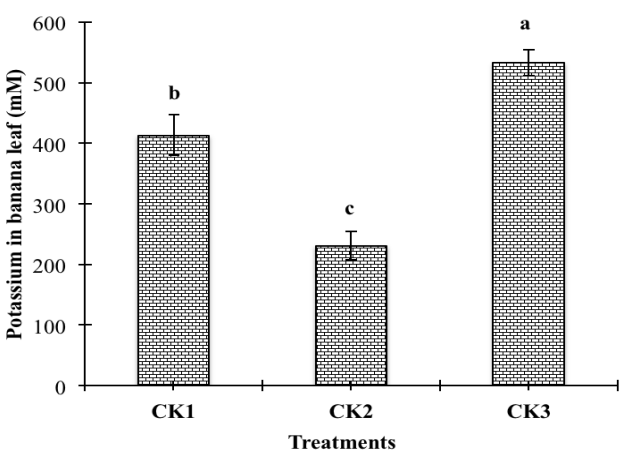

Fig. 3. Effect of bone meal compost on potassium content in banana leaf sap extract after seven months of the treated plants.

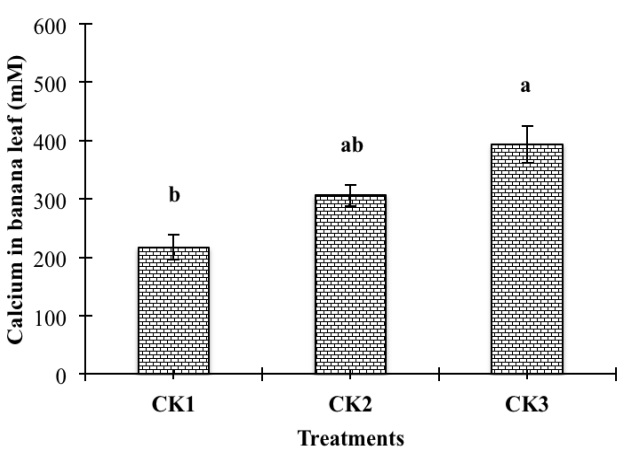

Fig. 4. Effect of bone meal compost on calcium content in banana leaf sap extract after seven months of the treated plants.

Conclusion

Banana plants are cultivated in medium type textured soil due to the fibrous root, having high absorption of water and air movement inside soil. For the management of high quality and quantity of fruit product it may require high amount of chemical fertilizer and several management practices. The finding of the experiments highlighted the challengeable results regarding the growth improvement of banana crop and soil nutrient availability to crop with the combine application of bone meal compost and inorganic fertilizer. Furthermore, findings also indicate improvement in ion content in banana leaf sap as well as in the top layers of soil with the addition of bone compost and recommended chemical fertilizers. Throughout the finding of the results, it may be suggested for combine application of organic fertilizer in form of compost may be derived from the source of bone meal have highly positive impact on the growth and development of banana crop and production under field condition.

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