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EVALUATING THE COMBINED EFFECT OF COMPOST AND MINERAL FERTILIZERS ON SOIL HEALTH, GROWTH AND MINERAL ACQUISITION IN MAIZE (*ZEA MAYS* L.)

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Abstract

This research study was conducted to sort out the beneficial effects of combined use of compost with mineral fertilizer on soil properties as well as growth and nutrient acquisition of maize. Therefore, after selection of normal soil, 10 kg soil was filled in each pot. For layout of study, 11 treatments with three replications were applied using Completely Randomized Design (CRD). The results revealed that the maximum plant height, plant dry matter (49.32 g), root length (29.58 cm) and organic matter (1.73%) of maize plants were recorded for recommended dose of NPK + compost @ 12 t ha^{-1} (T_8) whereas the minimum plant height, total biomass (23.67 g), root length (14.17 cm) and organic matter (0.68%) were noted in T_3 (compost @ 4 t ha^{-1}) compared to others. Maximum nitrogen contents in soil (0.087%), phosphorus concentration in soil (16.67 ppm), potassium concentration in soil (203 ppm) were recorded in T_8. The highest nitrogen contents of plants (3.17%), the highest phosphorus concentration of plants (1.05%) and the highest potassium concentration of plants (2.80%) were noted for T_8. Similarly, the maximum value of nitrogen concentration in maize root (3.11%), the maximum phosphorus concentration in root (0.97%) and the maximum potassium concentration in root (2.78%) were recorded in T8. Alone use of compost and chemical fertilizer remained the least effective, while the integrated use of compost@ 12 t ha^{-1} and mineral NPK (T_8) proved to be the best treatment.

Key words: Compost, Fertilizer, Growth, Maize, Soil characteristics, Yield components.

Introduction

One of the most cultivated cereals in Pakistan is maize (*Zea mays* L.) with production of 3.341 M tons from an area of 0.939 M ha (Economic Survey of Pakistan, 2016-17). It is an important cereal crop that has multiple uses for humans, animals and raw material for many industries (Shahzad *et al*., 2019). Maize grains are also nutritious containing high content of starch, protein, vitamins and oil etc. It also contains plenty of nutrients like N, P, Ca and Fe (Arain, 2013). It has many uses in industries such as manufacturing of corn oil, cosmetics, wax, alcohol etc. (Ahmad & Rehman, 2007).

Composting is the process by which organic matter is decomposed biologically into stable product by the action of microorganisms in the presence of air (Smith & Collins, 2007). During this process, conversion of organic material into stable products is carried out which can serve as good source of soil organic matter (Raza & Jalil, 2016). It is cheap and environmentally benign method of waste management. It is a process in which organic waste material is biologically changed into amorphous humus that can be kept and applied without any environmental effects (Al-Bataina *et al*., 2016; Mengistu *et al*., 2018). Compost being enriched with essential nutrients, improves soil physio-chemical properties as well as soil health (Kranz *et al*., 2020). Up gradation of soil organic matter content and resultantly, betterment in water movement, soil water content, aeration, soil structure and nutrient supplying capacity of soil take place by the application of compost. Compost incorporation also increased soil microbial activity (Elsayad & Khater, 2015; Beck-Broichsitter *et al*., 2018).

In Pakistan, maize yield is relatively less in contrast to other countries. There are several reasons for this reduced yield including poor nutritional status of soil, shortage of water etc. Therefore, artificial application of nutrients NPK in organic (compost) or mineral (fertilizers) form is mandatory for getting better yield of maize (Eltelib *et al*., 2006).

Use of organic nutritional sources performs dual function as they not only provide nutrients but also improve soil properties for getting high crop yield (Beck-Broichsitter *et al*., 2018). Synergistic use of organic and mineral fertilizers performed better when used in combination (Sabah *et al*., 2016). The beneficial effects of the organic source thus compel to be combined along with fertilizer to improve the efficiency of the later one and recycle certain natural nutrient pools to promote sustainable soil fertility and crop production (Moe *et al*., 2019). Judicious use of mineral and organic nutritional sources limits the reliance on costly chemical fertilizers but also contribute toward achieving sustainability in agriculture (Ning *et al*., 2017).

Mineral fertilizers application is mandatory for overcoming nutrient deficiencies in soils. But being costly input poor farmers are unable to afford them. Similarly, present scenario of energy crisis and unavailability of mineral fertilizers at time when required by crops make it compulsory to employ organic sources of nutrients in the form of composts, organic manures, poultry droppings, green manures and crop leftovers etc. in addition to mineral fertilizers (Elsayad & Khater, 2015). Ultimate task of every grower is to get higher yield and lowering the cost of production. To achieve this task, scientific community is adopting innovative farming methods such as organic farming, integrated nutrient management etc. (Antil, 2012; Dhaliwal *et al*., 2019). Therefore, present study was designed to check improvement in soil health and growth and mineral acquisition of maize by combined use of compost and mineral fertilizers.

Materials and Methods

Treatments and layout of study: In order to testify an improvement in soil health and growth and mineral acquisition of maize by combined use of compost and mineral fertilizers, a pot study was performed at CoA, UOS in 2014. After choosing soil with desired characteristics (Table 1), pots were filled @ 10 kg of soil. Compost was prepared and analyzed before application to the soil (Table 3). Compost was incorporated in pots 20 days before sowing as per treatment plan for proper decomposition. Collection of soil samples was performed and then samples were prepared for different analyses following the protocols suggested by Handbook 60. Three replications of various treatments of the study were used including T1 = NPK @ 160: 80: 60 kg ha^{-1}(Control); T2 = ½ recommended NPK; T3 = 4 t $ha^{-1}$of compost; T4 = 8 t $ha^{-1}$of compost; T5 = 12 t $ha^{-1}$of compost; T6 = T1+ 4 t $ha^{-1}$of compost; T7 = T1 + 8 t $ha^{-1}$of compost; T8 = T1 + 12 t $ha^{-1}$of compost; T9 = T2 + 4 t $ha^{-1}$of compost; T10 = T2+ 8 t $ha^{-1}$of compost and T11 = T2 + 12 t $ha^{-1}$of compost.

Crop husbandry: Sowing of five seeds of FM3 maize variety was done in all pots. Later on, only 3 plants were raised was raised till maturity and then harvesting was carried out. Collection of soil and plant samples (roots and shoots) from each pot was performed followed by sample preparation and subsequent analysis in laboratory. Irrigation was performed (analysis of water Table 2) according to the need of crop.

Table 1. Soil characteristics used in experiment.

Characteristics	Unit	Value
pH	-	7.92
ECe	dSm^{-1}	1.78
Organic matter %	%	0.77
HCO_3^-	mmol c L^{-1}	3.06
Available K (d)	ppm	349
Phosphorus (e)	ppm	8
SO_4^{+2}	mmolc L^{-1}	5.81
Na	mmolc L^{-1}	14
$CaCO_3$ (c)	%	3.95
Sand	%	45.1
Silt	%	26.8
clay	%	28.1
Textural class (a)	-	Sandy clay loam

Table 2. Analysis for irrigation water used in experiment.

Characteristics	Values	Unit
ECe	0.88	dsm^{-1}
Total soluble salts (TSS)	7.78	mmolc L^{-1}
Carbonates (CO_3^{2-})	Nil	mmolc L^{-1}
Bicarbonate (HCO_3^-)	6.2	mmolc L^{-1}
Chlorides (Cl^-)	1.4	mmolc L^{-1}
Sulphate (SO_4^{2-})	0.17	mmolc L^{-1}
Calcium + magnesium	2.41	mmolc L^{-1}
Sodium	5.36	mmolc L^{-1}
Sodium adsorption ratio (SAR)	4.9	$(mmolc\ L^{-1})^{1/2}$
Residual sodium carbonates (RSC)	3.79	mmolc L^{-1}

Table 3. Analysis of compost used in experiment.

Characteristics	Values	Unit
Total N	2.0	%
Organic content	24.5	%
Potassium	1.9	%
phosphorus	2.9	%
Ca	1.6	%
Mg	0.7	%
Zn	170	ppm
B	36	ppm

Sample preparation and analysis: Soil and plant samples were collected from each pot and then shifted to laboratory where samples were oven dried and prepared for different chemical analyses using protocols as suggested by Handbook 60 (U.S Salinity Laboratory Staff, 1969). Determination of organic matter percentage in soil samples was done by employing method reported by Walkley & Black (1934). Plant samples were oven dried at 80°C followed by particle size reduction using grinding mill. Wet digestion of plant samples was done on hot plate using mixture of nitric acid and perchloric acid (1:2). After sample preparation, nitrogen content of plants was determined by Kjeldahl method (Bremner & Mulvaney, 1996). While P (Watnabe & Olsen, 1965) and K (Method 18, P 100, Handbook 60) concentrations was determined using spectrophotometer (Beckman photometer 1211) and flame photometer (Jenway Model PFP-7).

Statistical analysis: Analysis of Variance (ANOVA) was calculated for all set of data (Steel *et al*., 1997) using software Statistics 8.1. Comparison of means was performed using Least Significant Difference test.

Results and Discussion

Plant height (cm): Plant height of any crop is a key agronomic parameter contributing to yield. Data revealed that compost incorporation in any case (sole or combined with mineral fertilizers) significantly increased the plant height. However, it is the integrated use of compost with recommended rate of NPK that performed best in terms of increasing plant height (Fig. 1). Height of maize plants was maximized up to 100 cm in T_8 (recommended dose of NPK + compost @ 12 t ha^{-1}) in contrast to height of 69 cm noted for T_3 (compost @ 4 t ha^{-1}). Significant differences were noted between T_1 (NPK at recommended rate) and T_2 (NPK at ½ recommended rate). A slight increase in plant height for T_2 (73.33 cm) was noted which was more than T_3 (69.92 cm). However, difference of plan height in these two treatments was non-significant statistically. Similar trend was noted for treatments T_4 (compost @ 8 t ha^{-1}) and T_9 (T_2 + compost @ 4 t ha^{-1}) as both these two treatments indicated plant height of 75.92 and 75 cm respectively. Results showed that treatments T_6, T_7 and T_{11} remained at par with each other indicating values of 91.50, 96.75 and 92.92 cm respectively. Application of compost proved better when coupled with chemical fertilizer. Findings of pervious researchers also confirmed these results (Sheikh *et al*., 2000; Sabah *et al*., 2016; Sabah *et al*., 2018).

Total biomass (g): Data indicated that total biomass of maize plants enhanced by integrated application of compost and mineral fertilizers as compared to those pots receiving only compost or mineral fertilizer (Fig. 2). Minimum biomass (23.67 g) was noted in T_3 receiving 4 t ha^{-1} of compost. Whereas, maximum value (49.32 g) was recorded in T_8 (T_2 + 12 t ha^{-1} of compost). Significant differences were noted between T_1 (recommended dose of NPK) and T_2 (half recommended dose of NPK). A slight increase in biomass for T_2 (28.33 g) was noted which was more than T_3 (23.66 g). However, difference of plant dry weight in these two treatments was non-significant statistically. Similar trend was noted for treatments T_4 (compost @ 8 t ha^{-1}) and T_9 (T_2 + compost @ 4 t ha^{-1}) and both these two treatments indicated plants dry weight 32.33 and 32.0 g respectively. Finding of Coulibaly *et al.*, (2019) also support these results by concluding that use of compost caused greater grain and fodder yields of maize. Similarly, Aziz *et al.*, (2010) also reported the effectiveness of integrated use of compost and mineral nutrients for improvement of maize yield.

Root length (cm): Integrated effect of compost and mineral fertilizers on root length of maize plants is presented in (Fig. 3). Use of compost indicated significant effect on root length of maize plants. Minimum root length (14.17 cm) was noted in T_3 (compost @ 4 t ha^{-1}). On the other hand, maximum value of root length (29.58 cm) was noted for T_8 (T_1 + compost @ 12 t ha^{-1}). Significant differences were noted between T_1 (NPK at recommended rate) and T_2 (NPK at ½ recommended rate). A little increase in root length of T_2 (15.0 cm) when compared with T_3 (14.17 cm). However, difference of root length in these two treatments was non-significant statistically. Similar trend was noted for treatments T_4 (compost @ 8 t ha^{-1}) and T_9 (T_2 + compost @ 4 t ha^{-1}) as both these two treatments indicated root length 16.25 and 17.0 cm respectively. Results showed that treatments T_6 (T_1 + Compost@ 4 t ha^{-1}) and T_{11} (T_2 + compost@ t ha^{-1}) remained at par with each other indicating values 23.25 and 24.75 cm respectively. Our findings are similar to the conclusions of Sabah *et al.*, (2018) who determined that collective application of small amount of inorganic fertilizers and compost increased maize yield parameters. *Shah et al.*, (2007) also reported an enhancement in root growth when compost was applied with mineral fertilizers.

Soil organic matter (%): A useful indicatory of nutritional status of soil is organic matter. Results related to effect of compost and mineral fertilizers on soil organic matter fractions are depicted in (Fig. 4). This effect was found positive when application of compost was done either separately or in integration with mineral fertilizers. The lower most soil organic matter content (0.68 %) was recorded in T_2 (NPK at ½ recommended rate). On the other hand, highest level of 1.73 % organic matter was found in T_8 (T_1 + Compost @ 12 t ha^{-1}). Treatments T_1 (0.89), T_3 (0.81), T_4 (0.82), T_5 (0.89), T_6 (1.08), T_7 (1.28), T_9 (0.86), T_{10} (0.97) and T_{11} (1.16 %) revealed significant differences when compared with each other. It was observed that organic content of soil was more where the application of compost was more. Findings of that this research study were in same direction of pervious researchers like Sarwar (2005), (Sabah *et al.*, 2016) and Sarwar *et al.*, (2020) who stated that soil organic matter status up graded by use of compost.

Soil nitrogen contents (%): Results concerning integrated effect of compost and mineral fertilizers on nitrogen percentage of soil (Fig. 5) revealed considerable alteration regarding nitrogen content in the soil when adjudged statistically. Treatment receiving 4 t ha^{-1} of compost (T_3) proved inferior to all other treatments in terms of soil nitrogen percentage (0.03%). On the other hand, treatment receiving 12 t ha^{-1} of compost in addition to mineral fertilizer at recommended rate (T_8) rate proved superior in this regard with value of 0.08% nitrogen content. It was noticed that better results were achieved where combined application of compost with mineral fertilizers was done as compare to their sole use. Literature suggested that compost contain significant quantities of phosphorus, nitrogen, and potassium and it also contains carbon that can raise the organic matter fraction in soils (Chivenge *et al.*, 2011; Jothimani & Sangeetha, 2012; Sabah *et al.*, 2016; Sarwar *et al.*, 2020).

Soil phosphorus contents (ppm): Phosphorus performs critical roles in many important processes in plants. A significant improvement in soil P content was noticed by incorporation of compost at different rate with and without mineral fertilizers (Fig. 6). Treatment T_8 receiving 12 t ha^{-1} of compost along with mineral fertilizer at recommended rate performed best in terms of increasing phosphorus concentration showing value of 16.67 ppm while, lowest concentration of P was observed in treatment T_2 where mineral fertilizers were applied at half recommended rate. Treatments T_1 (NPK at recommended rate), T_2 (NPK at ½ recommended rate) and T_3 (4 t ha^{-1} of compost) remained at par statistically. Findings of other scientists also favored these results suggesting that it is the integrated use of compost in different combinations with mineral fertilizers that performed better than their sole use (Rautarary *et al.*, 2003). Sabah *et al.*, (2016), Sabah *et al.*, (2018) and Sarwar *et al.*, (2020) also suggested that compost use improved soil organic matter and subsequently P, Ca^{2+}, Mg^{2+} and, K^+ concentrations.

Soil potassium contents (ppm): Improvement in soil potassium concentration by combined use of compost and mineral fertilizers was depicted in (Fig. 7). The effect was found positive in terms of soil potassium concentration. Highest K content (203 ppm) was observed for T_8 (recommended dose of NPK + Compost @ 12 t ha^{-1}) followed by T_{11} (T_2 + 12 t ha^{-1} of compost) with value of 197 ppm and lowest soil K content (109 ppm) was recorded in T_2 (NPK at ½ recommended rate). It was observed that potassium concentration was more where the dose of compost was more. Results and findings of previous researchers are also in the same direction. Bokhtiar & Sakurai (2005) noted an increase in calcium, potassium, copper, magnesium, phosphorus, manganese, zinc and iron concentrations with the use of organic manure versus inorganic fertilizers. Sarwar *et al.*, (2020) also stated that combine use of compost and chemical fertilizers would be capable in maintaining better soil fertility status.

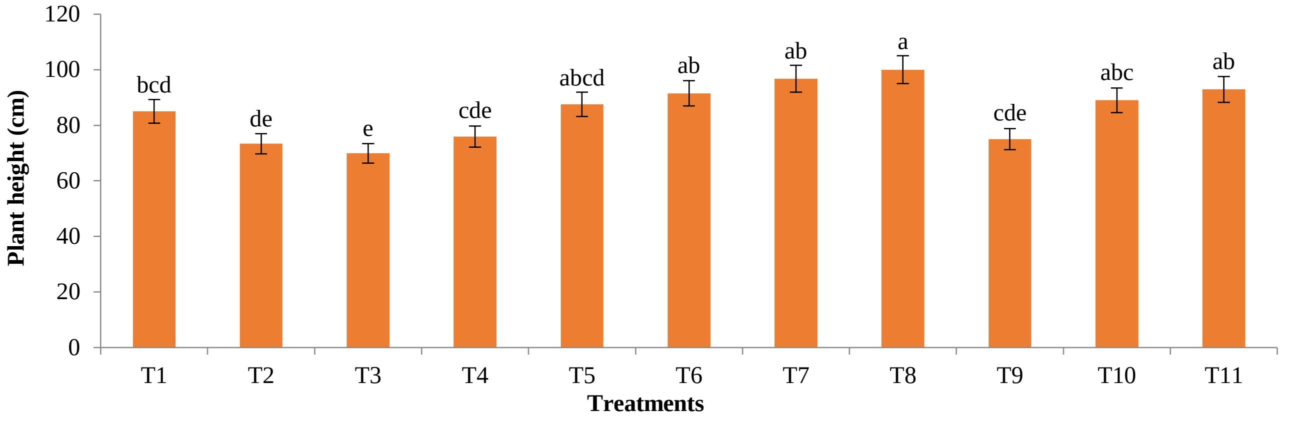

Fig. 1. Integrated effect of compost and mineral fertilizer on plant height (cm) in maize.

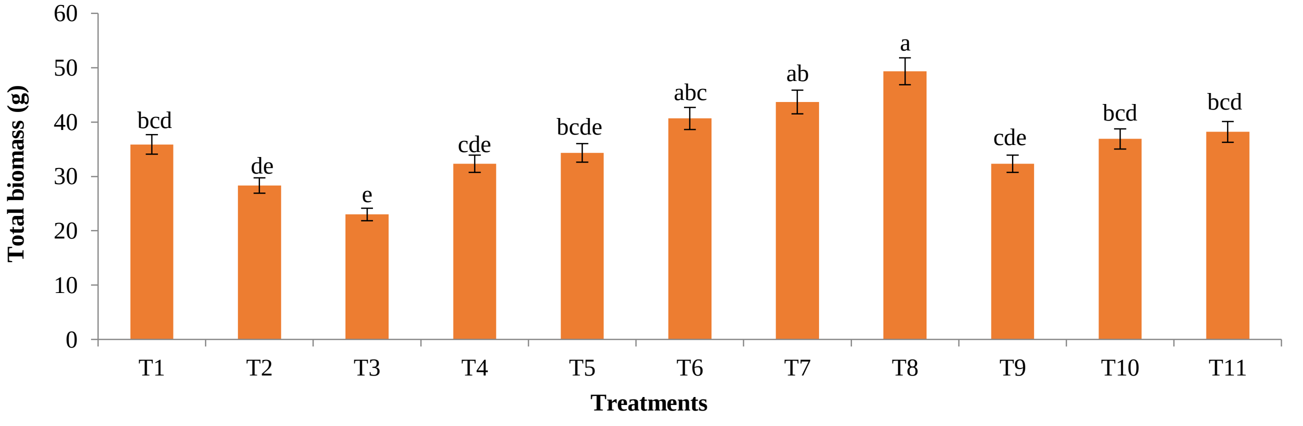

Fig. 2. Integrated effect of compost and mineral fertilizer on total plants biomass (g) in maize.

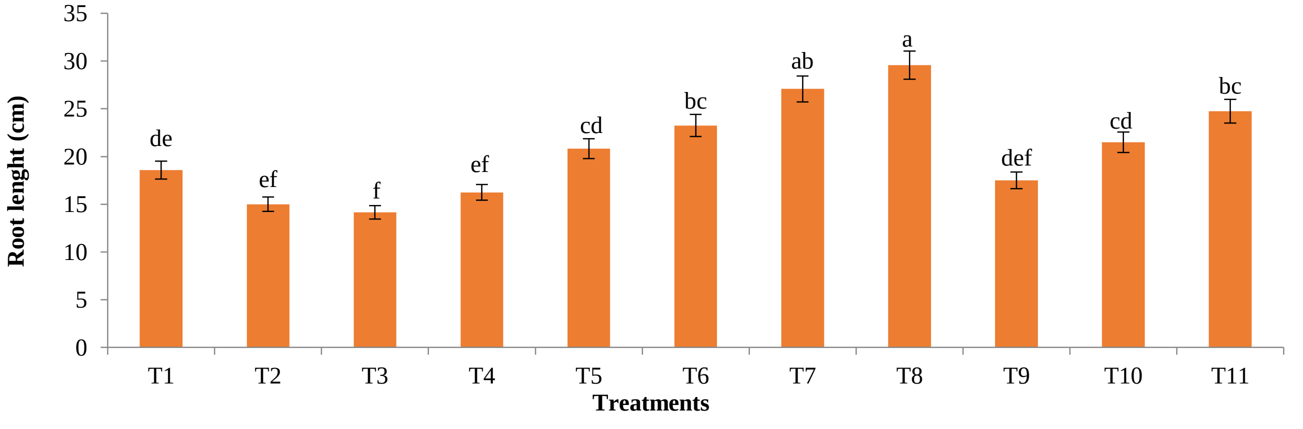

Fig. 3. Integrated effect of compost with mineral fertilizers on root length (cm) in maize.

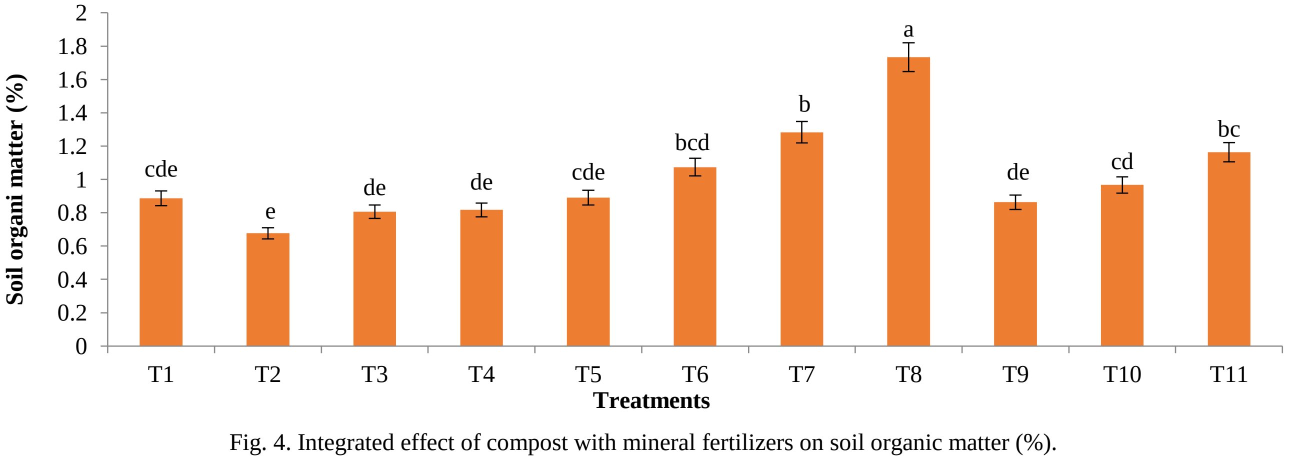

Fig. 4. Integrated effect of compost with mineral fertilizers on soil organic matter (%).

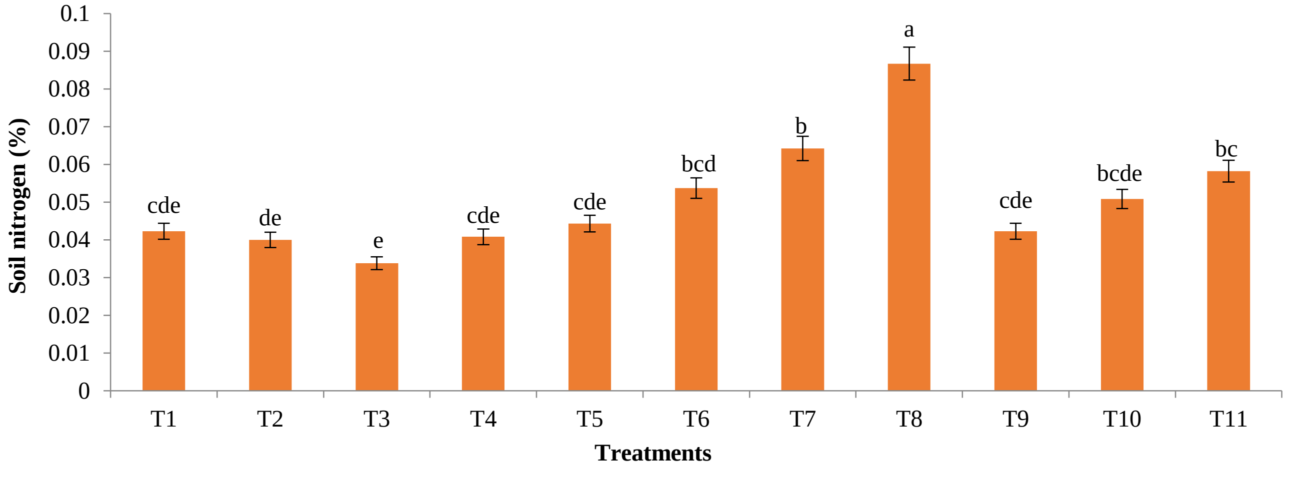

Fig. 5. Integrated Effect of compost with mineral fertilizers on soil nitrogen (%).

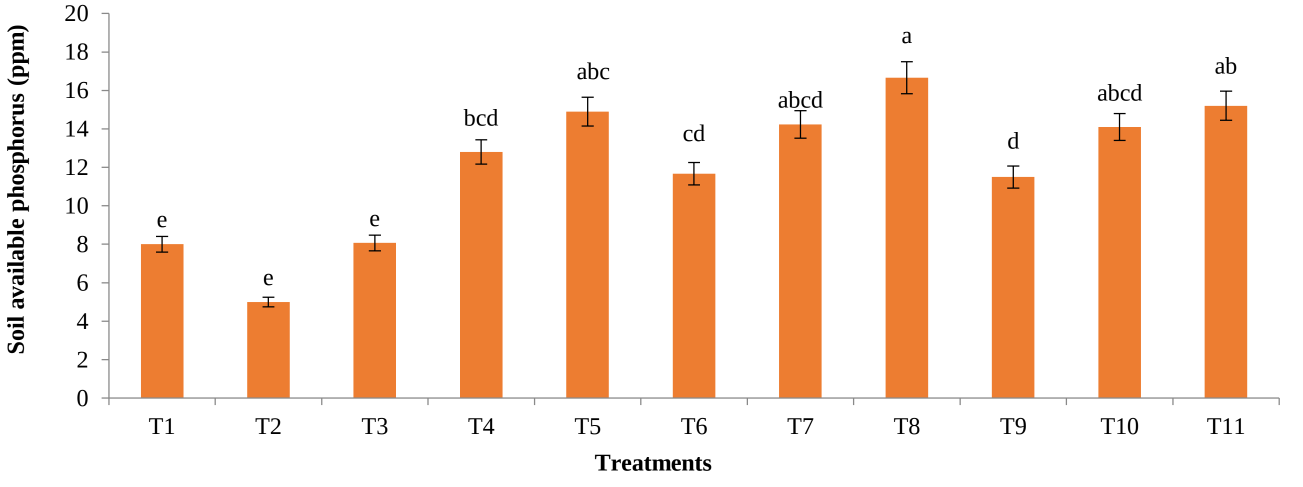

Fig. 6. Integrated Effect of compost with mineral fertilizers on available phosphorus (ppm).

Nitrogen concentration in maize plants: Integrated effect of compost and mineral fertilizers on nitrogen concentration of maize shoot has been presented in (Fig. 8). The lowest value of shoot nitrogen content was noticed in T_3 (compost @ 4 t ha^{-1}) showing level of 0.71%. Maximum value of nitrogen 3.17% was noted for T_8 (T_1+ compost @ 12 t ha^{-1}) followed by T_7 (T_1+ compost @ 8 t ha^{-1}) with a value of 2.98%. A minor increase in nitrogen concentration for T_2 (0.89) was noted which was more than T_3 (0.71%) but difference of these two treatments was non-significant statistically. Significant differences were noted between T_1 (NPK at recommended rate) and T_2 (NPK at ½ recommended rate). Bokhtiar & Sakurai (2005), Sabah *et al.*, (2018) also reported the same. Similarly, Sial *et al.*, (2007) findings also favored results of this study.

Phosphorus concentration in maize plants: A significant improvement in maize P concentration by use of compost in integration with mineral fertilizers was depicted in (Fig. 9). Minimum phosphorus concentration (0.19%) was found in T_2 (NPK at recommended rate). Maximum phosphorus concentration 1.05% was noted for T_8 (T_1 + compost @ 12 t ha^{-1}). There were significant differences among treatments T_3 (compost @ 4 t ha^{-1}), T_4 (compost @ 8 t ha^{-1}), T_6 (T_1 + Compost @ 4 t ha^{-1}), T_8 (T_1 + compost @ t ha^{-1}), T_9 (T_1 + compost @ 4 t ha^{-1}), T_{10} (T_2 + compost @ 8 t ha^{-1}) and T_{11} (T_2 + compost @ 12 t ha^{-1}). Findings of Ahmad *et al.*, (2007), Sabah *et al.*, (2018) and Sarwar *et al.*, (2020) also indicated that nutrient concentrations in leaves of maize were improved with organic manure than with mineral fertilizer alone.

Potassium concentration in maize plants: Results concerning integrated effect of compost and mineral fertilizers on maize shoot potassium content (Fig. 10) revealed that there was a significant alteration regarding maize shoot potassium content when adjudged statistically. Highest noted value for maize shoot potassium content was 2.80% in T_8 (T_1 + compost 12 t ha^{-1}) and lowest potassium concentration maize shoot (1.80%) was found for treatment T_2 (NPK at ½ recommended rate). It was noticed that concentration of potassium was gradually enhanced with the increase of compost dose and the best results were obtained by combined use of compost and fertilizers. (Bokhtiar & Sakurai, 2005) and Sial *et al.*, (2007) also reported an improvement in NPK contents of maize plant as a result of integrated use of compost and mineral nutritional sources.

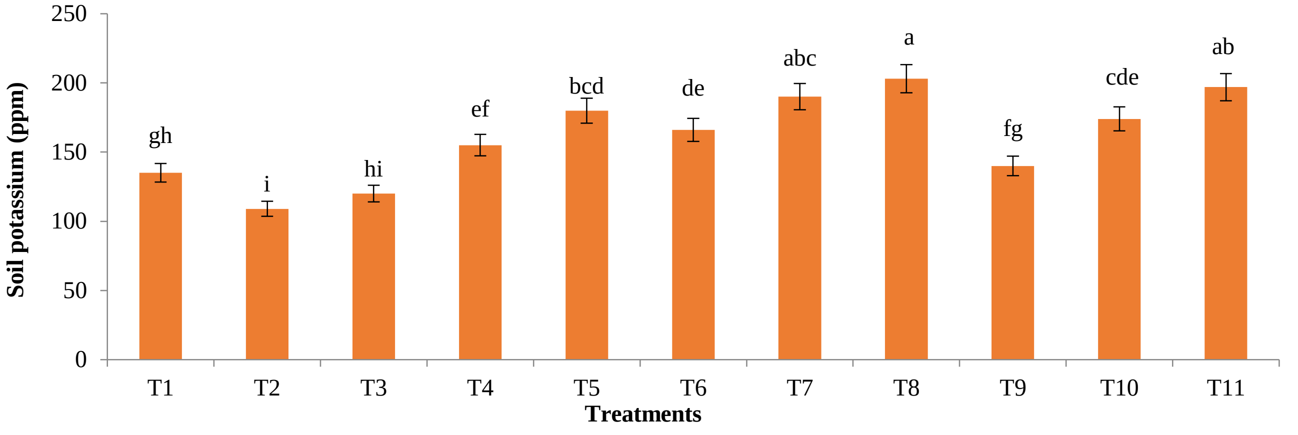

Fig. 7. Integrated Effect of compost with mineral fertilizers on potassium concentration in soil (ppm).

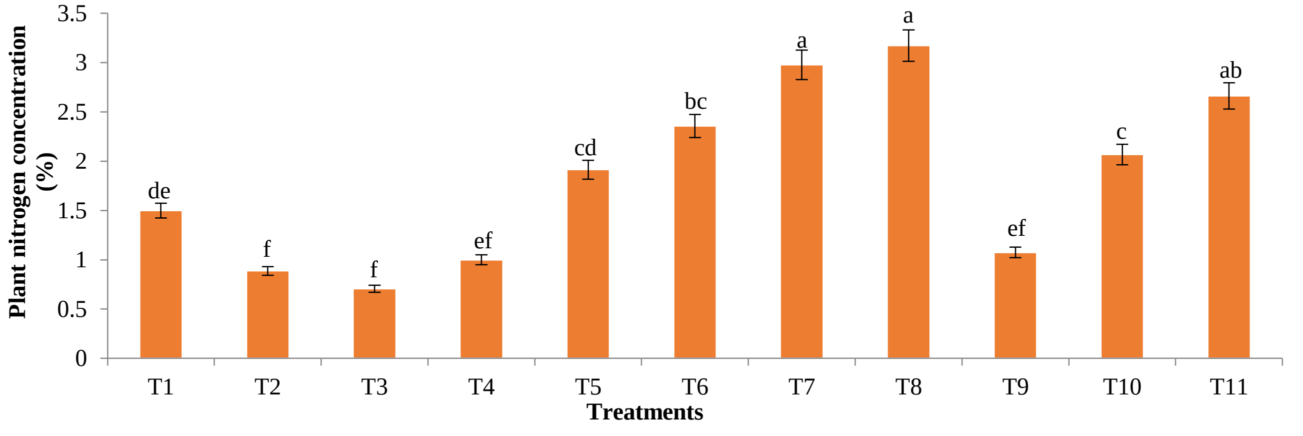

Fig. 8. Integrated effect of compost with mineral fertilizers on nitrogen concentration in maize plants (%).

Nitrogen concentration in roots of maize plants (%): A significant improvement in N concentration of maize root by integrated use of compost and mineral fertilizers was depicted in (Fig. 11). Minimum N concentration (0.68 %) was found in T_3 (compost @ 4 t ha^{-1}) that was reached to maximum value of N concentration 3.11 % was noted for T_8 (T_1 + compost @ 12 t ha^{-1}). Treatment T_7 (T_1 + compost @ 8 t ha^{-1}) stand next in this regard showing a value of 2.94% nitrogen. A minor increase in nitrogen concentration for T_2 (0.86) was noted which was more than T_3 (0.68%) but difference of these two treatments was also non-significant statistically. Significant differences were noted between T_1 (NPK at recommended rate) and T_2 (NPK at ½ recommended rate). Integrated use of compost and chemical fertilizers proved better than single application of compost and NPK fertilizers. Results of Shah *et al*., (2007) also supported these findings regarding improvement in N % by application of compost treatment. Similarly, it was concluded that mineral fertilizer + compost performed better in boosting maize nutrient content (Zhang *et al*., 2000).

Phosphorus concentration in roots of maize plants (%): Results concerning effect of compost and mineral fertilizers on maize root P content (Fig. 12) revealed considerable enhancement in root P content of maize when adjudged statistically. Highest noted value for root P content was 0.97 % in T_8 (T_1 + compost 12 t ha^{-1}) and lowest P concentration of maize root (0.18%) was found for treatment T_2 (NPK at ½ recommended rate). Compost incorporation improved soil organic matter content and other characteristics that contribute to better growth environment for plant with improved nutrients uptake (Sarwar *et al*., 2020). Ribeiro *et al*., (2007) also stated that nutrient uptake by roots, chlorophyll content, root vigor and soluble sugar were enhanced through the use of compost.

Potassium concentration in roots of maize plants (%): An improvement in potassium concentration of maize roots by addition of compost and inorganic fertilizers was presented in (Fig. 13). Results indicated that use of chemical fertilizers with compost positively affected potassium uptake by maize roots. Maximum potassium concentration of 2.78% was noted for T_8 (T_1 + compost 12 t ha^{-1}) and minimum potassium concentration in plant roots (1.76%) was noted for treatment T_2 (NPK at ½ recommended rate). Treatments T_3 (compost @ 4 t ha^{-1}), T_6 (T_1 + Compost@ 4 t ha^{-1}) and T_9 (T_2 + compost @ 4 t ha^{-1}) proved to be significant statistically. However, treatments T_1 and T_4 (compost @ 8 t ha^{-1}) remained at par in term of statistics. In the same way, T_7 (T_1 + compost @ 8 t ha^{-1}) and T_{11} (T_2 + compost @ 12 t ha^{-1}) were also at par statistically. But the concentration of potassium was gradually enhanced with the increase of compost dose and the best results were obtained by combined use of compost and fertilizers. Warman and Termeer (2005) and Mantovi *et al*., (2005) also claimed that nutrient acquisition of maize plant increased with the use of compost.

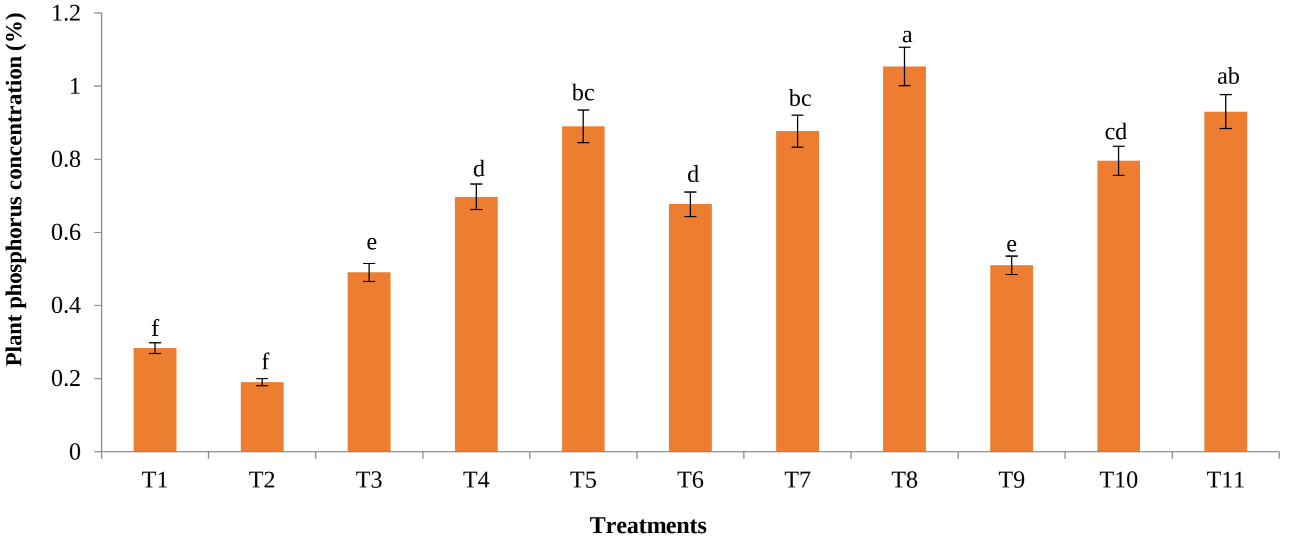

Fig. 9. Integrated effect of compost with mineral fertilizers on phosphorus concentration in maize plants (%).

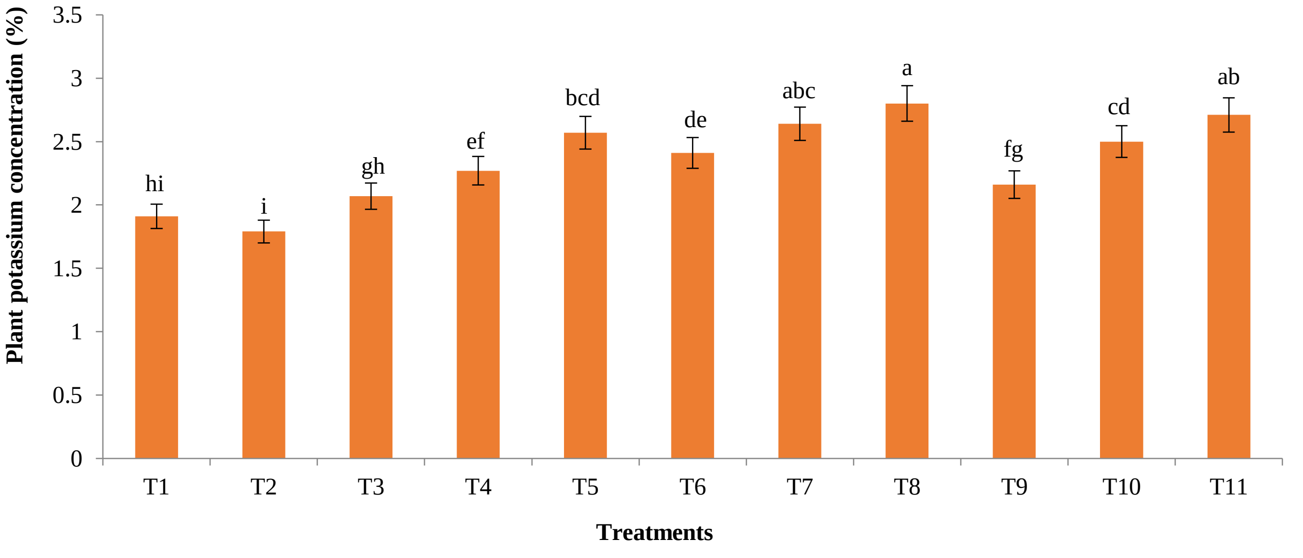

Fig. 10. Integrated effect of compost with mineral fertilizers on potassium concentration in maize plants (%).

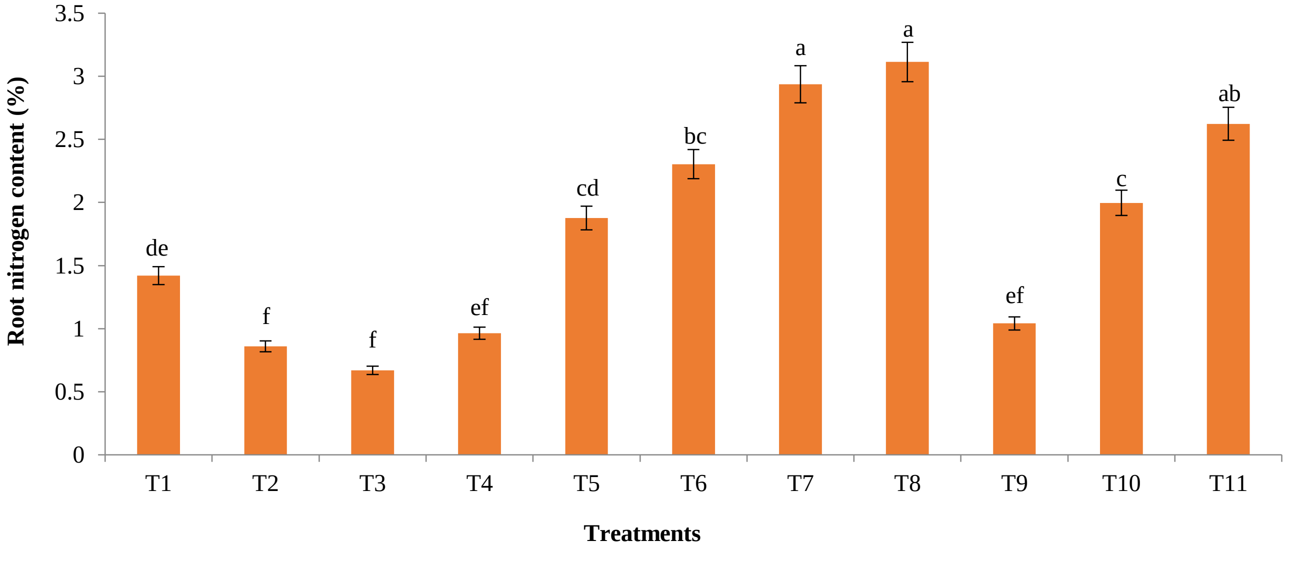

Fig. 11. Integrated effect of compost with mineral fertilizers on N concentration in roots of maize plants (%).

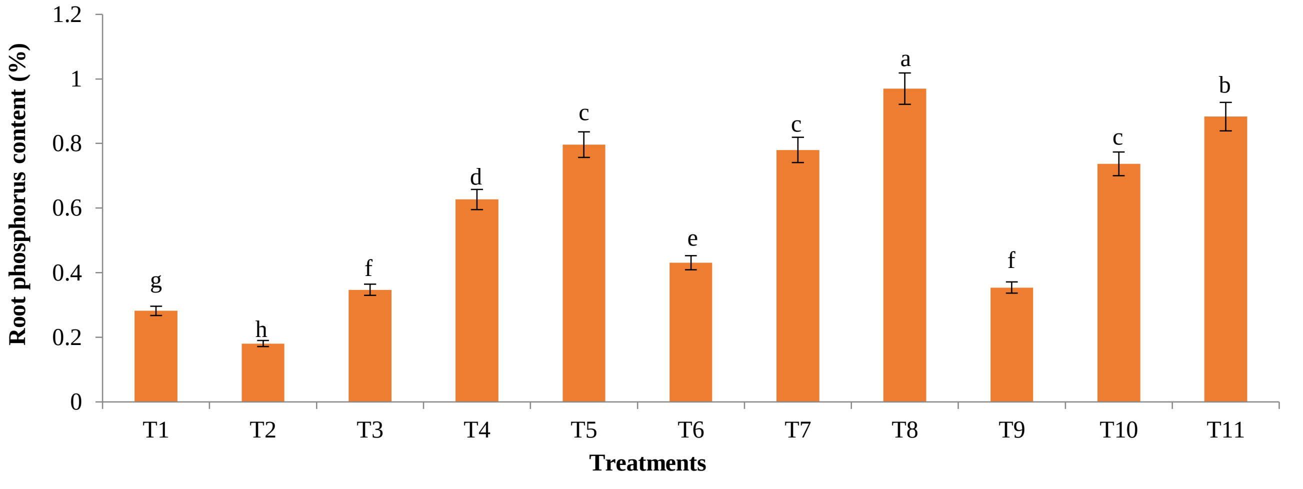

Fig. 12. Integrated effect of compost with mineral fertilizers on P concentration in roots of maize plants (%).

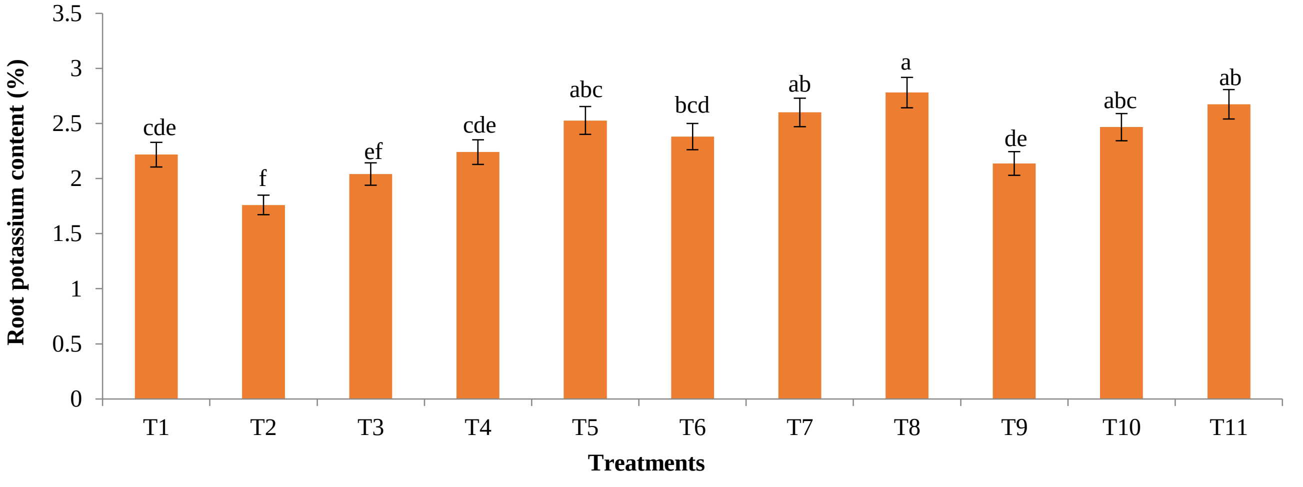

Fig. 13. Integrated effect of compost with mineral fertilizers on K concentration (%) in roots of maize plants (%).

Conclusion

Integrated effect of compost and mineral fertilizers at recommended rate increased the root and shoots biomass of maize plant and also depicted positive effect on soil chemical properties. Hence, it can be said that recommended dose of NPK when coupled with compost @ 12 t ha^{-1} significantly improved the agronomic performance of maize as well as soil chemical properties.

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