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Comparing efficacy of hydroponically and conventionally grown tomatoes

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Abstract

To improve local production of vegetables and to reduce intake of contaminants coming from toxic sprays on vegetables, there is need to promote kitchen gardening. The present study was carried out to grow tomatoes for kitchen gardening purpose using various growth medias like hydroponics, soil, compost and different combination of soil and compost. Treatments included hydroponic solution (Hoagland's solution), control (soil), soil:compost (75:25), soil: compost (50:50), soil: compost (25:75), compost (100 %) and soil with recommended NPK fertilizers. Tomato variety "Sahil" was used for this study. Tomato seedlings were obtained from commercial nursery and sown in December, 2016 in pots with above mentioned treatments. For hydroponics, Hoagland solution was prepared and placed in plastic beakers. Sampling from pots was done after crop harvesting, while plant sampling was done at maturity stage. The data obtained was analysed statistically using CRD to draw results. It was noted that soil nitrogen content (22.1mg kg^{-1}) was higher with compost. While higher concentration of P (38 mg kg^{-1}) and K (139.9 mg kg^{-1}) was also recorded in C100. Highest tomato yield (2231.1 g) was noted in hydroponics. Recommended NPK treatment gave 1187.1 g yield per pot. Lowest yield (808 g) was recorded in control where no amendment was added. It was concluded that increased application of compost increased the nutrient status which consequently increased crop yield but increase in nutrients and yield was lower as compared to hydroponics.

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Introduction

Pakistan is an agricultural country as this sector contributes 21% in GDP. However with the passage of time the contribution of agriculture in GDP is decreasing (ESP, 2015-16). In 2014 Pakistan imported agricultural products worth 1.012 billion dollars from different countries (ESP, 2014-15). Recently government took initiative of promoting kitchen gardening. Under this initiative seasonal vegetable seeds will be provided to general public. Various vegetables can be grown in soil and in hydroponics. Cultivation of plants with no soil by using suitable concentration of nutrients is called hydroponics. In hydroponics soil is not needed but medium contains all the mineral elements which are essential for plant growth. Due to absence of soil, soil borne diseases are not an issue in hydroponics which otherwise reduce the crop yield under field conditions. Crop yield in soilless medium is many times higher than crop yield from soil medium (Jasman *et al.*, 2016). Zekki *et al.* (1996) reported 3.80 kg per plant marketable yield of tomatoes grown in hydroponics. Hydroponics is considered modern form of agriculture due to higher yield per unit area. However there are many drawbacks which hinder its wide spread acceptance by farming community. Hydroponics establishment is expensive and requires consistent and reliable energy supply. In hydroponics imported fertilizers are used and these are costly than normal fertilizer available in market.

Common practice is to grow vegetables in soil. However mixture of soil and compost and compost alone can also be used for growing vegetables. However cultivation of vegetables in soil is also accompanied by various disease attacks like Fusarium and Verticillium wilts (Bashour *et al.*, 2013). There is need to compare these systems of vegetable production at household level to determine which system performs better in terms of yield and feasibility. Tomato (Lycopersicon esculentum) was used as an experimental crop to compare various systems of cultivation at household level. It is one of the main horticultural crop (Flores *et al.*, 2010). It gives us many important vitamins and minerals (Dorais *et al.*, 2005). Tomato is a yearly self crossing crop and it belongs to the family Solanaceae (Mourvaki *et al.*, 2005). For the consumption of tomato at household level it is considered a major food crop and is liked the world over (Tigchelaar, 1986).

So the present study was carried out to compare the effectiveness of conventional and nonconventional system of vegetable production at household level.

Materials and methods

Greenhouse Experiment

The current study was carried out in the Department of Soil Science, PMAS-Arid Agriculture University, Rawalpindi, Pakistan in 2015-16. Efficiency of tomatoes grown hydroponically and in conventional system was compared.

Hydroponic system involved plastic pots in which hydroponic solution was poured. A thermo pore sheet was cut according to the size of pot which was used as a lid on the pot. Holes were made in the thermo pore sheet and sponge material was used to support and fix plants in the holes. Nutrient solution was prepared in the laboratory using Hoagland's solution recipe. Aeration was provided through aeration pumps. Along with hydroponics other treatments included: control, recommended NPK (30-25-25), 25% compost+75% soil, 50% compost+50% soil, 75% compost+25% soil and 100% compost. Completely randomized design (CRD) was used in this experiment. Tomato variety 'Sahil' was used for this experiment. In each pot three seedlings were maintained. Cultural practices like hoeing and pruning were carried out as and when required as growth proceeded. Soil sampling was carried out at the start of experiment and then after crop harvest. Plant samples were taken before fruit formation.

Preparation of Hoagland solution

Nutrient solution was prepared by following Hoagland solution recipe. Following salts were used with given quantities (Table 1). Analysis of soil and compost is given in Tables 2-3 respectively.

Analytical methods

Electrical conductivity (EC) and pH of soil samples was determined by Rhodes (1982) and McLean (1982). Soil organic matter and soil texture were determined by Nelson and Sommers (1982) and Gee and Bauder (1962) respectively. AB-DTPA method (Soltanpour and Workman, 1979) was used for the determination of soil NO_3-N, extractable P, K and micronutrients. Plant nitrogen and phosphorus were determined by the method described by Anderson and Ingram (1993). Total K and micronutrients were determined by wet digesting the plant samples (Chapman and Pratt, 1961). Water analysis was carried out by using the procedures described by Eaton (2005).

Statistical analysis

Statistical analysis of data was performed by using Statistix 8.1 and by using (ANOVA) following completely randomized design (CRD). Mean difference was acknowledged at < 0.05 significance level (Steel *et al.*, 1997).

Results and discussion

pH variations during composting

Soil electrical conductivity (EC), pH and organic matter (OM) were affected significantly by the application of various treatments. Lower pH (7.1) was noted where higher dose of compost (C100) was applied while comparatively higher pH (7.5) was noted with the application of chemical fertilizer (Figure 1). In control, pH was 7.4. With increased application of compost a decrease was noted in pH.

Decrease in pH could be due to the decomposition of organic material by microbes where by various acids like Fulvic acids, Humic acids and Hymatomelanic acids are produced and H^+ ions are released which consequently can decrease pH of the medium (Sarir *et al.*, 2005).

Table 1. Salts used for Hoagland solution.

Sr. No.	Salt	Quantity
1	Potassium nitrate	15.54 g L^{-1}
2	Potassium sulfate	13.40 g L^{-1}
3	Potassium dihydrogen phosphate	13.17 g L^{-1}
4	Ferrous ammonium sulfate	21 g L^{-1}
5	Copper sulfate	11.78 g L^{-1}
6	Zinc sulfate	13.24 g L^{-1}
7	Manganese sulfate	8.23 g L^{-1}
8	Calcium chloride	11.02 g L^{-1}
9	Magnesium sulfate	30.8 g L^{-1}
10	Boric acid	17.16 g L^{-1}

Table 2. Physico-chemical properties of soil.

Sr. No.	Soil properties	Value
1	Sand (%)	56.1
2	Silt (%)	23.3
3	Clay (%)	20.6
4	Texture	Sandy clay loam
5	EC (dSm^{-1})	0.32
6	pH	7.35
7	organic matter (%)	0.51
8	NO_3-N (mg kg^{-1})	3.93
9	Olsen P (mg kg^{-1})	4.31
10	K (mg kg^{-1})	73.2
11	Zn (mg kg^{-1})	0.74
12	Fe (mg kg^{-1})	1.87
13	Mn (mg kg^{-1})	1.12
14	Cu (mg kg^{-1})	0.82

Electrical conductivity variations during composting

It was noted that EC of the mixture increased with the addition of increasing quantities of compost (Figure 2). Among compost and soil treatments, the highest EC (0.62 dSm^{-1}) was recorded with C100, followed by C75 + S25 (0.54 dSm^{-1}). Control treatment showed the lowest EC (0.26 dSm^{-1}). Compost is a rich source of nutrients which are released during the decomposition process of composting. Mineralization of nutrients into soil could be a probable cause of increase in EC. Carmo *et al.* (2016) reported an increase in soil EC by the addition of organic manures but this increase was below the range that could affect plants negatively.

Table 3. Compost analysis for chemical properties.

Sr. No.	Compost properties	Value
1	pH	7.1
2	EC (dSm^{-1})	0.6
3	Organic carbon (%)	54
4	N (%)	2.5
5	P (%)	0.5
6	Extractable K (%)	1.5
7	Zinc (mg kg^{-1})	89.2
8	Iron (mg kg^{-1})	171
9	Manganese (mg kg^{-1})	302.6
10	Copper (mg kg^{-1})	240

Organic matter variations

As expected, increase in OM was high (1.4 %) where higher quantity of compost (C100) was applied while the lowest OM (0.57 %) was noted in control (Figure 3). With increased quantity of compost OM in soil improved. Organic matter is the measure of organic carbon in soil. As compost is rich in organic carbon so its addition significantly improved organic carbon content. This increase in organic carbon is also supported by the findings of Ryals *et al.* (2014) who reported increased C:N ratio which increased the organic carbon content of soil.

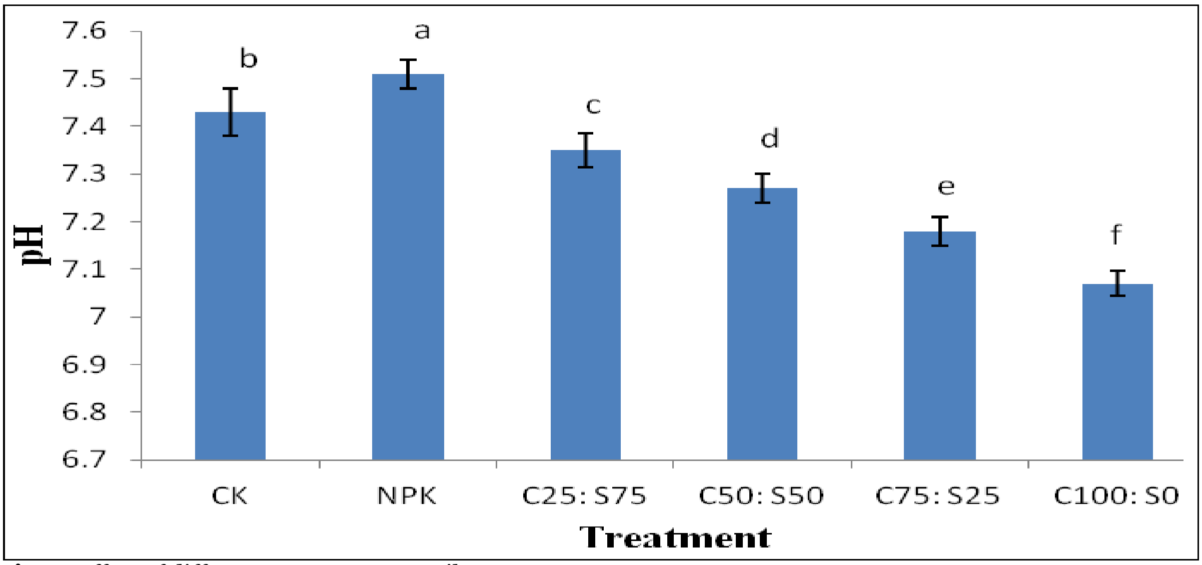

Fig. 1. Effect of different treatments on soil pH.

Extractable nitrogen

Data regarding the effect of organic and inorganic amendments on soil NO_3-N has been presented in Figure 4. The highest soil nitrogen (22.1 mg kg^{-1}) was noted with C100 and it was followed by C75+S25 (17.11 mg kg^{-1}) and NPK (12.74 mg kg^{-1}) respectively.

The lowest soil N (5.7 mg kg^{-1}) was noted with control. It was noted that with increasing proportion of compost, soil N increased correspondingly.

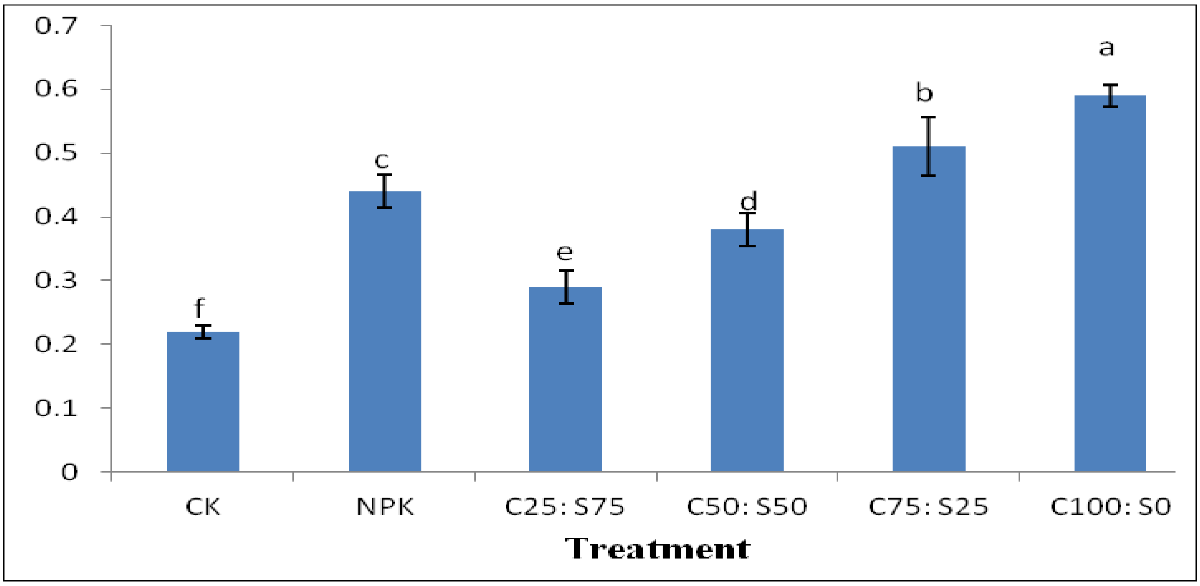

Fig. 2. Effect of different treatments on soil EC.

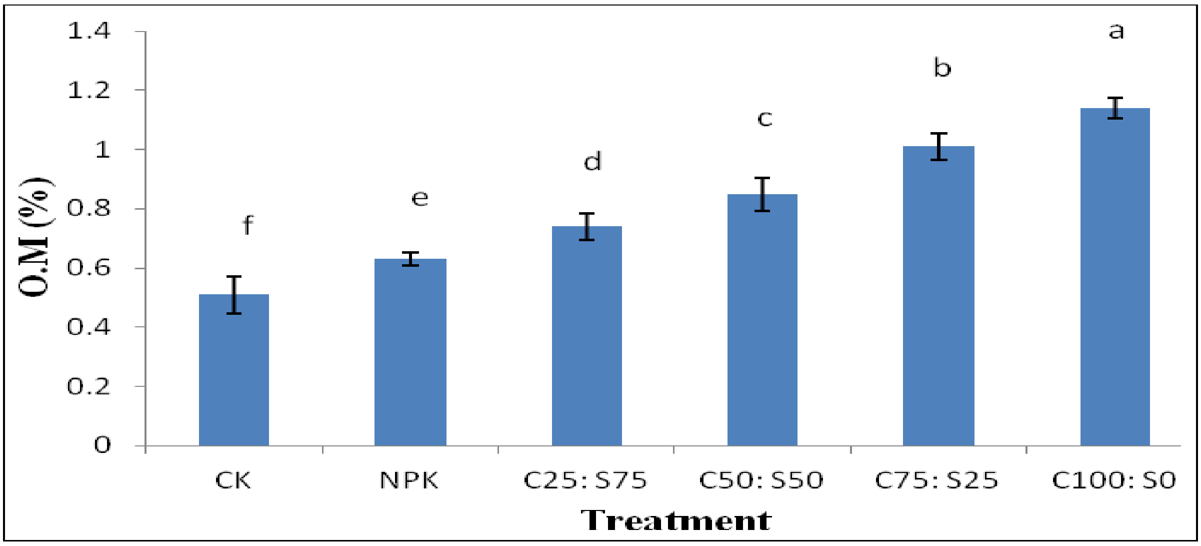

Fig. 3. Effect of different treatments on soil organic matter.

Increase in soil nitrogen could be due to the mineralization of compost, releasing considerable amount of nitrogen which plant can easily uptake from the medium (Weber *et al.*, 2014). Due to the application of compost, 32-79% increase in soil N has been reported (Chalhoub *et al.*, 2013). Soil N from NPK treatment was less which could be due to the losses of N as NH_3 gas and its interactions in soil, even losses of N as NO_3^- leaching have been reported (Evanylo *et al.*, 2008).

Extractable phosphorus

Similar sequence was also noted for extractable P in soil where the highest P (38.5 mg kg^{-1}) was noted in C100 (Figure 5). The lowest value (4.39 mg kg^{-1}) was noted in control. So compost application positively affected the soil P content. Phosphorus is highly unavailable in soil. In acidic soil P precipitates or adsorbed by Al and Fe oxides making it unavailable to plants (Khan *et al.*, 2009).

In alkaline soil it forms precipitates with Ca reducing its bioavailability (Sanchez-Alcala *et al.*, 2014). By the addition of compost to soil, P concentration increases due to its mineralization (Nest *et al.*, 2015) and also by the fact that organic manures application reduce fixation sites for P and thereby increasing its bioavailability (Qayyum *et al.*, 2015).

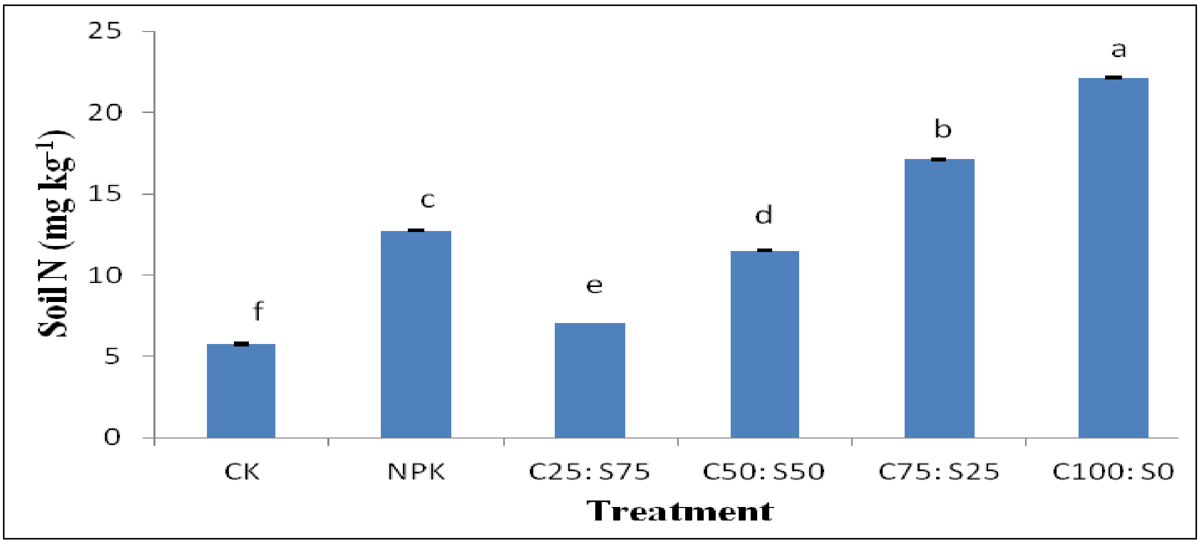

Fig. 4. Effect of different treatments on soil nitrate nitrogen.

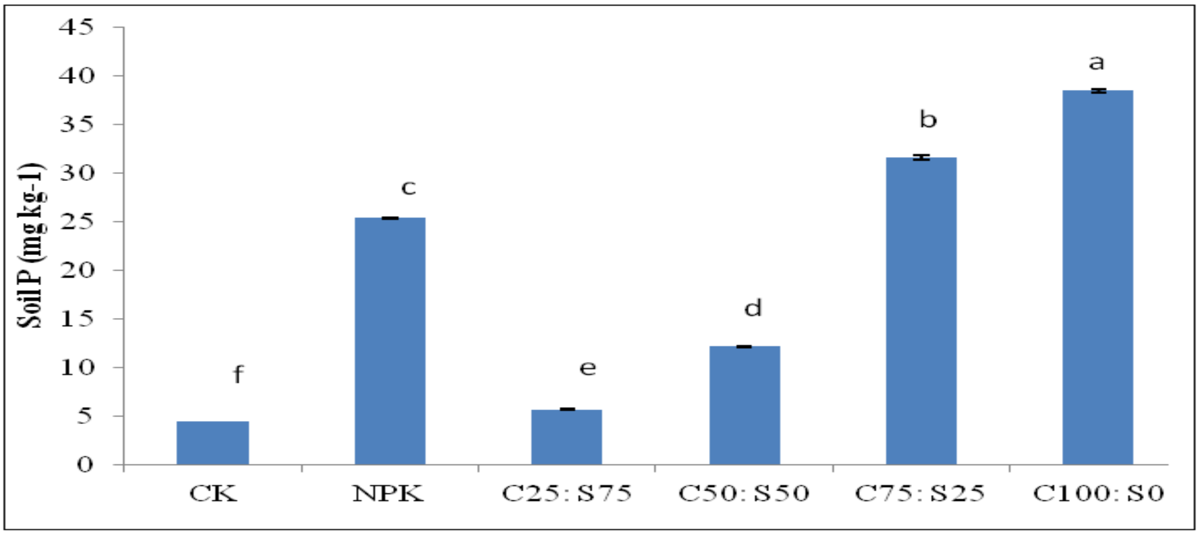

Fig. 5. Effect of different treatments on soil Phosphorous.

Dao and Cavgelli, (2003) also reported that the application of compost @ 10 t ha^{-1} increased the concentration of P in soil significantly.

Extractable Potassium

The highest soil K (139.94 mg kg^{-1}) was also noted with the application of highest dose of compost (C100). With the application of recommended dose of NPK, soil K was 110.3 mg kg^{-1} (Figure 6). It showed that compost application was a good source of soil K. Kavitha and Subramanian (2007) reported that compost application improved soil K and its uptake by plants while Torkashvand and Kaviani (2014) also reported improved soil K and 40% improvement in plant growth by the application of compost.

Macronutrient uptake by plants

Chemical analysis of plant samples revealed the highest nitrogen (Figure 7), phosphorus (Figure 8) and potassium (Figure 9) contents in hydroponically grown plants. Nitrogen, phosphorus and potassium in these samples were 3.6, 0.93 and 5.1% respectively.

Among compost treatments the highest N, P, K contents were noted in C100 where these were 3.25, 0.71 and 4.78%. It was followed by C75+S25.

The lowest values for N, P, K were noted in control treatment (Figure 7–9). Treatments receiving higher quantities of compost also showed higher macronutrient content.

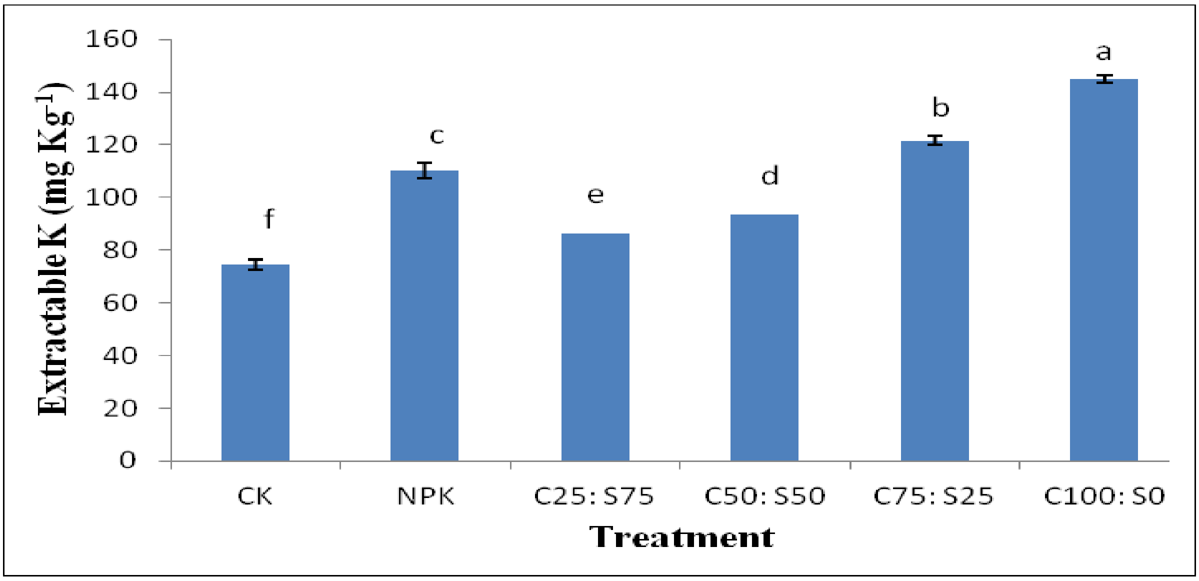

Fig. 6. Effect of different treatments on soil Potassium.

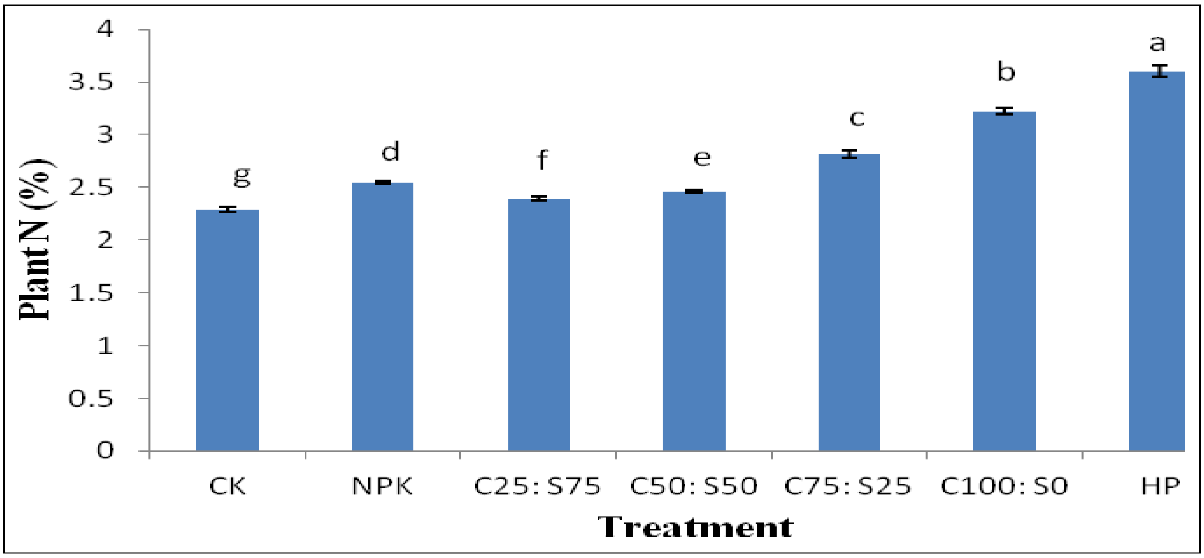

Fig. 7. Effect of different treatments on plant N.

This is understandable as more compost application means more mineralization and availability of nutrients. However the nutrient uptake from hydroponic solution was high because the losses and fixation problems were minimum (Gravel *et al.*, 2007). Compost addition also increases nutrient availability because fixation problems are less but nutrients are not as easily available as in hydroponic solution (Abbasi *et al.*, 2001). Lower level of Cl in hydroponic solution also enhances availability and uptake of P by plants (Royer *et al.*, 2016) while excessice salinity has been reported to suppress K uptake by plants (Horchani *et al*, 2010). Low salinity has been reported to enhance K uptake by plants in nutrient solution (Chen *et al.*, 2007).

Tomato yield

The data regarding tomato yield per pot has been presented in Figure 10. The highest tomato yield per pot was noted in hydroponically grown tomatoes followed by C100. The lowest yield (808.05 g) was recorded in control. Yield from NPK treatment was higher than C25 + S75 (862.65 g) and C50 + S50 (1054.14 g). However it was lesser than that in C75 + S25 (1289.43 g). Yield from hydroponically grown tomatoes was higher because of greater nutrient availability. Higher nutrient availability could be due to the fact that no nutrient loss either in the form of nutrient fixation and nutrient leaching takes place. In the field situation even applied nutrients are not fully available. Efficiency of applied fertilizer is reported to be 30% due to fixation of applied nutrients in soil, their chemical reactions and leaching losses (Noa and Peter, 2015). So tomato yield from control and even NPK applied treatment was lesser than that from hydroponics.

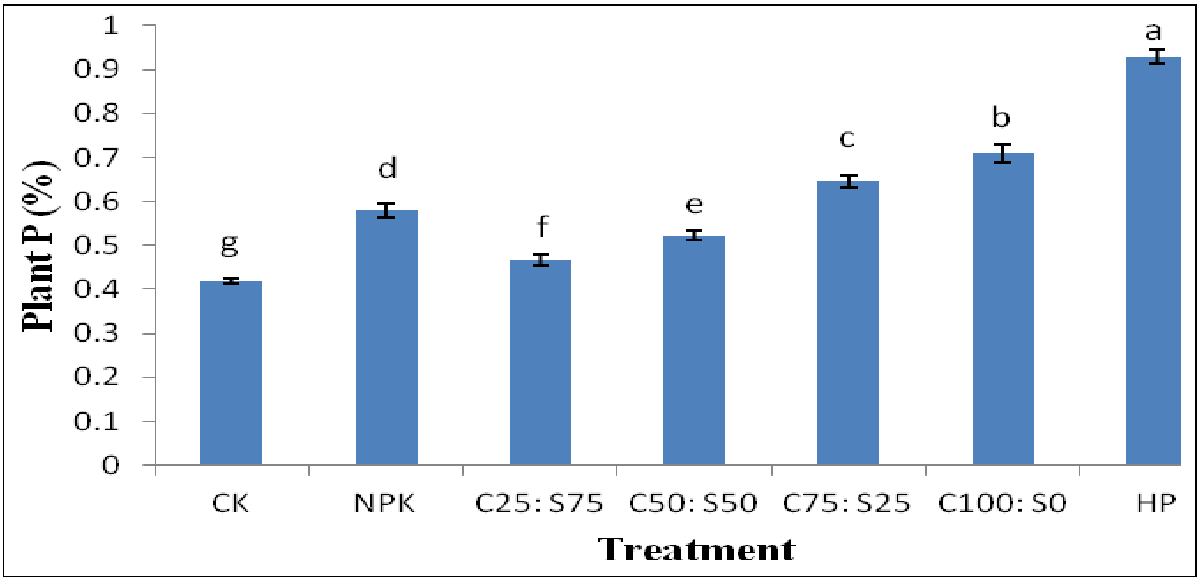

Fig. 8. Effect of different treatments and hydroponic on plant P.

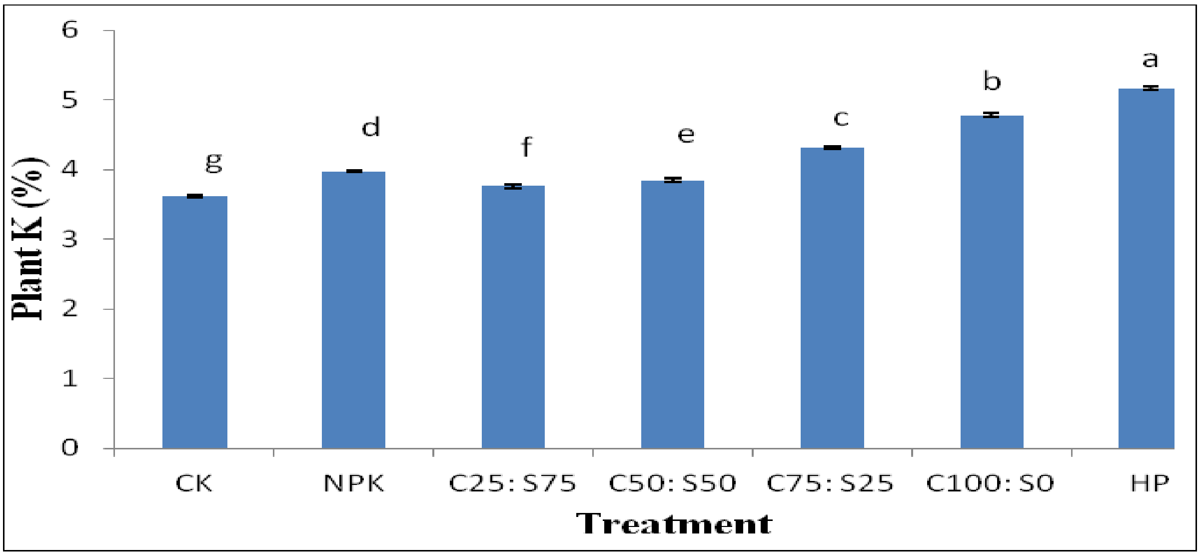

Fig. 9. Effect of different treatments and hydroponic on plant K.

In our study the yield obtained from hydroponics was 63.78 % higher than control, 46.78 % higher than NPK treatment and 22.06 % higher than C100. Roosta and Hamidpour, (2011) have also reported higher yield from hydroponically grown vegetables compared to other system. Compost treatment has also improved yield but it was lesser than hydroponic treatment. Mineralization of nutrients from compost is slow so it could not compete with hydroponics. However tomato yield has improved with increased application of MSWC.

It could also be due to the fact that organic manure application in soil reduces fixation of nutrients by competing with them for fixation sites in soil. Noa and Peter (2015) reported 77% fixation of applied N fertilizer in field conditions.

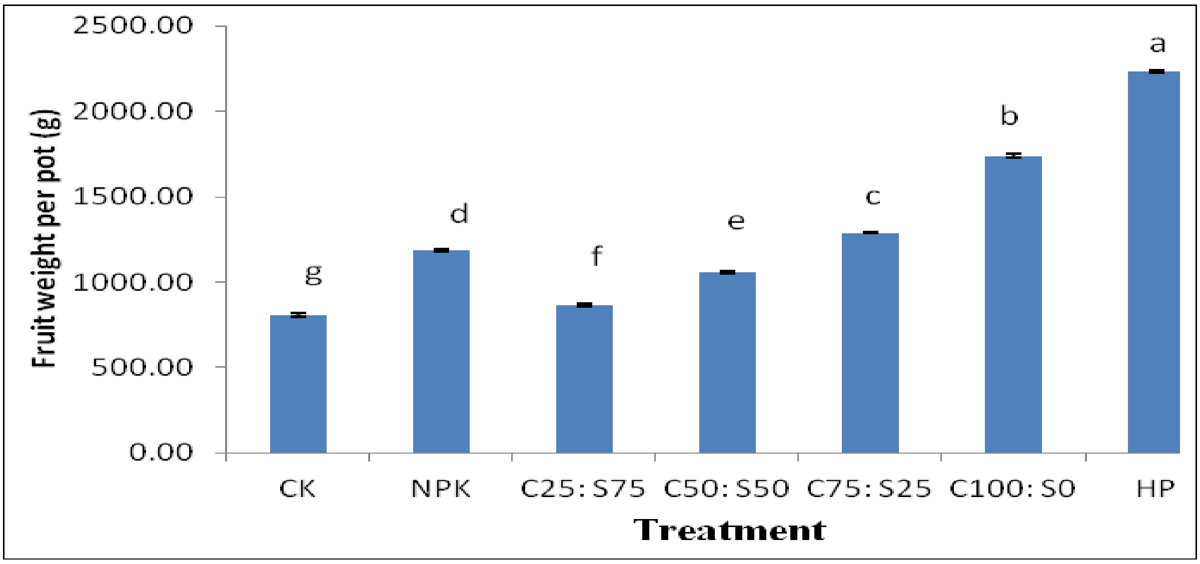

Fig. 10. Effect of different treatments on tomato yield per pot.

Conclusion

It was concluded that increased application of compost increased the nutrient status which consequently increased crop yield but increase in nutrients and yield was lower as compared to hydroponics.

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