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Effect of integrated nutrient management on nutrient recovery, nutrient use efficiency and relative agronomic efficiency of grafted tomato

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Abstract
Tomato *(Solanum lycopersicon)* is one of the widely grown vegetable and most important food crops in India. It is rich in minerals, essential amino acids, sugars, dietary fibres, vitamins and organic acids. It is well responsive to fertilizer application and reported to be heavy feeders of nutrients. Supply of balanced nutrients can increase the yield, fruit quality and taste of tomato fruit. A pot experiment was conducted using integrated nutrient management practices in grafted tomato during 2017-2018. The experimental results revealed that the treatment 100% inorganic nitrogen showed highest Nitrogen and potassium recovery and use efficiency compared to 100% organic nitrogen and combination of inorganic and inorganic treatments, whereas combination of organic and inorganic nutrients showed highest phosphorus recovery and use efficiency. The grafted tomato maintained the mean recovery of N, P and K of 66.7, 27.1 and 100.4 per cent compared to 27.1, 11.1 and 50.4 per cent with non-grafted tomato and 21.7, 9.2 and 44.3 per cent with self-grafted tomato respectively. And the mean nutrient use efficiency of N, P and K was 18.2, 37.6 and 30 g dry fruit per g of N, P and K applied compared to 3.92, 28.7 and 6.6 with non-grafted tomato and 2.7, 27.8 and 3.6 with self-grafted tomato respectively. Relative agronomic efficiency of the present study showed that the completely inorganic nitrogen performed better than completely organic nitrogen or any other combinations of organic with inorganic.

Keywords: Integrated nutrient management, grafted tomato, organic and inorganic nitrogen, nutrient recovery and use efficiency, relative agronomic efficiency

Introduction
Improvement of nutrient recovery and use efficiency is an essential pre-requisite for expansion of crop production into marginal lands with low nutrient availability. The nutrients most commonly limiting plant growth are N, P, K and S. Nutrient use efficiency depends on the ability of nutrient to efficiently uptake of the nutrient from the soil, but also on transport, storage, mobilization, usage within the plant, and even on the environment. One of the most universal adaptations to nutrient-limited soils is a change in root structure that may increase the overall surface area of the root to increase nutrient acquisition or may increase elongation of the root system to access new nutrient sources in the soil. These changes can lead to an increase in the allocation of nutrients to overall root growth, thus resulting in greater root to shoot ratios in nutrient-limited plants (Lopez-Bucio *et al.*, 2003) [13].
In our experiment we have taken Utkal Anushree (Brinjal) as root stock and Utkal Kumari (Tomato) as scion, not only developed resistance to fungal and bacterial wilt but also profuse rooting system enabled better uptake, recovery and use efficiency of nutrients from deeper zone resulted in increasing the yield.

Material Method
The experiment was conducted in Central Horticultural Experiment Station (Aiginia), Bhubaneswar with Brinjal Grafted Tomato, Non-Grafted Tomato, Self-Grafted Tomato during 2017-18 in a Completely Randomized Design with six treatments with Grafting interaction. Grafted Tomatoes (BT-10 grafted on brinjal var. Utkal Anushree), non-grafted and self-grafted tomatoes were evaluated with six treatments i.e. T_1 (Absolute Control), T_2 (100% inorganic nitrogen), T_3 (7% inorganic nitrogen + 25% organic nitrogen), T_4 (50% inorganic nitrogen + 50% organic nitrogen), T_5 (25% inorganic nitrogen + 75% organic nitrogen), T_6 (100% organic nitrogen) and each treatment was replicated thrice. Each ploy bag was filled with 15 kg soil.
Before grafting, scion and rootstock were exposed to sunshine for three days. Two crop varieties *viz*. Tomato- Utkal Kumari (BT-10) and Brinjal-Utkal Anushree were sown in the protrys. In Grafted Tomato Utkal Kumari (BT-10) scion were grafted onto the Utkal Anushree (brinjal var.) rootstock and in Self Grafted Tomato Utkal Kumari (BT-10) scion were grafted

onto the Utkal Kumari (BT-10) rootstock using "side grafting" method. Non-grafted seedlings were used directly. Grafting was carried out at 2-3 leaf stage of scion seedlings and 3-4 leaf stage of root stock. Grafting was carried out in moist chambers. Grafting was made with similar thickness of scion and root stock which was cut at 45^0 and joined by using plastic clips.

The grafted plants were transplanted after thirty-five days after sowing. Then they were exposed to water stress before being taken to moisture chambers. This process was carried out to ensure high grafting success. The grafted seedlings were transferred to humidified chambers with a relative humidity of 85-95 per cent for five days to allow the graft union to heal, then intensity of light was gradually increased with decrease and relative humidity. Then the seedlings were transferred to the normal nursery where healing process was continued for two weeks before they were transplanted. Plants were grown under natural light conditions.

Nutrient uptake was calculated based on dry weight or biomass produced by plant and fruit with there respective nutrient concentrations and the nutrient recovery and use efficiencies are calculated based on the these Empirical formulae:

$$\text{Apparent Nutrient Recovery (\%)}: \frac{\text{Uptake of } N_F - \text{Uptake of } N_C}{\text{Amount of Nutrient Applied}} \times 100$$

$$\text{Nutrient Use Efficiency}: \frac{\text{Kg fruit produced}}{\text{Kg Nutrient Applied}}$$

$$\text{Relative Agronomic Efficiency (\%)}: \frac{\text{The yield}_F\ (\text{Kg ha}^{-1}) - \text{Yield}_C\ (\text{Kg ha}^{-1})}{\text{Yield STD}_F\ (\text{Kg ha}^{-1}) - \text{Yield}_C\ (\text{Kg ha}^{-1})} \times 100$$

Where, F, C, N and STD denote Fertilized, Non-fertilized control plots, Nutrient applied and Standard plot respectively.

Statistical analysis

The experimental data pertaining to yield were recorded, compiled in appropriate tables and analyzed statistically as per the procedure appropriate to the design (Panse and Sukhatme, 1978) and Gomez and Gomez (1976). All the data were statistically analyzed by two factorial CRD ANOVA.

Results and Discussion

The influence of integrated nutrient management on nutrient recovery, nutrient use efficiency and agronomic efficiency of grafted tomato crop was studied, where the crop received soil test based recommended dose (200:156:125 N: P_2O_5:K_2O Kg ha^{-1}) of inorganic nutrients and organic nutrients, either alone or in integration. The experimental soil was acidic in nature and it was ameliorated with calcium carbonate @ 0.2 LR.

Influence INM practices on Apparent nutrient recovery, Nutrient use efficiency

Nitrogen recovery and use efficiency

It was observed that nitrogen recovery varied between 22.2 and 97 (%), lowest in self-grafted tomato with T_6 and highest in grafted tomato with T_2 (Fig-1). The mean recovery of nitrogen by self-grafted tomato was 21.7 per cent followed by 27.1 per cent with non-grafted tomato and highest with grafted tomato (66.7%). The recovery of nitrogen was almost equal with the combinations of organic or inorganic nitrogen. Nitrogen use efficiency varied between 1.3 and 20 (g Dry fruit per g N applied), lowest in self-grafted tomato with T_6 and highest in grafted tomato with T_2 (Fig-2). The mean nitrogen use efficiency of grafted tomato (18.2 g dry fruit/g N applied) was highest followed by non-grafted tomato (3.92 g dry fruit/g N applied) and self-grafted tomato (2.7 g dry fruit/g N applied). The INM practices for three types of grafted tomatoes, indicated that the T_2 recorded highest nitrogen recovery and use efficiency irrespective of grafts. However, the recovery and use efficiency increased with incremental proportion of inorganic nitrogen in three types of tomatoes. It might be due to immobilisation of nitrogen in organic applied treatments and high nitrogen availability in inorganic nitrogen treatments. These results were supported by Lynch *et al.*, 2004 [12], that after application of higher dose of organic fertilizer, nitrogen immobilization was happened in the first crop season followed by mineralization during the second crop.

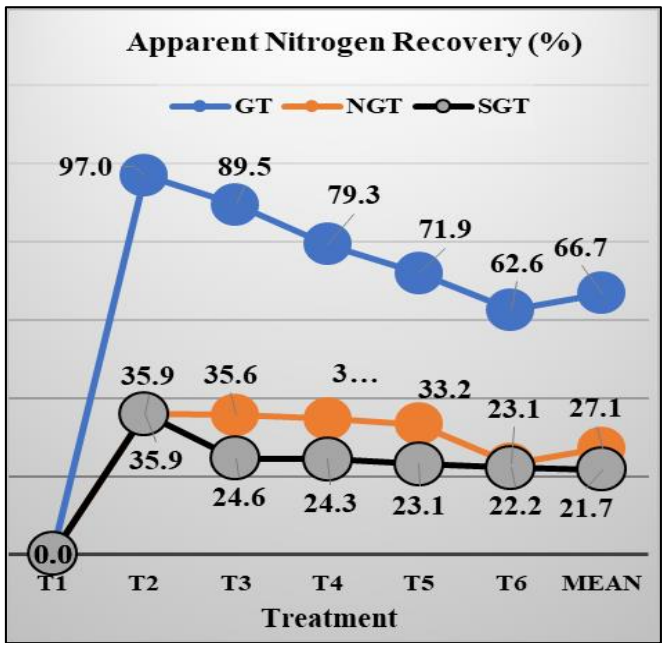

Fig 1: Apparent Nitrogen Recovery (%)

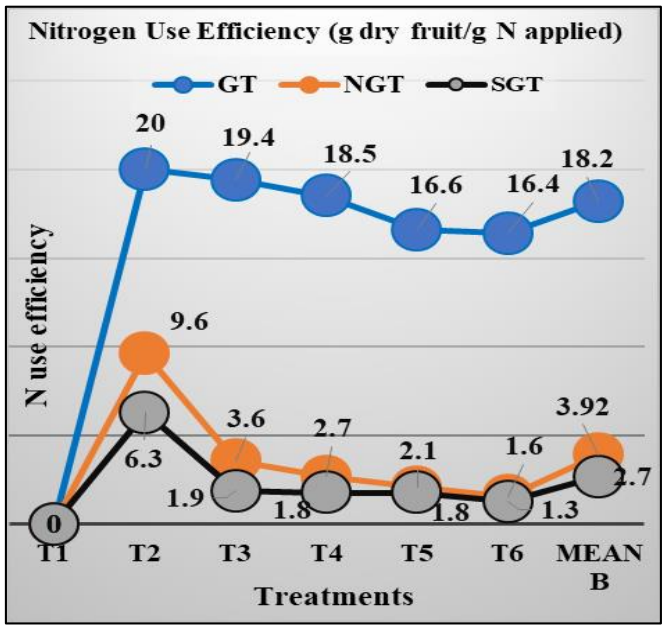

Fig 2: Nitrogen Use Efficiency (g dry fruit/g N applied)

Phosphorus recovery and use efficiency

It was observed that phosphorus recovery varied between 7 and 44.8 (%), lowest in self-grafted tomato with T_6 and highest in grafted tomato with T_4 (Fig-3). Over all, the grafted tomato recorded highest mean phosphorus recovery 27.5% fallowed by non-grafted 11.1% and self-grafted tomatoes 9.2%. And the phosphorus use efficiency varied between 28 and 53.7 (g Dry fruit per g P applied), lowest in self-grafted tomato with T_6 and highest in grafted tomato with T_4 (Fig-4). The mean phosphorus use efficiency of grafted tomato (37.6 g Dry fruit per g P applied) was highest followed by non-grafted tomato (28.7 g Dry fruit per g P applied) and self-grafted tomato (27.8 g Dry fruit per g P applied). The combinations of inorganic and organic nutrient treatments showed highest phosphorus recovery and use efficiency than the inorganic and organic treatments alone. The INM practices for three types of grafted tomatoes, indicated that the T_4 recorded highest phosphorus recovery and use efficiency irrespective of grafts. It may be due to the experimental soil was acidic in nature which has property of phosphorus fixation, by application of organics to soils the microbial population increases in soil which have been responsible to increase the availability of P in soil by producing organic acids (Verma and Rawat, 1999) [16]. Unlike N, P is strongly absorbed by soils. As a result, most soils contain abundant amount of P, as it hardly leaches out of the soil profile. Because tomatoes take up relatively smaller amount of P than the amounts of N and K, the concentration of P in tomato is also smaller. The results were supported by Ghosh *et al.* (2014) [16] and Azam *et al.* (2013) [2] that the integration of organic fertilizers along with synthetic fertilizers results into highest phosphorus recovery and use efficiency by plants.

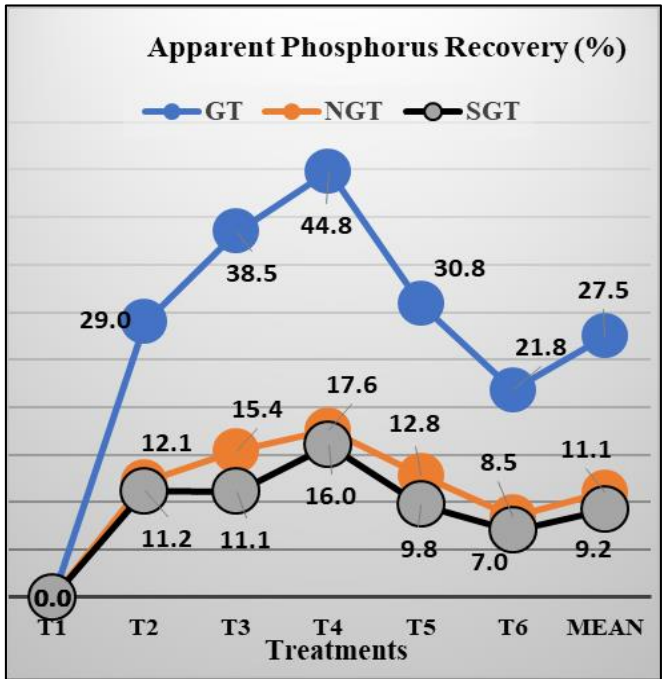

Fig 3: Apparent Phosphorus Recovery (%)

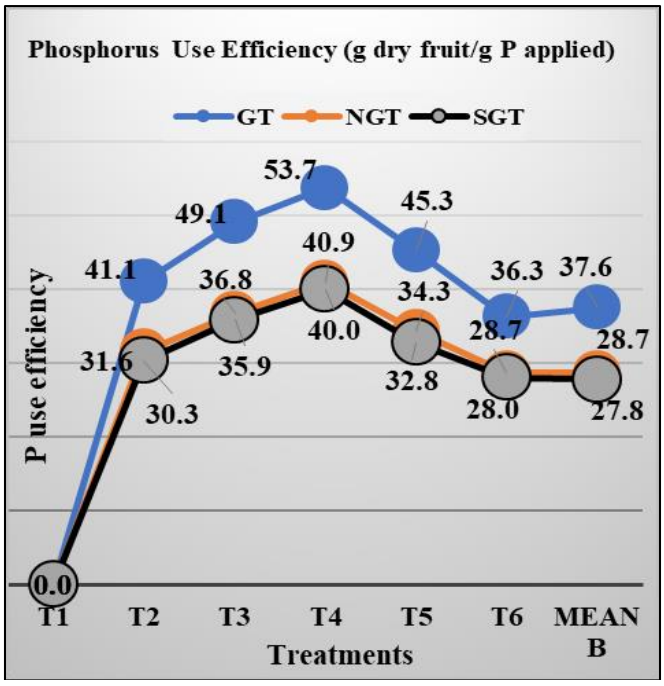

Fig 4: Phosphorus Use Efficiency (g dry fruit/g P applied)

Potassium recovery and use efficiency

The apparent potassium recovery by grafted tomatoes varied between 40.4 and 137.4 (%), lowest in self-grafted tomato with T_6 and highest in grafted tomato with T_2 (Fig-5). Among three types of grafted tomatoes, the grafted tomato recorded highest mean potassium recovery 100.4 (%) fallowed by non-grafted and self-grafted tomatoes were 50.4 and 44.3 (%) respectively. The grafted tomato recorded double potassium recovery compared to non-grafted and self-grafted tomatoes. And the potassium use efficiency varied between 1.0 and 35.0 (g Dry fruit per g K applied), lowest in self-grafted tomato with T_6 and highest in grafted tomato with T_2 (Fig-6). The mean potassium use efficiency of grafted tomato (30.0 g Dry fruit per g K applied) was highest followed by non-grafted tomato (6.6 g Dry fruit per g K applied) and self-grafted tomato (3.6 g Dry fruit per g K applied). However, the potassium recovery and use efficiency increased with incremental proportion of inorganic nitrogen in three types of tomatoes. As like as with nitrogen, potassium is also absorbed by tomato in large amount because it is not fixed in acid soil. These observations indicate that tomato responded quite well to inorganic fertilization than combinations of inorganic and

organic fertilization or organic fertilization only. But this was contrary to the general notion that inorganic and organic fertilization is better than inorganic fertilization only. Probably, the contradiction here could be due to nutrient imbalance. Pyo *et al*., 2010 [14], reported that low affinity transport systems generally function when potassium levels in the soil are adequate for plant growth and development. This process is mediated by ion channels in the plasma membrane of root cells, allowing passive transport of K^+ from areas of relatively high external concentration into the plant cells where the concentration of K^+ is lower. The expression of these low affinity transporters does not appear to be significantly affected by potassium availability.

In any INM packages, grafted tomato was superior to non-grafted and self-grafted tomato as far as nutrient recovery and use efficiency is concerned. It might be due to root traits of brinjal root-stock which has more root density and number of root hairs and lateral and vertical development of roots which increased the absorption and translocation of nutrients. The results corroborated by earlier findings of Davis *et al*., 2008b; Lee, 1994; Ruiz, Romero 1999; Leonardi and Giuffrida 2006; Martínez-Ballesta *et al*., 2010; Colla *et al*., 2011; Lee and Oda, 2003; Desire Djidonou (2012) [4, 9, 15, 10, 13, 3, 8, 5].

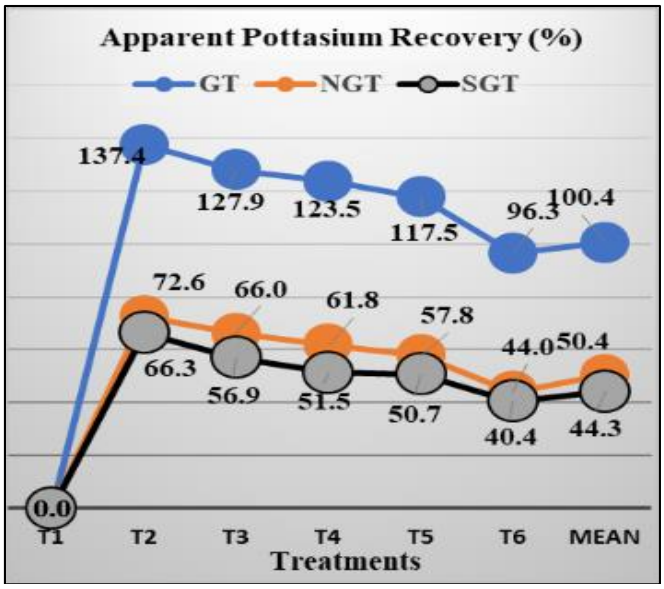

Fig 5: Apparent Potassium Recovery (%)

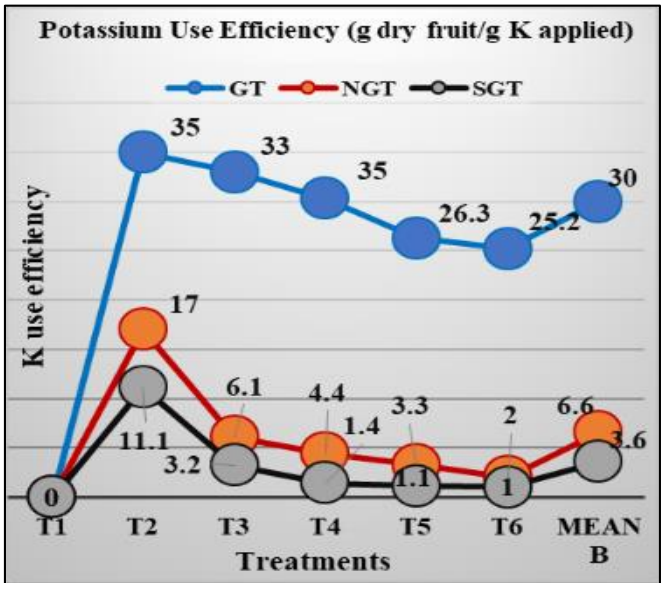

Fig. 6: Potassium Use Efficiency (g dry fruit/g K applied)

Relative Agronomic Efficiency (%)

The data relating relative agronomic efficiency (considering the performance of total dry biomass production due to 100% inorganic N as 100) have been presented in Fig-7.

Based on the RAE values different INM packages be arranged as:

100% inorganic nitrogen > 75% inorganic nitrogen + 25% organic nitrogen > 50% inorganic nitrogen + 50% organic nitrogen > 25% inorganic nitrogen + 75% organic nitrogen > 100% organic nitrogen irrespective of the types of grafts. This trend indicated that for the present study the completely inorganic nitrogen performed better than completely organic nitrogen or any other combinations of organic with inorganic.

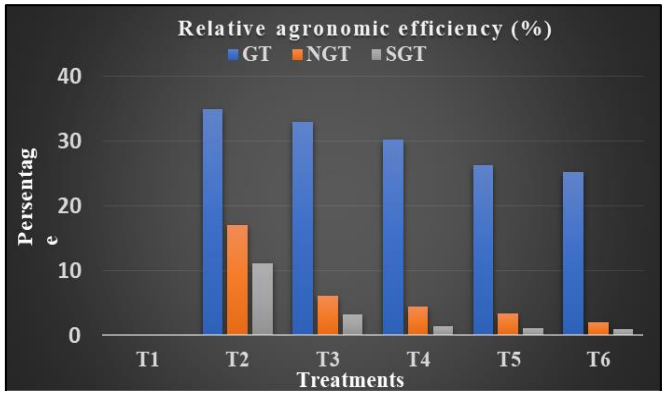

Fig 7: Relative agronomic efficiency (%)

Concussion

The treatment 100% inorganic nitrogen showed highest nitrogen and potassium recovery and use efficiency compared to 100% organic nitrogen and combination of inorganic and inorganic treatments. Overall, the grafted tomato has shown highest nutrient recovery, nutrient use efficiency and highest fruit yield compared to non-grafted tomato, as the grafted tomato has strong root system of brinjal with higher root surface area and more number of root hairs for maximum uptake of nutrients. This indicated the efficiency of grafting tomatoes on brinjal root stock for enhancing yields and income.

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