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Studies on the impact of soil application of biofertilizers on growth and yield of Kinnow mandarin

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Abstract
A field study was conducted to see the effect of soil application of biofertilizers on growth and yield of Kinnow mandarin on 10 year old plants. *Azotobacter chroococcum* Mac 27, *Azotobacter chroococcum* HT 54 and *Pseudomonas* P36 were used alone and in combination at two RDF (recommended dose of fertilizers) levels i.e. 75% and 100%. Maximum plant height, spread, flowers per twig, initial fruit set, number of fruits and yield were obtained with soil application of *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36 applied with 100% RDF, however, average fruit weight was not significantly affected. The treatment significantly reduced fruit drop.

Keywords: Kinnow, Azotobacter, pseudomonas, growth, yield, fruit drop

Introduction
Citrus is an important fruit crop of India and grown throughout the country except in the temperate regions. It covers 14.9 % of total fruit area of country with the productivity of 10.3 t/ha. In Haryana, citrus has become a major fruit crop with a productivity of 12.1 t/ha (Anonymous 2015) [1]. Kinnow mandarin is a hybrid of 'King' (*Citrus nobilis*) × 'Willow Leaf' (*Citrus deliciosa*). Major Kinnow producing states are Punjab, Rajasthan, Haryana, Madhya Pradesh, Andhra Pradesh and Maharashtra.
Kinnow orange is rich source of minerals and elements. Chemical fertilizers fulfill the major nutrient requirement of the crop but their excessive and unbalanced use may lead to ecological hazards and depletion of physico-chemical properties of the soil and ultimately affect crop yields. Under such circumstances, there is need to consider alternate source of nutrients which may enhance crop yields without having adverse effects on soil properties. Biofertilizers are considered as a cheap and, eco-friendly source for improving soil fertility status. Increasing and extending the role of biofertilizers may reduce the need for chemical fertilizers and decrease the adverse environmental effects (Rafet *et al.*, 2007) [4]. The relevant information In Kinnow mandarin is hardly available in literature. The present study was, thus, aimed to investigate the role of N-fixing Azotobacter strains and P-solubilizing bacteria on growth and yield of Kinnow mandarin under agro-climatic conditions of western Haryana.

Materials and Methods
The present study was conducted at the experimental orchard, Department of Horticulture, CCS, Haryana Agricultural University, Hisar on 10 year old kinnow plants. Biofertilizers were applied in ring method 75cm away from tree trunk. 50ml biofertilizer was used to make final volume of 5 litre with water and applied uniformly around tree rhizosphere. The height of the tree was measured with well marked measuring pole up to the maximum point of height, ignoring the off type shoots and expressed in meter (m). Distance between point to which the branches of the tree had grown in the east-west and north-south direction were measured and average was expressed in meter (m). Four twigs were selected in each direction on the tree and number of flowers were counted and average was expressed as number of flowers per twig The initial fruit set was calculated by subtracting the number of fruits set at initial stage from total number of flowers on tagged twigs. The percent initial fruit set was calculated by using the formula given below.

$$\text{Initial fruit set (\%)} = \frac{\text{Initial fruit set}}{\text{Total number of flowers}} \times 100$$

Number of fruit drop was calculated by counting the fruits dropped on monthly basis from May onwards till harvesting and the average of three replications was expressed as number of fruit drop. Total number of fruits per tree of three replications was counted at the time of harvesting and average was expressed as number of fruits per tree. Five randomly selected fruits per replication were taken from different positions of tree and weighed with the help of pan electronic balance. The average was expressed as average fruit weight in gram (g). Yield was calculated by multiplying total number of fruits with average fruit weight and average has been expressed in kilograms per tree (Kg/tree).

Results and Discussion

Studies on Crop Growth

Plant Height and Average Plant Spread

A perusal of data in table 1 indicates that plant height and plant spread were significantly affected by various soil applied biofertilizer treatments and their combinations. Maximum plant height of 3.14m was recorded with T_7 i.e. 100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36 but found at par with all the treatments except T_2 and control (100% RDF). Minimum plant height 2.85m was observed with control. Maximum average plant spread of 2.88m was registered with T_7 (100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36) which was at par with T_3 and all the biofertilizer treatments with 100% RDF application. Minimum average plant spread of 2.40m was observed with control i.e. (100% RDF). All the biofertilizer treatments in combination with 100% RDF proved significant in increasing plant spread over control.

The increase in the plant height and plant spread might be due to the built of colonies of the applied bio-fertilizer inoculates and their growth promoting effects including the synthesis of plant growth promoting substances (Tien *et al.*, 1979; Sharma and Bhutani, 1998) [7, 5]. Boughalleb *et al.* (2011) [2] reported that *Azotobacter* imparts a major role in photosynthesis by fixing the nitrogen which is a constituent of protein and chlorophyll, thereby enhancing the accumulation of carbohydrates which in turn increases the growth of the plants.

Number of flowers/twig, initial fruit set and number of fruit drop

Number of flowers per twig was not significantly affected by the soil application of various biofertilizers (Table 2). However, maximum number of flowers per twig was recorded with T_7 (100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36) closely followed by T_8 and T_5. All the 100% RDF + biofertilizer combinations were, numerically, found better over all the 75% RDF + biofertilizer treatments and control (100% RDF) except for T_6. Minimum number of flowers per twig was recorded in control.

Initial fruit set (%) was not significantly affected by different biofertillizers application in combinations with both RDF levels i.e. 100% and 75%. Maximum fruit set (55.63%) was observed with T_7 (100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36) closely followed by.

Table 1: Effect of soil application of biofertilizers on plant height (m) and average plant spread (m) of Kinnow mandarin

Treatments	Plant height (m)	Average plant spread (m)
T_1: 75% RDF + *Azotobacter chroococcum* Mac 27	2.92	2.55
T_2:75% RDF + *Azotobacter chroococcum* HT 54	2.89	2.57
T_3:75% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P 36	3.01	2.66
T_4:75% RDF + *Azotobacter chroococcum* HT 54 + *Pseudomonas* P 36	2.96	2.61
T_5:100% RDF + *Azotobacter chroococcum* Mac 27	3.00	2.70
T_6:100% RDF + *Azotobacter chroococcum* HT 54	2.96	2.74
T_7:100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P 36	3.14	2.88
T_8:100% RDF + *Azotobacter chroococcum* HT 54 + *Pseudomonas* P 36	3.10	2.82
T_9:Control (RDF)	2.85	2.40
CD at 5%	0.24	0.24

T_5 and T_8. All the 100% RDF + biofertilizer treatments were found numerically superior over control. Minimum fruit set (50.50%) was observed with control (100%) RDF.

Different biofertilizer treatments significantly affected number of fruit drop in Kinnow mandarin. Minimum number of fruit drop (575.67) was recorded with T_7 (100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36) which was at par with T_5, T_6 and T_8. All the 100% RDF + biofertilizer combinations were found superior to that of control. Maximum number of fruit drop (672.00) was observed with control (100% RDF). The increase in number of flowers per twig, initial fruit set and reduced number of fruit drop might be attributed to increased nutrient availability from *Azotobacter* and PSB which may have increased various endogenous hormonal levels in plant tissue which might be responsible for enhancing flowering pollen germination and pollen tube which might have ultimately increased fruit set and higher fruit retention (Godage *et al.*, 2013) [3].

Table 2: Effect of soil application of biofertilizers on number of flowers per twig, initial fruit set (%) and number of fruit drop of Kinnow mandarin

Treatments	Number of flowers per twig	Initial fruit set (%)	Number of fruit drop
T_1: 75% RDF + *Azotobacter chroococcum* Mac 27	12.2	48.72	634.33
T_2:75% RDF + *Azotobacter chroococcum* HT 54	12.0	47.72	651.00
T_3:75% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P 36	12.6	50.70	614.67
T_4:75% RDF + *Azotobacter chroococcum* HT 54 + *Pseudomonas* P 36	12.3	49.07	624.33
T_5:100% RDF + *Azotobacter chroococcum* Mac 27	13.0	54.12	579.33
T_6:100% RDF + *Azotobacter chroococcum* HT 54	12.6	52.73	606.00

T_7:100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P 36	13.4	54.93	575.67
T_8:100% RDF + *Azotobacter chroococcum* HT 54 + *Pseudomonas* P 36	13.3	53.86	578.67
T_9:Control (RDF)	12.0	50.03	672.00
CD at 5%	NS	NS	38.27

Fruit Yield and Yield Parameters

Number of Fruits/Tree, Average Fruit Weight and Fruit Yield

The data in table 3 reveal that different biofertilizer treatments significantly influenced number of fruits per tree. The maximum number of fruits per tree (543.33) was recorded with T_7 (100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36) which was found at par with T_5, T_6 and T_8. All the 100% RDF + biofertilizer treatments were found significantly superior over control in increasing number of fruits per tree. Minimum number of fruits per tree was observed in control (484.33). Average fruit weight was not significantly affected by various biofertilizer treatments, however, numerically T_2 (75% RDF + *Azotobacter chroococcum* HT 54) and T_6 (100 % RDF + *Azotobacter chroococcum* HT 54) gave highest average fruit weight and minimum values were observed in control.

Fruit yield of Kinnow was significantly influenced by different biofertilizer treatments at both RDF levels (75% and 100%). Maximum yield of 82.9 kg/tree was observed with T_7 (100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P36), the effect of which was found at par with all the biofertilizer treatments at 100% RDF (T_5, T6 and T_8). Minimum yield (72.3 kg/tree) was recorded in control (100% RDF) closely followed by T_2. All the biofertilizers treatments were found superior to control.

Table 3: Effect of soil application of biofertilizers on number of fruits per tree, average fruit weight (g) and yield (Kg/tree) of Kinnow mandarin

Treatments	Number of fruits per tree	Average fruit weight (g)	Yield (Kg/tree)
T_1: 75% RDF + *Azotobacter chroococcum* Mac 27	501.33	151.7	76.0
T_2:75% RDF + *Azotobacter chroococcum* HT 54	491.67	152.3	74.8
T_3:75% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P 36	524.00	150.0	78.6
T_4:75% RDF + *Azotobacter chroococcum* HT 54 + *Pseudomonas* P 36	512.00	151.3	77.5
T_5:100% RDF + *Azotobacter chroococcum* Mac 27	532.67	152.7	81.2
T_6:100% RDF + *Azotobacter chroococcum* HT 54	520.67	153.3	79.7
T_7:100% RDF + *Azotobacter chroococcum* Mac 27 + *Pseudomonas* P 36	543.33	152.7	82.9
T_8:100% RDF + *Azotobacter chroococcum* HT 54 + *Pseudomonas* P 36	537.00	152.3	81.8
T_9:Control (RDF)	484.33	149.3	72.3
CD at 5%	31.04	NS	4.2

Increase in number of fruits per tree and yield might be due to the increased fruit set and reduced fruit drop. The nitrogen fixers and phosphorus solubilizers might have increased the availability of nitrogen and phosphorus by increasing their translocation from roots to fruit and leaves to fruit (Singh and Singh, 2009) [6]. Biofertilizers may have helped improve the overall plant health and ecosystem, thereby enhancing assimilate portioning.

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