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*RESEARCH PAPER*

# Integrated use of organic and inorganic fertilizers with bio-inoculants on yield, soil fertility and quality of Nagpur mandarin (*Citrus reticulata* Blanco)

S.S. HADOLE, SHIVMALA WAGHMARE AND S.D. JADHAO*
Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA (M.S.) INDIA (Email : sdjadhao@rediffmail.com)

**Abstract :** The experiment was conducted to study the impact of integrated use of organic and inorganic fertilizers with bio-inoculants on yield, quality and soil fertility of Nagpur mandarin (cv. NAGPURI SANTRA) during 2011-12. The experiment was conducted on 11-12 years old (Bearing) citrus (cv. NAGPURI SANTRA) orchard planted under high density (6 m × 6 m) comprising five treatments, *viz.*, control (RDF as per package of practice), 100 per cent RDF + VAM + PSB + *Azospirillum* (100 g/plant), 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant), 75 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant), 50 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant)+ *Azospirillum* (100 g/plant). The experiment was laid out in Randomized Block Design with four replications. The highest fruit yield (112.75 kg tree$^{-1}$) was recorded in recommended dose of fertilizer (100% RDF + VAM 500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g /plant) followed by 100 per cent RDF + VAM + PSB + *Azospirillum* (100 g/plant) (99.01 kg tree$^{-1}$). The yield was increased, respectively to the extent of 36 and 19 per cent over control. The fruit weight also influenced significantly with the application of RDF (100% RDF + VAM 500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g /plant) (149.98 g fruit$^{-1}$). The fruit diameter also exhibited similar trend. Similarly, N (2.57%), P (0.36%) and K (1.69%) content in leaves were recorded maximum in RDF (100% RDF + VAM 500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g /plant). Fruit quality attributes in terms of total soluble solids (TSS), total sugars and ascorbic acid were improved with RDF (100% RDF + VAM 500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g /plant), however, maximum acidity was found in control treatment. The post harvest fertility status in terms of organic carbon (6.6 g kg$^{-1}$), available N (257.53 kg ha$^{-1}$), $P_2O_5$ (26.86 kg ha$^{-1}$) and $K_2O$ (542 kg ha$^{-1}$) were improved with RDF (100% RDF + VAM 500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g /plant).

**Key Words :** Nagpur mandarin, Bio-inoculants, Yield, Soil fertility, Total soluble solids, Ascorbic acid, *Azospirillum*

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## INTRODUCTION

Nagpur mandarin is the main fruit crop of Central India. In Maharashtra, Amravati and Nagpur division of Vidarbha are the principal orange growing districts. Nagpuri santra is the most popular cultivar of Vidarbha region due to its shape, colour, quality and marketability

*** Author for correspondence**

but has the disadvantages of low yield per unit area, high production cost, alternate bearing and highly susceptibility to disease. Inadequate and unbalanced use of inorganic fertilizers accompanied with restricted use of organic manures and biofertilizers have made the soils not only deficient in certain nutrients, but also deteriorated the soil health. Use of excessive inorganic fertilizers has not only resulted in soil and water pollution but also increased the incidences of disease, insect and pest attacks reducing the productivity and quality of fruit crops. Under these circumstances, integrated use of organic manures, inorganic fertilizers and biofertilizers has assumed great importance for sustainable production and maintaining soil health. The organic manures and biofertilizers not only supply macro and micronutrients, but also improve the soil physical, chemical and biological health under citrus cultivation. Inoculants of *Azospirillum* either sole or in combination have been shown to improve nitrogen nutrition of plants through biological $N_2$ fixation and also secretion of some growth promoting substances which affect the growth, nutrition and microbial activity in the rhizosphere (Zayed, 1999). The phosphate solubilizing micro-organisms (*Pseudomonas)* play an important role in conversion of unavailable inorganic P (Ca-P, Fe-P and Al-P) into available inorganic P forms through secretion of organic acids and enzymes, arbuscular mycorrhizal fungi (AMF), on the other hand arbuscular mycorrhizal fungi in soils throughout the world play an important role in affecting the plant growth through mobilization of nutrients. Symbiotic beneficial effects of AM fungi have been reported in many fruit crops such as citrus (Cruz *et al*., 2000). Inoculation of *Azospirillum* and arbuscular mycorrhizal fungi (AMF) either alone or in integration with organic or inorganic fertilizers on yield, nutrient content and quality of citrus under rainfed conditions has not been studied at large. Present investigation was, therefore, conducted to assess integrated effect of organic and inorganic fertilizers with biofertilizers on yield, nutrient content, fertility and quality of citrus.

## MATERIAL AND METHODS

A field experiment was conducted on 11-12 years old (bearing) citrus (cv. NAGPURI SANTRA) orchard planted under high density (6 m × 6 m) during 2011-12. The orchard site is situated at an altitude of 307.4 m above mean sea level (MSL) at the intersection of 20°40' North latitude and 77°02' East latitude. Average annual precipitation is 819 mm, out of which approximately 86 per cent receive during June to September. The orchard soil was shallow (Typic Haplusterts), moderately well drained high organic carbon (6.0 g $kg^{-1}$), available N (199.20 kg $ha^{-1}$), available $P_2O_5$ (19.8 kg $ha^{-1}$) and $K_2O$ (508.40 kg $ha^{-1}$) were recorded before initiation of experiment. The treatments were : $T_1$ – control recommended dose of fertilizers as per package of practice (100% NPK) 1200 g N; 400 g $P_2O_5$ $tree^{-1}$ and 50 kg FYM $tree^{-1}$, $T_2$ – 100 per cent RDF + VAM + PSB + *Azospirillum* (100 g/ plant), $T_3$ (100% RDF+ VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant), $T_4$ – 75 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant), $T_5$ – 50 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant). The experiment was laid out in a Randomized Block Design with four replications. For biofertilizers and AMF inoculation, the top layer of soil was removed to a depth of 5-10 cm, exposing the newly formed feeder roots when root system was active and new roots were formed without damaging root system. The nutrient composition of farm yard manure on dry weight basis was 0.61, 0.23 and 0.58 per cent of N, P and K, respectively. The uniform cultural practices were applied to the experimental trees. After fruit harvest, yield of different grades of fruits as well as size and weight of fruits of randomly selected (5 fruits $tree^{-1}$) were recorded. Biochemical analysis of fruits was done with the standard procedure of AOAC (1968). Briefly, the acidity of fruit juice was determined by titrating the diluted fruit juice against 0.1 N NaOH using phenolphthalein as indicator and represented as per cent. Whereas, ascorbic acid was determined by 2, 6 dichlorophenol indophenol dye method. Briefly, the fruit juice was titrated against 2, 6- dichlorphenol indophenol dye solution to a light pink colour, which persisted for 15 seconds. Results were expressed as mg/100 g of fruit flesh. The reducing sugar was estimated by dinitro-salicylic acid method and total sugar was estimated by using phenol-sulphuric acid. The non-reducing sugar was calculated by subtracting reducing sugar from total sugar. Leaves samples were collected from the middle portion of current seasons growth of fruiting shoots for nutrient estimation as per standards procedure. The soil samples were collected, processed and analyzed for organic C and available N, P and K as per standard methods (Jackson, 1973).

## RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

### Yield attributes, yield and quality of fruits :

Yield attributes of fruit *viz.,* fruit diameter, fruit weight, Nagpur mandarin significantly increased over control due to application of organic manures with inoculation of biofertilizers. Maximum fruit size, fruit weight were recorded with the application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) (Table 1). Similarly, maximum fruit yield was also recorded with the application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) followed by 100 per cent RDF + VAM + PSB + *Azospirillum* (100 g/plant) each and increased the fruit yield to the tune of 37 and 19 per cent over control, respectively.

The higher uptake of nutrients in the tissues of Nagpur mandarin with recommended dose of NPK might have occurred due to stimulation of the rates of various physiological and metabolic processes resulting in better size, weight and fruit yield of Nagpur mandarin. These results are in accordance with the findings of Treder (2007). Application of inorganic fertilizers with biofertilizers inoculation showed highest response in respect of fruit attributes as compared to the application of organic manures with and without integration of biofertilizers (Do-Amarante *et al.,* 2008).

Data on acidity, the most important characteristics of fruit quality of Nagpur mandarin shows that all the treatments significantly reduced the acidity over control (Table 1). The highest acidity (0.72%) was recorded under control whereas, lowest (0.64%) acidity was recorded under 100 per cent RDF + VAM (500 g/plant). This might be due to low N content under FYM treated fruit as compared to inorganic treatment resulting in lower N:Ca ratio. Highest total soluble solids (11.71°B), total sugar (7.90%) and ascorbic acid content (42.84 mg 100 $ml^{-1}$) were recorded with the application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) (Table 1). Application of inorganic fertilizers with integration of biofertilizers show remarkable effect on the quality of orange fruit (Marathe and Bharambe, 2005).

### Nutrient content in leaves :

Application of organic and inorganic fertilizers with inoculation of biofertilizer significantly increased the N, P and K content in leaves and over control (Table 2). The application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) recorded highest N (2.57 %) and P (0.36%) content in leaves followed by 100 per cent RDF + VAM + PSB + *Azospirillum* (100 g/plant) and 75 per cent RDF + VAM

**Table 1 : Effect of different treatments on fruit yield attributes, yield and quality of Nagpur mandarin cv. NAGPUR SANTRA**

| Treatments | Fruit yield attributes and yield | | | Fruit quality | | | |
|---|---|---|---|---|---|---|---|
| | Fruit yield (kg $tree^{-1}$) | Fruit wt. (g $tree^{-1}$) | Fruit diameter (cm) | Acidity (%) | TSS ($^0$B) | Total sugars (%) | Ascorbic acid (mg 100 $ml^{-1}$) |
| $T_1$ | 83.04 | 136.48 | 5.41 | 0.72 | 11.00 | 7.28 | 39.42 |
| $T_2$ | 99.01 | 146.82 | 5.70 | 0.70 | 11.41 | 7.78 | 42.68 |
| $T_3$ | 112.75 | 149.98 | 5.72 | 0.64 | 11.71 | 7.90 | 42.84 |
| $T_4$ | 98.34 | 145.57 | 5.56 | 0.71 | 11.37 | 7.56 | 43.10 |
| $T_5$ | 93.06 | 144.67 | 5.47 | 0.69 | 11.27 | 7.42 | 42.58 |
| C.D. (P=0.05) | 2.74 | 3.30 | 0.18 | 0.028 | 0.41 | 0.038 | 2.25 |

**Table 2 : Effect of different treatments on nutrient content of leaves and fertility status of Nagpur mandarin cv. NAGPUR SANTRA**

| Treatments | Nutrient content in leaves | | | Organic carbon (g $kg^{-1}$) | Fertility status after harvest | | |
|---|---|---|---|---|---|---|---|
| | N (%) | P (%) | K (%) | | Available N | Available P | Available K |
| $T_1$ | 2.03 | 0.24 | 1.40 | 6.2 | 216.75 | 19.46 | 516.40 |
| $T_2$ | 2.46 | 0.34 | 1.63 | 6.5 | 243.25 | 25.55 | 535.56 |
| $T_3$ | 2.57 | 0.36 | 1.69 | 6.6 | 257.53 | 26.86 | 542.07 |
| $T_4$ | 2.43 | 0.32 | 1.60 | 6.4 | 233.25 | 23.86 | 532.86 |
| $T_5$ | 2.33 | 0.28 | 1.49 | 6.3 | 233.10 | 21.01 | 528.56 |
| C.D. (P=0.05) | 0.35 | 0.030 | 0.18 | - | 9.68 | 4.92 | 4.85 |
| Initial value | | | | 6.0 | 199.20 | 19.8 | 508.40 |

(500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant). Inoculation of *Azospirillum* and AMF with inorganic fertilizers slightly improved the N and P content in leaves. The highest K content (1.69%) was recorded with the application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant). These results are in conformity with those reported by El-Boray *et al*. (2007).

**Soil fertility :**

Application of organic and inorganic fertilizers with integration of biofertilizers significantly affected the soil fertility of orange orchard (Table 2). Application of FYM with inoculation of biofertilizers significantly improved the soil organic carbon (SOC) content over control. The application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) recorded maximum (SOC) (6.6 g $kg^{-1}$).

Available N, P and K content were significantly affected due to application of organic and inorganic fertilizers with integration of biofertilizers over control. The application of 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) recorded maximum available N (257.53 kg $ha^{-1}$), available P (26.86 kg $ha^{-1}$). The build up of available P in soil due to $T_3$ and $T_2$ treatment was 13 and 11 per cent, respectively over initial status of P. This might be due to release of organic acids (chiefly malic and citric acid) from decomposition of organic manures which helps in solubilization of unavailable P. Inoculation of arbuscular mycorrhizal fungi (AMF) provides conducive physical environment which helps in mobilization of P into available P and also prevent the precipitation and fixation of applied phosphorus and keep in an available form (Do- Amarante *et al*., 2008). Inoculation of biofertilizers with FYM showed similar effect on the availability of K. Highest available K (542.07 kg $ha^{-1}$) was recorded under 100 per cent RDF + VAM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) treatment followed by 100 per cent RDF + VAM + PSB + *Azospirillum* (100 g/plant).

**Relationship among fruit diameter and fruits quality:**

The relationship studies indicated that, fruit diameter significantly influenced the fruit quality in terms of total soluble solids (r = 0.800**) and total sugars (r =0.984*) except acidity (r = 0.432) (Fig. 1). The improvement in fruit quality (total soluble solids and total sugars) as a

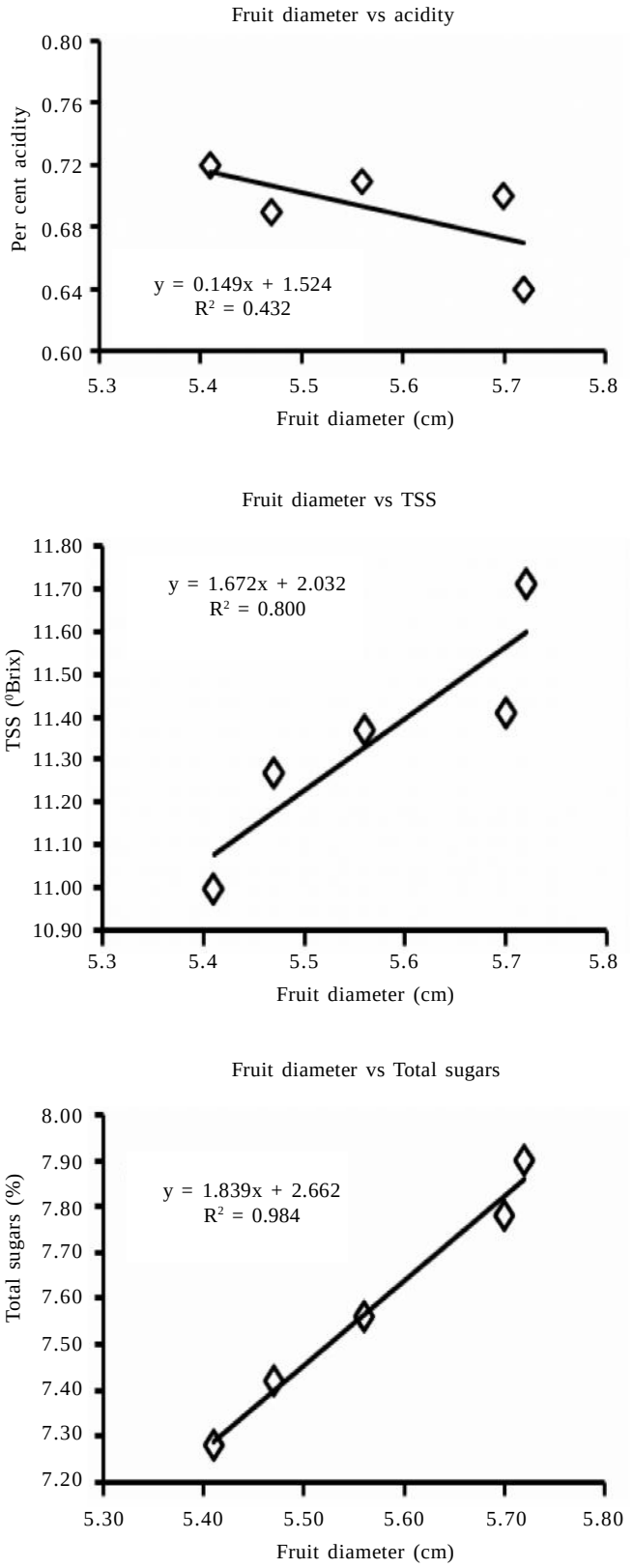


**Fig. 1 : Relationship among fruit quality and biochemical parameters**

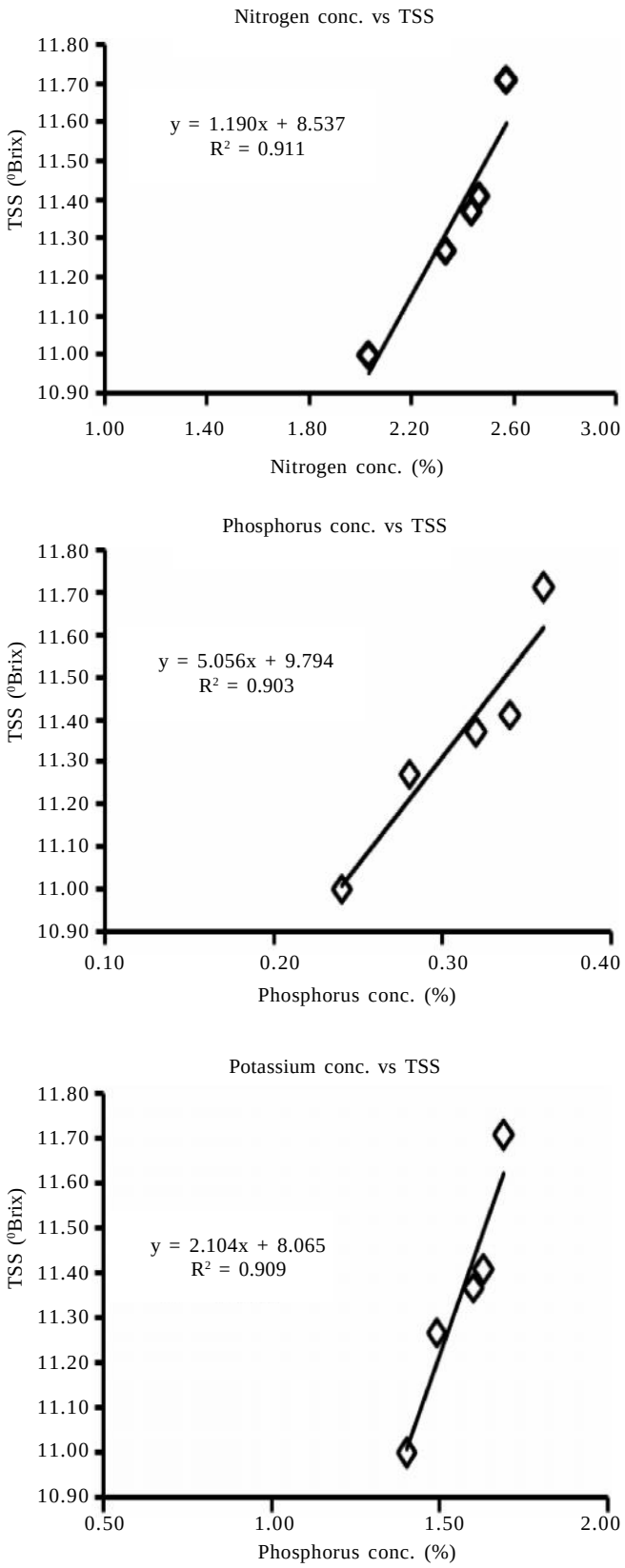


**Fig. 2 : Relationship among nutrient concentration and total soluble solids**

result fruit diameter may due to conversion of polysaccharides to sugars. Whereas, acidity decreased with increase in the fruit diameter may be due dissolution of fruit juice.

**Relationship among nutrient concentration and total soluble solids :**

The relationship studies indicated that, nutrient concentration in leaf significantly influenced the total soluble solids (Fig. 2). The total soluble solids of fruits were significantly influenced by nitrogen (r =0.911*) followed by potassium (r =0.906) and phosphorus (r =0.903*) indicating role of primary nutrients in improving fruit quality especially in terms of total soluble solids (Patil *et al.*, 2011; Jain *et al*., 2012 and Choudhary *et al*., 2013).

**Conclusion :**

From the above results, it is concluded that application of organic manure with integration of bio-inoculants, markedly improved the fruit quality but fruit yield and fertility status of soil increased only marginally. However, application of recommended dose of fertilizer as per package of practice achieved the highest fruit yield and improved fertility status but was slightly inferior in fruit quality. Therefore, the integration of inorganic fertilizers with organic manures and biofertlizers can achieve the highest fruit yield with improved fruit quality and soil fertility status of Nagpur mandarin.

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