Plant Archives Vol. 25, No. 1, 2025 pp. 167-172 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.025

STUDIES ON INTEGRATING INORGANIC NUTRIENTS AND BIOFERTILIZER APPLICATION ON THE PERFORMANCE OF SWEET ORANGE CV. MALTA IN THE GANGETIC ALLUVIAL SOIL OF WEST BENGAL INDIA

Aranyak Banerjee[1], Waris Habeeb[2*], Madhumita Basu[3], Shubham Jain[4], Md. Abu Hasan[1] and Sumana Balo[5]

[1]Department of Fruit Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia,West Bengal (741252), India.

[2] Research associate KVK Kishanganj, Bihar agricultural University, Sabour Bhagalpur Bihar, (INDIA) 813210.

[3] Department of Plant Pathology, Senior Scientist, Biosar, Kolkata, West Bengal (70089), India.

[4]Department of Horticulture, Gyanveer University Sagar (M.P.), India.

[5]Department of Soil Science and Agricultural Chemistry, School of Agriculture, GIET University, Gunupur, Rayagada, Odisha- 765022, India.

*Corresponding author E-mail: warishabeeb@yahoo.in

(Date of Receiving-18-11-2024; Date of Acceptance-19-01-2025)

ABSTRACT

The current investigation was carried out at a farmer's field in Sendanga, North 24 Parganas, West Bengal, India, from January to September of 2020-2021. The latitude and longitude of the location are 22.894 and 88.601. This work was designed with a Completely Randomized Design (CRD), with eight different treatments and four replications. The findings from the research regarding the effects of several doses and combinations of biofertilizers on growth parameters as well as quality parameters have been summarized. The experiment focused on a five-year-old sweet orange cv. Malta plants grafted onto Pummelo (*Citrus grandis*) rootstock, with a spacing of 5 m × 5 m. The results of this investigation demonstrated that the treatment involving (*Azotobacter chroococcum*100 g + *Azospirillum lipoferum* 100 g) + (*Paenibacillus polymyxa* 100 g + *VAM* 100 g) + (*Bacillus megaterium* 100 g + *Frateuria aurantia* 100 g) + 30 kg Vermicompost per plant (T8) exhibited superior performance compared to inorganic nutrient application (RDF + 30 kg Vermicompost) concerning growth, yield as well as quality parameters of Malta plants. Considering these aspects, T8 resulted in maximum increases in growth parameters, including plant height, tree spread and the highest average fruit weight (210.55 g). Furthermore, T8 displayed the most elevated fruit quality parameters, such as TSS content of 10.75ºBrix and higher levels of reducing sugar as well as ascorbic acid content.

***Keywords*:** *Azotobacter*, *Azospirillum*,fruit quality,Citrus sinensis, VAM, yield

Introduction

The sweet orange (*Citrus sinensis*) is a prominent member of the citrus family, belonging to the Rutaceae family and Aurantoidae sub-family (Russo *et al*., 2021). Columbus introduced these plants from the Western Hemisphere in the fifteenth century (Vashisth and Kadyampakeni, 2020). Primarily, it was introduced in the China region but has been distributed worldwide (Mahato *et al*., 2022). Citrus output reached a record-breaking 146 million tons globally in 2017, making it the leading fruit (Arah *et al*., 2016). Malta is a delicious and nutritious cultivar of sweet orange. Leaf aroma is entirely different from other members of the citrus group. The peel contains essential oils for flavor, baking and food products. Sweet oranges (*C. sinensis*) contain 0.7 grams of protein, 9.9 grams of carbs, and 0.2 grams of fat per 100 grams, which provides almost 45 kilocalories of energy. Per 100 millilitres of juice, it provides 39 calories and contains 9.8 grams of total carbs (soluble sugars), 0.5 grams of proteins, and very little fat (Bellavite and Donzelli, 2020).

Carotenoids, ascorbic acid and flavanones are other components of fruits that contribute to their therapeutic value. It is a good source of citric acid among all fruit crops. West Bengal is now a major emerging site for this fruit crop because of its versatile edapho-climatic adaptability, compatibility of Gangetic soil, prolific bearing habit, ability to withstand various abiotic and biotic stresses, and high remunerative even without much care. It requires extensive spread production to augment the demand for Malta (table and processing purposes) and ensure regular cropping and surge production. Fertilizer plays a role, in providing nutrients to the soil boosting its immunity, with high levels of nourishment. But the high cost of chemical fertilizers has reduced profit amounts for the farmers. Hence, it needs to be ascertained that organic manure and biofertilizer can take the place of inorganic fertilizer without disturbing the fruit quality as well as fruit yield (Navarro and Morte, 2024). So, biofertilizers constitute a safe and environmentally friendly alternative to chemicals, seeking to boost soil qualities and prolong horticulture crop yield. (Nosheen *et al.*, 2021; Vidhya Devi and Sumathy, 2017; Pathak *et al.*, 2017). However, the fertility and health of the soil have been compromised by the ongoing use of strong chemical pesticides and fertilisers. Expensive inorganic fertilizers and the wastage of plant nutrients caused by leaching, volatilization, and denitrification create severe economic losses to growers. There have been numerous reports of multi-nutrient deficits and decreased soil productivity as a result of careless fertiliser usage. Applying crop residues, organic manures and biofertilizer is thought to be an inexpensive way to give plants readily available nutrients that will improve the growth, yield and quality of different fruit crops (Anand *et al.,* 2022). Nutrition in sweet oranges plays a vital role in maintaining vegetative growth, reproductive growth and qualitative fruits production for extended periods. A key contributing factor to India's citrus decline is improper and insufficient nutrition (Shilewant *et al.*, 2023). Therefore, the goal of the current study is to assess how the application of biofertilizers and inorganic nutrients affects the growth, production and quality of sweet orange cv. Malta.

Materials and Methods

The research was ccarried out at a farmer's field located in Sendanga, North 24 Parganas, West Bengal, Indiaduring 2020-2021. The study involved the five-year-old plant and was designed as a Completely Randomized Design (CRD) experiment comprising four replications and eight distinct treatments. These treatments included: T1 (Control): Application of recommended inorganic fertilizer doses (800g N, 400g P_2O_5, 400g K_2O per plant), T2: Application of *Azotobacter chrococcum* (200g) + *Azospirillum lipoferum* (200g), T3: Application of *Paenibacillus polymyxa* (200g) + Vesicular Arbuscular Mycorrhizae (VAM) (200g), T4: Application of *Bacillus megaterium* (200g) + *Frateuria aurantia* (200g), T5: Application of a combination of Azotobacter (100g) + *Azospirillum lipoferum* (100g) + *Paenibacillus polymyxa*(100g) + VAM (100g), T6: Application of a combination of *Paenibacillus polymyxa*(100g) + VAM (100g) + *Bacillus megaterium* (100g) + *Frateuria aurantia* (100g), T7: Application of a combination of *Azotobacter chrococcum* (100g) + *Azospirillum lipoferum* (100g) + *Bacillus megaterium* (100g) + *Frateuria aurantia* (100g), T8: Application of a combination of *Azotobacter chroococcum* (100g) + *Azospirillum lipoferum* (100g) + *Paenibacillus polymyxa*(100g) + VAM (100g) + *Bacillus megaterium* (100g) + *Frateuria aurantia* (100g).

Additionally, 30 kg of vermicompost was uniformly applied in all treatments. Notably, the vermicompost utilized in the experiment contained 1.9% nitrogen (N), 1.25% phosphorus (P_2O_5), and 1.22% potassium (K_2O). Vermicompost was applied at a rate of 30 kg per plant, and biofertilizers were applied individually or in various combinations, except T8, which received 600g of biofertilizers. This application was carried out twice, first during the flowering season on 1st March 2020 and subsequently at the Marble fruit stage on 1stAugust 2020, under the tree canopy. Their respective treatment groups thoroughly mixed the biofertilizers with farmyard manure (FYM) or vermicompost.

Throughout the experiment, measurements were taken for tree height and tree spread. At harvest, mature green-stage fruits were collected and their weights were recorded using a digital balance. Parameters including TSS, acidity, and total sugars were evaluated in compliance with the Association of Official Analytical Chemists' (A.O.A.C., 2005) guidelines. The procedure outlined by Ranganna 1979 in 2000 was used to quantify the ascorbic acid content.

Statistical analysis was performed using the OPSTAT software, with a standard analysis of variance (ANOVA) procedure, following the established protocol suggested by Panse and Sukhatme 1995 .

Results and Discussion

The information shown in Table 1 makes it clear that the application of vermicompost and biofertilizers significantlyaffected the plant height of Malta. A noteworthy maximize enhancement in plant height, 3.39 meters, was observed in T7 treatment, followed closely

Table 1: Impact of inorganic nutrient and biofertilizers on Plant Height, Canopy Spread E-W and N-S (m), Fruit set (%), Fruit drop, Days from flowering to fruit, Number of fruits/tree, Average fruit weight (g) and Fruit yield (kg tree^{-1})

Treat-ment	Plant Height	Canopy Spread (E-W)	Canopy Spread (N-S)	Fruit set (%)	Fruit drop	Days from flowering to fruit	No. of fruits tree^{-1}	Average fruit weight (g)	Fruit yield (kg tree^{-1})
T1	2.09^{e}	1.77^{bc}	1.83^{ab}	23.35^{h}	87.16^{a}	242^{a}	165.07^{h}	181.18^{h}	30.7^{g}
T2	2.89^{bc}	1.89^{abc}	1.91^{ab}	24.17^{f}	84.83^{b}	235^{b}	168.13^{g}	190.08^{e}	31.35^{g}
T3	2.22^{de}	1.41^{de}	1.46^{cd}	24.62^{e}	84.26^{c}	231^{c}	173.85^{d}	185.92^{g}	32.11^{f}
T4	3.12^{b}	1.22^{e}	1.27^{d}	23.89^{g}	83.75^{d}	228^{d}	172.36^{f}	187.18^{f}	32.69^{e}
T5	3.05^{b}	1.95^{ab}	1.98^{a}	25.07^{d}	82.28^{f}	221^{e}	174.21^{c}	195.5^{c}	34.05^{c}
T6	2.43^{d}	1.63^{cd}	1.66^{bc}	27.11^{b}	80.12^{g}	216^{f}	175.12^{b}	202.49^{b}	35.37^{b}
T7	3.39^{a}	2.01^{ab}	2.03^{a}	25.53^{c}	82.75^{e}	232^{c}	173.17^{e}	192.48^{d}	33.48^{d}
T8	2.71^{c}	2.09^{a}	2.11^{a}	29.27^{a}	78.27^{h}	210^{g}	178.62^{a}	210.58^{a}	37.6^{a}
SE(m)	0.016	0.017	0.017	0.018	0.013	1.443	0.02	0.029	0.085
CD	0.047	0.05	0.048	0.052	0.037	4.238	0.058	0.086	0.249

by the T4 treatment, which exhibited a plant height achieve up to of 3.12 meters. In contrast, the T1 treatment showed the lowest increase in plant height, only 2.09 meters. The substantial increase in plant height observed in the T7 treatment can be attributed to the enhanced nutrient availability resulting from the combined application of vermicompost and biofertilizers. Conversely, the limited increase in plant height in the T4 treatment may be attributed to using a single type of biofertilizer, which may not have provided enough nutrients for optimal plant growth. It is worth noting that augmentation in the vegetative growth as well as other related factors may be attributed to increased chlorophyll production due to the inoculation of nitrogen-fixing microorganisms. Additionally, microorganisms in the rhizosphere that produce plantgrowth regulators, which are then taken by the roots, could have contributed to the increased vegetative growth. Similar findings of increased plant physical characters with the application of vermicompost as well as biofertilizers have been summarized in studies conducted by Marathe *et al.,* 2007 in sweet orange., Furthermore,maximumcanopy spread in E-W (2.09 m) as well as in N-S (2.11 m) were observed from T8 treatment while T4 treatment demonstrated the smallest canopy spread in E-W(1.22 m) as well as in N-S(1.27 m). The substantial spread observed in the T8 treatment, in terms of N-S and E-W dimensions, can be attributed to the augmented vegetative growth, which may have resulted from the greater availability of nutrients, thus assisting the plant's increased photosynthetic accumulation.

Fig. 1: Some experimental activities.

The maximum fruit set (29.27%) and minimum fruit drop percentage (78.27%)were found in the T8 treatment, whereas minimumfruit set and maximumfruit drop percentage were observed under Control (Table 1).The minimum days taken from flowering to fruit harvest was 210 days found in the plants receiving treatment T8 and maximum was recorded under the treatment of T1, having 242 days. The results are due to the biofertilizers' extended nutrient availability throughout the growth phase, which may have improved flowering and produced more flowers. The current results are supported by the obserations of Athani *et al.*, 2005 in guava. The minimal number of days needed for the first flower to appear suggests that all the necessary components for early

Fig. 2: Flowering Stage (a); Fruit set stage (b).

Table 2. Impact of inorganic nutrient and biofertilizers on Total Sugar, Reducing Sugar, Ascorbic acid, Juice, Rind, Weight of seeds/fruit, Number of seedsfruit^{-1}, Rind thickness and shelf life of fruit

Treat-ment	Total sugar (%)	Reducing sugar (%)	Ascorbic acid	Juice (%)	Rind (%)	Weight of seeds per fruit(g)	No. of seeds per fruit	Rind thickness	Shelf life of fruit	TSS (^{0} Brix)
T1	4.95^{d}	2.43^{d}	46.33^{h}	40.63^{h}	30.14^{a}	4.02^{a}	17.63^{a}	4.37^{a}	14.25^{g}	8.63^{f}
T2	5.32^{d}	2.65^{cd}	48.69^{f}	44.59^{e}	29.02^{b}	3.86^{a}	17.07^{b}	4.12^{a}	15.03^{f}	8.98^{e}
T3	5.06^{d}	2.51^{d}	47.25^{g}	41.24^{g}	28.59^{c}	3.38^{b}	16.55^{c}	4.21^{a}	15.65^{e}	8.3^{g}
T4	5.28^{d}	2.72^{bcd}	49.76^{e}	42.82^{f}	27.78^{d}	3.51^{b}	16.15^{d}	4.32^{a}	16.55^{d}	9.81^{d}
T5	6^{bc}	2.89^{abc}	53.24^{c}	47.47^{c}	27.19^{e}	3.11^{c}	14.55^{e}	3.37^{c}	17.5^{c}	10.12^{bc}
T6	6.23^{ab}	2.98^{ab}	54.95^{b}	49.78^{b}	26.45^{f}	2.973^{c}	13.95^{f}	3.28^{c}	18.07^{b}	10.24^{b}
T7	5.8^{c}	2.81^{bc}	52.05^{d}	45.61^{d}	26.08^{g}	3.42^{b}	14.12^{f}	3.68^{b}	16.35^{d}	9.98^{cd}
T8	6.48^{a}	3.15^{a}	56.51^{a}	50.27^{a}	26.18^{g}	2.58^{d}	13.47^{g}	3.17^{c}	18.89^{a}	10.75^{a}
SE(m)	0.016	0.016	0.015	0.017	0.016	0.017	0.015	0.017	0.017	0.03
CD	0.089	0.047	0.047	0.044	0.049	0.046	0.051	0.045	0.049	0.089

flowering are supplied by a balanced biofertilizer treatment.

The resultsshowed that differences among the no. of fruits/plant (Table 1) were significantly influenced by biofertilizers. T8 recorded maximum no. of fruits (178.62 fruits/plant) and was at par with T6 (175.12 fruits/tree). The minimum (165.07 fruits/tree) was recorded by T1 (Control). A similar result was reported by Ibe *et al.*, 2011 in citrus. The treatment T8 recorded maximum average fruit weight (210.58g) and was at par with the treatment T3 (202.49g). T1 recorded minimum average fruit weight (181.15 g). According to the results, all of the treatments considerably raised average yield above the control group while having varying effects on measures related to fruit quality. T8 recorded the maximum fruit yield (37.60 kg/plant) whereas T1 recorded the minimum (29.88 kg/plant). Applying biofertilizer improved the soil's porosity, internal drainage, nutritional content, and water conservation. This resulted in fewer fruit drops, more fruits overall, greater fruit weight, and increased orange yield. Dubey and Yadav 2003 on Khasi mandarin (*Citrus reticulate Blanco*) also reported that application of 110 kg pig manure + 750 g N + 650 g P produced maximum fruit yield/tree (163 kg) and minimum fruit drop (19.73%) in Khasi mandarin.

The highest TSS (10.75 ºBrix) was recorded in T8 (Table 2) which was at par with T6 (10.24 ºBrix), T5 (10.12 ºBrix) and T7 (9.98 ºBrix). T1 recorded the lowest TSS (8.30 ºBrix). The maximum total sugar (6.48%), reducing sugar (3.15%) as well as non-reducing sugar content (3.33%) were recorded in T8 while the minimums (4.95%, 2.43% and 2.52%, respectively) were recorded by T1. Fruits with higher sugar contents have better nutritional delivery and increased growth hormone production, which promotes cell division. Srivastava *et al.*, 2014 reported similar outcomes with papaya. Highest ascorbic acid content (56.51 mg/100 ml juice) was observed in T8 and was at par with T6 (54.95mg/100 ml juice). The minimum (46.33 mg/100 ml juice) was observed in T1. The right ratio of vermicompost to biofertilizers delivered nutrients at the right time and in the right amount, that hastened the chemical properties of orange. Abdalla *et al.*, 2011 also reported a similar result in grapefruit.The highest juice percentage (50.27%) was recorded in T8. T1 recorded the lowest juice percentage (40.63%). Shamseldin *et al.*, 2010 reported similar outcomes. In order to decrease nematode survival in the soil and enhance the quality of Washington Navel oranges, they investigated microbial bio-fertilization techniques. Khehra *et al.*, 2016 also reported a similar result in lemon. The maximum rind percentage (30.14%) was recorded in T1 and the minimum (26.08%) in T8. Highest weight of seeds per fruit (4.02 g) was observed from T1 whereas T8 recorded the minimum (2.58 g). The highest no. of seeds (17.63 seeds/fruit) was observed in T1 and lowest (13.47 seeds/fruit) in T8. Vadak *et al.*,

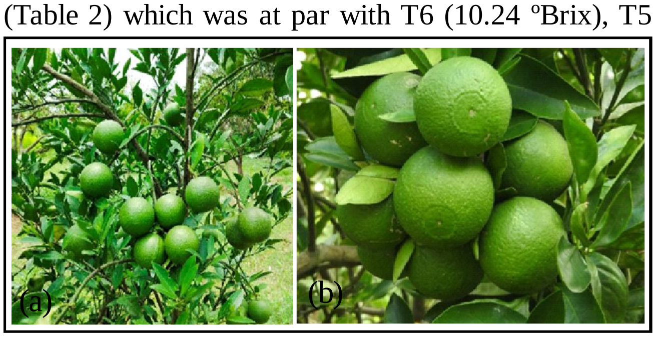
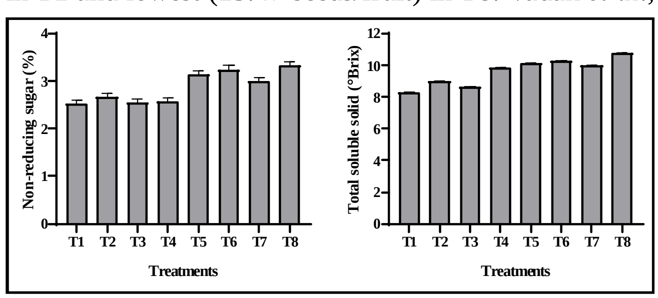


Fig. 3: Fruiting Stage (a); Mature stage (b).



2014 also reported a similar result in sweet orange. The minimum rind thickness (3.17mm) was recorded by T8. At the same time, the maximum (4.37 mm) was recorded by T1. Sharaf *et al*., 2011 reported similar outcomes with Washington Navel Orange.

The data indicated that the differences due to the application of vermicompost as well as biofertilizers on the shelf life of fruit were non-significant. However, highest shelf life (18.89 days) was observed from T8 where as the minimum (14.25 days) was recorded by T1 (Table 2). Improvement of shelf life due to the application of biofertilizers showed maximum shelf life with minimum respiration rate during storage. Better fruit quality concerning rind%, rind thickness, no. of seeds/fruit as well as seed weight/fruit might be because vermicompost and biofertilizers increased the amount of food materials in plants, which made it easier for the plants to employ those resources for fruit development.

It was established that (*Azotobacter chroococcum* 100 g + *Azospirillum sp.* 100 g) + (*Paenibacillus polymyxa* 100 g + VAM 100 g) + (*Bacillus megaterium* 100 g + *Frateuria aurantia* 100 g) + 30 kg Vermicompost (T8) produced the best results in terms of fruit quality. Organic farming can produce fruit sustainably while simultaneously increasing yield and quality. This organic technique equalled the performance of the control group (T1), which applied FYM and inorganic fertilizer at prescribed dosages.

Authors' Contributions

All the field experiments and laboratory analysis (AB), Preparation of the manuscript (AB,NB); Conceptualization of the experiments (AB, Md.AH, MB); Analysis of data (AB); Editing of the manuscript (NB).

Declaration

The authors declare that they do not have any conflict of interest.

Reference

Arah, I.K., Ahorbo G.K., Anku E.K., Kumah E.K. and Amaglo H. (2016). Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review. *Adv. Agric.*

Anand, K., Pandey G.K., Kaur T., Pericak O., Olson C., Mohan R., Akansha K., Yadav A., Devi R. and Kour D. (2022). Arbuscular mycorrhizal fungi as a potential biofertilizers for agricultural sustainability. *J. Appl. Biol. Biotechnol.*, **10(1)**, 90-107.

Anonymous (1990). Official Methods of Analysis, Association of Official Agriculture Chemists, 14th Ed. Washington, DC, USA.

Abdalla, A.M.E., Abdelmonem M.A., El-Tilib Hassan S., Ibrahim Abdelaziz Hashim and Abdelkarim H. Awadelkarim (2011). Response of foster grapefruit (*Citrus* sp.) to organic and inorganic fertilization in central Sudan. *Ann. Agric. Sci.*, **56**, 37-41.

Athani, S.I., Prabhuraj H.S., Ustad A.I., Swamy G.S.K., Patil P.B. and Kotikal Y.K. (2005). Effect of organic and inorganic fertilizers on vegetative growth parameters, fruit characters, quality and yield of 'Sardar'guava. In 1st International Guava Symposium. 5-8.

Bellavite, P. and Donzelli A. (2020). Hesperidin and SARS-CoV-2: New Light on the Healthy Function of Citrus Fruits. Antioxidants (Basel); **9(8)**, 742.doi: 10.3390/antiox9080742.

Dubey, A.K. and Yadav D.S. (2003). Response of Khasi mandarin (*Citrus reticulata* Blanco) to organic versus inorganic fertilization. *Indian J. of Agril. Res*., **37(3)**, 214-218.

Ibe, R.B., Lawal I.O. and Olaniyan A.A. (2011). Economic analysis of citrus yields as influenced by organo-mineral fertilizer treatments in Ibadan, Southwest Nigeria. *World j. agric. sci.*, **7(4)**, 425-429.

Khehra, S. and Bal J.S. (2016). Influence of combined use of organic, inorganic, and biological sources of nutrients on fruit quality in lemon. *Int. J. Agri, Environ and Biotech*., **9(1)**, 85-88.

Marathe, R.A. and Bharambe P.R. (2007). Micrological population in the rhizosphere as affected by organic, inorganic, and biofertilizer and their influence on sweet orange's soil and leaf nutrient status. *PKV Res J*, **29**, 20-23.

Mahato, S., Ghosh S.N., Mondal T. and Bauri F.K. (2022). Effect of nutrient feeding on controlling leaf chlorosis, yield and physico-chemical composition of sweet orange (*Citrus sinensis* L. Osbeck) cv. Mosambi.

Navarro, J.M. and Morte A. (2024). Arbuscular Mycorrhizal Fungi as Biofertilizers to Increase the Plant Quality of Sour-Orange Seedlings. *Agronomy*, **14(1)**, 230.

Nosheen, S., Ajmal I. and Song Y. (2021). Microbes as biofertilizers, a potential approach for sustainable crop production. *Sustainability*, **13(4)**, 1868.

Panse, V.G. and Sukhatme P.V. (1995). Statistical Methods for Agriculture Workers, ICAR, New Delhi.

Ranganna, G.S. (1979). Manual of analysis of fruit and vegetable products. Tata Mc Graw Hill Publishing Company, Ltd. New Delhi. 12-15.

Russo, C., Maugeri A., Lombardo G.E., Musumeci L., Barreca D., Rapisarda A. and Navarra M. (2021). The second life of Citrus fruit waste: A valuable source of bioactive compounds. *Molecules*. **26(19)**, 5991.

Shilewant, S., Kausadikar H.K., Gourkhede P.H. and Patil V.D. (2023). The Effect of Different Nutrient Management Practices on Yield and Leaf Nutrient Composition of Sweet Orange (*Citrus sinensis* L. Osbec). *Int. j. plant soil sci.*, **35(18)**, 1545-1553.

Srivastava, A., Singh J.K. and Singh H.K. (2014). Integrated nutrient management (INM) on papaya's grow, yield, and quality (*Carica papaya* L.) cv. CO-7. *The Asian J. Hort*., **9**, 390-395.

Sharaf, M.M., Bakry Kh. A. and EL-Gioushy S.F. (2011). The influence of some bio and organic nutritive addenda on growth, productivity, fruit quality, and nutritional status of Washington navel orange trees. *Egypt J. Appl. Sci*., **26(9)**, 135-140.

Shamseldin, A., El-Sheikh M.H., Hassan H.S.A., Kabeil S.S. and Borg-elarab N. (2010). Microbial biofertilization approaches to improve yield and quality of Washington navel orange and reduce the survival of nematode in the soil. *J. Am. Sci.*, **6(12)**, 264-271.

Vashisth, T. and Kadyampakeni D. (2020). Diagnosis and management of nutrient constraints in citrus. In Fruit Crops: Diagnosis and Management of Nutrient Constraints, Srivastava *et al*., (Eds). *Elsevier.* 723-737.

Vadak, Y., Patil M.B., Diwan K. and Kadam A. (2014). The Interaction effect of bio-fertilizers and reducing chemical fertilizers on the physicochemical characters of sweet orange (*Citrus sinensis Osbeck*). *The Asian J. Hort*., **9(1)**, 64-67.