



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(7): 1242-1245
Received: 02-04-2026
Accepted: 08-05-2026

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Growth and development of Valencia orange (*Citrus sinensis* L. Osbeck) under integrated nutrient management practices

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7p.6087>

Abstract

The present investigation entitled “Effects of Nano Nutrients Foliar Spray and Integrated Organic–Inorganic Soil Nutrient Management on Establishment and Growth of Valencia Orange (*Citrus sinensis* L. Osbeck)” was conducted during February to May, 2026 at the Crop Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh. The experiment was laid out in a Randomized Block Design (RBD) comprising 11 treatments with three replications to evaluate the effect of integrated nutrient management on the establishment and early growth of Valencia orange. Observations were recorded on plant height, stem girth, canopy spread, number of primary and secondary branches, number of leaves, leaf area, chlorophyll content, Leaf Area Index (LAI), survival percentage and Plant Vigour Index (PVI). The results revealed significant differences among the treatments, with T₁₀ (75% RDF + Vermicompost @ 5 kg + Nano N + Nano P + Nano K) consistently recording the highest values for all growth and physiological parameters, followed by T₉ (75% RDF + FYM @ 20 kg + Nano N + Nano P + Nano K), whereas the control (T₀) exhibited the lowest performance. The integrated application of organic, inorganic and nano nutrient sources enhanced nutrient availability, improved vegetative growth and promoted better plant establishment. Therefore, the application of 75% RDF + Vermicompost @ 5 kg per plant along with foliar spray of Nano N, Nano P and Nano K may be recommended as an efficient and sustainable nutrient management strategy for successful establishment and early growth of Valencia orange under the agro-climatic conditions of Prayagraj.

Keywords: Valencia orange, *Citrus sinensis*, nano nutrients, integrated nutrient management, vermicompost and FYM

Introduction

Citrus is one of the most economically important fruit crops cultivated globally, in terms of area harvested and the quantity of fruit harvested annually. Sweet orange (*Citrus sinensis* L. Osbeck) is the most widely consumed citrus fruit in the citrus group, with the largest proportion of global citrus production, and cultivars such as Valencia are highly valued for their late maturity, high juice content, and dual use for fresh consumption and processing. However, successful establishment and early vegetative growth of Valencia orange trees rely heavily upon an adequate and balanced supply of both macro- and micronutrients during the critical juvenile phase during which root systems are still developing and trees are most sensitive to nutritional stress. Traditionally, the conventional management of citrus orchards has been the application of inorganic fertilizers to the soil in meeting the nitrogen, phosphorus and potassium requirements. While this has worked well in the short term, the prolonged and exclusive use of chemical fertilizers has been linked to a decrease in soil organic matter, decreased microbial activity, leaching and increasing input costs, leading to a search for more sustainable alternatives by growers and researchers. Integrated nutrient management (INM) comprising of organic manures, biofertilizers and lower doses of inorganic fertilizers has been extensively advocated in citrus orchards as it improves the physical and biological health of the soil and supplies nutrients in readily available forms. In newly established orchards, the addition of organic sources such as compost or farmyard manure with beneficial microorganisms, including *Azotobacter* and

phosphorus-solubilizing bacteria, has been reported to improve root proliferation and overall tree vigor more than inorganic fertilization alone. Similarly, field studies on mature Valencia orange trees indicated that the replacement of a portion of the recommended mineral NPK dose with organic compost plus biofertilizer inoculation resulted in better vegetative growth, yield and fruit quality in comparison with sole dependence on mineral fertilizers.

In addition to the soil-based integrated approaches, foliar nutrition has received renewed interest as a complementary approach to rapidly and efficiently correct nutrient deficiencies because the nutrients absorbed through the leaf surface avoid many of the losses associated with soil fixation, leaching and antagonistic ion interactions. More recently, nanotechnology has opened new possibilities in this area through the development of nano-fertilizers, which have a significantly higher surface-area-to-volume ratio than their conventional counterparts, thus allowing greater cuticular penetration, more efficient nutrient uptake and faster translocation within plant tissues. Hence, foliar sprays with nano-enabled nutrients have been suggested to improve nutrient use efficiency while reducing the overall amount of fertilizer applied, which is of both economic and environmental benefit. This potential is supported by experimental evidence in citrus: moderate concentrations of nano-NPK formulations applied to orange trees via foliar application significantly improved vegetative growth traits compared to both untreated controls and higher, possibly phytotoxic doses. Similarly, Washington navel orange trees sprayed foliar with nano-iron showed improved vegetative growth, flowering, nutritional status, and fruit yield compared to conventional sulphate and chelated iron sources. Yield increases of more than 30 percent were noted under optimal nano-iron treatment.

However, most of the current studies have investigated either the integrated organic-inorganic fertilization of the soil or the nano-nutrient foliar application separately, with relatively little research on the combined effect of these two practices on the establishment and early growth of young Valencia orange trees. Considering that soil applied integrated nutrition contributes to the long-term soil fertility and root health, foliar nano-nutrition provides rapid and specific correction of aerial nutrient demand, a combined strategy could provide complementary and possibly synergistic benefits. The study of such an integrated approach is especially relevant to newly established orchards where rapid and uniform establishment directly controls time to first bearing and long-term orchard productivity. Therefore, the present investigation was undertaken to evaluate the effects of nano-nutrient foliar spray, integrated organic-inorganic soil nutrient management and their interaction on vegetative growth and establishment of young Valencia orange (*Citrus sinensis* L. Osbeck) trees to identify a nutrient management strategy that is both agronomically effective and environmentally sustainable.

Materials and Methods

The present investigation, titled “Effects of Nano Nutrients Foliar Spray and Integrated Organic-Inorganic Soil Nutrient Management on Establishment and Growth of Valencia Orange (*Citrus sinensis* L. Osbeck),” was conducted from February 2026 to May 2026. The experiment was organized using a Randomized Block Design (RBD) consisting of 11 treatments, each with 3 replications, T₀ – Control, T₁ – 100% Recommended Dose of Fertilizer (RDF), T₂ – 75% RDF, T₃ – 75% RDF + FYM @ 20 kg

plant⁻¹, T₄ – 75% RDF + Vermicompost @ 5 kg plant⁻¹, and T₅ – 75% RDF + Nano N @ 2 ml L⁻¹, T₆ – 75% RDF + Nano N + Nano K @ 2 ml L⁻¹, T₇ – 75% RDF + Nano N + Nano P @ 2 ml L⁻¹, T₈ – 75% RDF + Nano P + Nano K, T₉ – 75% RDF + FYM @ 20 kg + Nano N + Nano P + Nano K, and T₁₀ – 75% RDF + Vermicompost @ 5 kg + Nano N + Nano P + Nano K. Each treatment included 3 plants, resulting in a total of 18 experimental plots and 33 plants throughout the study. Healthy grafted plants were used as the planting material for this investigation. The primary objective of the study was to evaluate the effects of nano-nutrient foliar spray and integrated inorganic-organic soil nutrient management on the growth and development of Valencia orange.

Results and Discussion

The data recorded in Tables 1 and 2 showed that all the vegetative and physiological growth parameters exhibited a progressive increase from 30 days after treatment (DAT) to 90 DAT under all treatments. Among all the treatments, T₁₀ (75% RDF + Vermicompost @ 5 kg + Nano N + Nano P + Nano K) recorded the highest values followed by T₉ (75% RDF + FYM @ 20 kg + Nano N + Nano P + Nano K) throughout the study period, whereas the control (T₀) recorded the lowest values. At 90 DAT, the maximum plant height (110.94 cm) was observed under T₁₀, followed by T₉ (100.74 cm), against a minimum of 70.90 cm in the control. Similarly, the number of primary branches was highest under T₁₀ (8.46) and T₈ -75% RDF + Nano P + Nano K - (8.38), compared to 3.82 in the control, while the number of secondary branches peaked at 14.04 under T₁₀, followed by 13.28 under T₉, against 6.91 in the control. The number of leaves per plant followed the same trend, with T₁₀ (59.61), T₉ (58.28), and T₈ (56.58) outperforming the control (33.07). Physiological parameters mirrored this pattern: chlorophyll content was highest under T₁₀ (51.00 SPAD) and T₉ (49.70 SPAD) against 29.80 SPAD in the control; leaf area was maximum under T₁₀ (17.50 cm²) and T₉ (14.80 cm²) compared to 7.50 cm² in the control; and Leaf Area Index reached 0.78 under T₁₀ and 0.66 under T₉, against 0.23 in the control. Structural growth parameters also improved significantly with stem girth at 90 DAT recorded 3.05 cm under T₁₀, 2.93 cm under T₉ and 2.87 cm under T₈ compared to 1.52 cm in control while canopy spread was maximum under T₁₀ (47.70 cm) followed by T₈ (52.70 cm) and T₉ (45.10 cm) against 22.90 cm in control. Maximum Plant Vigour Index was recorded under T₁₀ (9.16) and T₉ (8.64) and minimum under control (4.89). The combined effect of vermicompost and nano-nutrient had improved the growth of Valencia orange by dint of increased photosynthetic activity, efficient use of nutrient uptake and better plant physiological process. The slow nutrient release continues from organic sources like vermicompost and FYM combined with the Nano nutrients may have improved the chloroplast development, plant metabolic activity, cell division which encourages the shoot formation, leaf production, canopy development and plant Vigor of Valencia orange. Similar findings were reported by El-Shereif *et al.* (2021) [3], Roshdy and Refaai (2016) [12], Khan *et al.* (2017) [7], Patel *et al.* (2018) [10], Verma *et al.* (2022) [18], Zulfiqar *et al.* (2019) [20], Salama (2012) [13], Jyothi and Hebsur (2017) [5], Wloch *et al.* (2023) [19], Sharma *et al.* (2021) [14], Kumar *et al.* (2022) [8], and Singh *et al.* (2020) [15] who reported the similar findings in the past like increase in vegetative growth, chlorophyll content and plant vigour of citrus and other crops through INM practices.

Table 1: Effect of Integrated Nutrient Management Practices on Plant height, No. of leaves, No. of Primary Branches and No. of Secondary Branches at different time interval.

Treatments	Plant Height (cm.)			No. of Leaves			No. of Primary Branches			No. of Secondary Branches		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T ₀ – Control	65.0	69.4	70.9	19.4	27.6	33.1	2.4	3.5	3.8	4	5.71	6.91
T ₁ – 100% RDF	68.3	74.1	77.6	25.8	39.4	53.0	3.7	5.9	6.4	5.5	7.95	9.51
T ₂ – 75% RDF	66.7	72.5	76.6	23.5	37.2	42.3	3.4	5.6	6.1	5	7.43	8.91
T ₃ - 75% RDF + FYM 20 kg.	76.9	82.0	85.6	23.5	33.6	46.8	4.0	6.2	6.7	6.1	8.46	10.21
T ₄ - 75% RDF + Vermi@5Kg	79.3	84.7	87.9	28.1	42.2	55.2	4.3	6.4	6.9	6.5	9.2	10.92
T ₅ - 75% RDF + Nano N @ 2 ml/L	68.2	73.6	77.3	26.6	39.9	53.2	3.8	6.0	6.4	5.9	8.35	9.92
T ₆ - 75% RDF + Nano N + Nano K @ 2 ml/L	71.2	76.8	80.3	27.0	40.9	54.1	4.1	6.2	6.7	6.2	8.86	10.41
T ₇ - 75% RDF + Nano N + Nano P @ 2 ml/L	75.8	81.3	84.7	26.3	39.7	53.1	4.1	6.3	6.7	6.4	9.02	10.72
T ₈ - 75% RDF + Nano P + Nano K	84.6	90.3	93.8	30.7	42.7	56.6	5.8	7.9	8.4	7.2	9.9	11.83
T ₉ - 75% RDF + FYM@20 kg + Nano N + Nano P + Nano K	91.6	96.6	100.7	32.0	45.2	58.3	5.0	7.3	7.8	8.3	11.32	13.28
T ₁₀ - 75% RDF + Vermi@5kg + Nano N + Nano P + Nano K	100.8	108.3	110.9	32.8	46.4	59.6	5.8	8.0	8.5	8.9	11.98	14.04
F- TEST	S	S	S	S	S	S	S	S	S	S	S	S
SE-d	1.77	1.54	1.46	0.97	1.52	1.5	0.30	0.31	0.31	0.05	0.12	0.05
CD (5%)	5.2	4.55	4.33	2.88	4.48	4.62	0.88	0.90	0.91	0.16	0.35	0.15
CV	3.9	3.23	2.95	6.3	6.66	5.20	12.21	8.42	7.94	1.47	2.29	0.82

Table 1: Effect of Integrated Nutrient Management Practices on Canopy spread, Stem girth, Chlorophyll content, Leaf area, Leaf area index, Plant vigour index at different time interval.

Treatments	Canopy Spread			Stem Girth			Chlorophyll Content	Leaf Area	Leaf area index	Plant vigour index
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT				
T ₀ – Control	19.6	20	22.1	0.9	1.3	1.50	29.8	7.5	0.23	4.89
T ₁ – 100% RDF	22.4	26.2	30.6	1.6	2.2	2.68	41.3	12.0	0.43	6.21
T ₂ – 75% RDF	19.6	23.3	27.9	1.5	2.3	2.60	35.4	10.8	0.38	5.85
T ₃ - 75% RDF + FYM 20 kg.	28.6	31.8	35.6	1.6	2.3	2.63	47.2	12.3	0.46	6.74
T ₄ - 75% RDF + Vermi@5Kg	24.1	28	31.9	1.5	2.3	2.69	45.8	13.0	0.49	7.15
T ₅ - 75% RDF + Nano N @ 2 ml/L	23.7	27.4	32	1.3	2.0	2.41	43.4	12.6	0.49	6.53
T ₆ - 75% RDF + Nano N + Nano K @ 2 ml/L	24.6	27.6	32.1	1.2	1.9	2.38	40.2	12.5	0.49	6.78
T ₇ - 75% RDF + Nano N + Nano P @ 2 ml/L	26.1	29.1	33	1.8	2.5	2.81	41.6	12.5	0.51	7.03
T ₈ - 75% RDF + Nano P + Nano K	25.2	28.3	32.7	1.8	2.5	2.87	37.0	13.3	0.57	7.7
T ₉ - 75% RDF + FYM@20 kg + Nano N + NanoP + Nano K	36.7	40.5	45.1	1.8	2.6	2.93	49.7	14.8	0.66	8.64
T ₁₀ - 75% RDF + Vermi@5kg + Nano N + Nano P + Nano K	39.6	43.2	47.7	1.9	2.7	3.05	51.0	17.5	0.78	9.16
F- TEST	S	S	S	S	S	S	S	S	S	S
SE-d	0.93	0.95	1.07	0.03	0.04	0.05	0.72	0.28	0.01	0.023
CD (5%)	2.73	2.79	3.15	0.08	0.13	0.15	2.13	0.83	0.04	0.013
CV	6.08	5.54	5.50	3.08	3.31	3.38	2.97	3.88	4.71	0.11

Conclusion

The present investigation demonstrated that integrated nutrient management significantly improved the establishment, vegetative growth and physiological attributes of Valencia orange under the agro-climatic conditions of Prayagraj. Among all the treatments, T₁₀ (75% RDF + Vermicompost @ 5 kg + Nano N + Nano P + Nano K) recorded the highest values for plant height, stem girth, canopy spread, branching, leaf production, leaf area, Leaf Area Index, chlorophyll content, survival percentage and Plant Vigour Index, followed by T₉, whereas the control (T₀) showed the lowest performance. The combined application of organic, inorganic and nano nutrients proved more effective than their individual application in promoting early plant establishment and growth. Therefore, this integrated nutrient management practice may be recommended for improving the establishment and productivity of Valencia orange and can serve as a sustainable nutrient management strategy for citrus growers under similar agro-climatic conditions.

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