Influence of Rootstock and Spraying with Amino Acids Solution in Growth and Chemical Content of Sweet Orange cv. "Local" Saplings

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Abstract

This study was conducted on local sweet orange saplings from May to December 2023 in the lath house of the Department of Horticulture and Landscape Gardening, College of Agriculture, University of Anbar, Ramadi, Iraq to investigate the impact of rootstock type (Sour orange, Rough lemon, Volkamer lemon, and Rangpur lime) and foliar spraying with Vegeamino solution (0, 1.50, and 1.75 ml L-1) on some vegetative growth characteristics and mineral content of the saplings. A factorial experiment was conducted using the Randomized Complete Block Design (RCBD) with three replicates per treatment and three saplings per experimental unit. The findings indicated that the rootstock type had a substantial influence on all studied attributes, notably the Rough lemon rootstock, which significantly outperformed the other rootstocks in terms of the number of primary branches, increment of leaves number, and dry weight of the vegetative parts, reaching 4.55 branch sapling-1, 56.22 leaf sapling-1, and 53.16 g, respectively. The same rootstock, without a significant difference from the Volkamer lemon rootstock, also achieved a substantial boosting the length of primary branches, leaves area, branches' total carbohydrate content, as well as the leaves content of N, P, K, and total chlorophyll, reaching 18.84 cm, 16.20 dm², 9.09%, 2.53%, 0.30%, 1.63%, and 1.37 mg g-1 fresh weight, respectively. Spraying with amino acids demonstrated a significant impact on all attributes, particularly the concentration of 1.75 ml L-1, which achieved the highest values of 4.16 branch sapling-1, 17.61 cm in length, 52.09 leaf sapling-1, 15.19 dm² leaves area, 50.63 g dry weight of vegetative parts, 9.08% total carbohydrate content in branches, and leaf content of 2.51% N, 0.28% P, 1.60% K, and 1.34 mg g-1 fresh weight of total chlorophyll.

Keywords: Citrus, Sweet orange, Rootstock type, Foliar application, Amino acids .

Introduction

Sweet Orange (Citrus sinensis (L.) Osbeck) is one of the citrus species that are most widely dispersed worldwide [30]. Its importance stems from the high nutritional value of its fruits, which are a source of many vitamins, especially Vitamin C, as well as vitamins A, B1, B2, B12, and P, some amino acids, and mineral elements. In addition, they play a role in treating many diseases [24]. The global production of oranges in 2021 was approximately 75,567,950 tons, with an area of 3,932,650 hectares cultivated [20]. In Iraq, the local sweet orange cultivar is commonly found in orchards, often grown under date palm trees. These orange trees are characterized by some variations in vegetative growth vigour and yield abundance [5]. The total number of fruitful orange trees in Iraq in 2020 was estimated at approximately 6,383,881 trees, producing around 142,717 tons, with an average yield per tree of about 22.4 kg [15.[

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The availability of well-grown saplings of suitable size for transplanting to the permanent location is a fundamental factor in the success of citrus cultivation. However, slow growth during the initial stages of sapling life and the long duration they remain in the nursery are significant challenges for nurserymen, leading to raised production costs. Therefore, some methods are employed to accelerate growth, including budded onto various types of rootstocks that differ in vegetative growth vigor.

Recently, several types of citrus rootstocks with different characteristics from the commonly used Sour orange rootstock have been introduced to Iraq. A sapling relies on two main parts: the scion and the rootstock, as well as the physiological relationship that binds them. It is known that the rootstock influences the vigor of the budded saplings on it, the size of their vegetative system, the productivity and quality of the fruits, and their resistance to various environmental conditions and diseases [22,13]. Therefore, using the appropriate rootstock is considered a guarantee for obtaining strong saplings capable of balanced growth in the permanent location. Numerous researchers have demonstrated the different impacts of citrus rootstocks on growth and chemical content of budded saplings, including [9] on Valencia orange saplings, [27] on Kinnow mandarin saplings, [4] on Local lemon saplings, [26] on Salustiana orange saplings, [29] on Local lemon saplings, and [23] on Shatangiu mandarin saplings.

Amino acids are biostimulants essential for biological processes in plant. Foliar applied of amino acids is an effective way to provide available building blocks for proteins [25]. Amino acids influence various biological activities that affect plant growth and development, enhancing the efficiency of photosynthesis and stomatal movement, as well as playing a role in resistance to environmental stresses [16]. Their importance lies in their widespread use, as they serve as precursors for the biosynthesis of certain plant hormones and are involved in the biosynthesis of various non-protein nitrogenous compounds such as pigments, enzyme cofactors, and vitamins, as well as in the formation of nitrogenous bases [12]. Many studies have highlighted the significant role of amino acids foliar spraying in promoting the growth of various types of saplings and fruit trees, including Washington navel orange trees [18], Canino apricot trees [17], Local sweet orange saplings [2], almond saplings [1], and Local lemon saplings [3.[

Therefore, this study aims to explore the potential for increasing the growth of saplings budded onto various types of citrus rootstocks, as well as the effect of foliar spraying with amino acids and their interaction, to bring the saplings to a suitable stage for transplanting to the permanent location in shortest possible time.

Materials and Methods

Site of the experiment

The study was conducted in the lath house of the Department of Horticulture and Landscape Gardening, College of Agriculture, University of Anbar, Iraq, from May 2023 to December 2023. To investigate the effects of citrus rootstock types (Sour orange, Rough lemon, Volkamer lemon, and Rangpur lime) and foliar spraying with amino solution (Vegeamino) on certain vegetative characteristics and the chemical constitution of local sweet orange saplings.

Budded sweet orange saplings on different rootstocks at the spring budding date

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(20/3/2023) were brought from the Karbala Nursery of certified Citrus of the General Company for Horticulture and Forestry, located in Sadda Al-Hindiya/Karbala on 25/4/2023. A total of 108 uniformly grown saplings were selected and cultivated in 7 kg capacity plastic bags. All necessary maintenance operations, including weeding and pest control were carried out as needed. Additionally, compound fertilizer NPK (20:20:20) was applied at a rate of 100 g per sapling, divided into four doses (May, June, September, and October) [6, 10]. Drip irrigation was used for watering the saplings. Soil samples were collected for some physical and chemical analyses before executing treatments (Table 1.(

Table 1. The experimental soils' physical and chemical characteristics

Physical properties (g kg^{-1} soil)				
Sand	Silt	Clay	Texture	
641.2	160.3	198.5	Sandy loam	
Chemical properties				
pH	EC (1:1) ds m^{-1}	N (mg kg^{-1} soil)	P (mg kg^{-1} soil)	K (mg kg^{-1} soil)
7.3	1.67	64.8	15.1	173.5

Treatments and experimental design

Two factors were used in the experiment, the first included four types of one-year-old citrus rootstocks: Sour orange (C. aurantium L.), Rough lemon (C. jambhiri Lush.), Volkamer lemon (C. volkameriana Ten. & Pasq.), Rangpur lime (C. limonia (L.) Osbeck), represented as SO, RO, VO, and RA sequentially. The second, the factor was foliar applied with three concentrations (V0, V1.50, and V1.75 ml L-1) of the amino solution under trade name Vegeamino produced by Artal Agronutrientes Co. / Spain and contains a mixture of seventeen free amino acids in the L-α form as shown in Table 2. Foliar spraying with amino acids was conducted early in the morning on 1/5, 1/6, 1/9, and 1/10/2023.

Table 2. Contents of Vegeamino solution

ASP.	0.181%	GLY.	1.951%	ALA.	0.158%
VAL.	0.018%	LEU.	0.007%	PRO.	0.066%
GLU.	16.23%	THR.	0.040%	TYR.	0.148%
PHE.	0.027%	LYS.	0.364%	HYP.	0.321%
SER.	0.317%	ARG.	0.007%	MET.	0.013%
ILE.	0.002%	HIS.	0.109%		

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A factorial experiment (4 × 3) was conducted within a Randomized Complete Block Design (RCBD) [7] with three replicates. Each replicate consisted of three saplings per treatment. Data were analyzed using the statistical software GeneStat, and the means were compared using the Least Significant Difference (L.S.D.) test at a 0.05 probability level.

Studied traits

The rate of increase in leaves number was determined by calculating the total number of leaves per sapling before applying the treatments (25/4) and again at the end of the experiment (1/12), then determining the rate of increase. After the end of the experiment, the other traits were measured, which included: Number and length of primary branches, Leaves area [14], Dry weight of vegetative system, Total carbohydrate content in the branches [8], Percentage of nitrogen, phosphorus, and potassium in leaves [11], Total chlorophyll content in leaves [21./

Results and Discussion

Vegetative growth traits

The results in Table 3 indicate that the rootstock type had a significant influence on all traits, particularly the Rough lemon (RO) rootstock, which significantly outperformed the other rootstock types in the primary branches number, increase in the leaves number, and vegetative system dry weight, reaching 4.55 branch sapling-1, 56.22 leaf sapling-1, and 53.16 g, respectively. The same rootstock, without a significant difference from the Volkamer lemon (VO) rootstock, also attained a significant increase in length of primary branches and leaves area, which were 18.84 and 18.31 cm, 16.20 and 15.04 dm² for the two rootstocks, respectively. In contrast, Sour orange (SO) rootstock recorded the lowest values, with 2.88 branch sapling-1, 11.35 cm branch length, 28.56 leaf sapling-1, 9.19 dm² leaves area, and 31.60 g dry weight of vegetative parts, respectively.

Foliar spraying with amino acid solution significantly affected all traits, especially treatment V1.75, which significantly excelled in the primary branches number (4.16 branch sapling-1), length of primary branches (17.61 cm), leaves number increment (52.09 leaf sapling-1), leaves area (15.19 dm²), and dry weight of the vegetative parts (50.63 g) in comparison with other transactions. Conversely, the lowest values were noted for treatment V0, reaching 2.99 branch sapling-1, 11.95 cm branch length, 31.67 leaf sapling-1, 9.99 dm² leaves area, and 33.12 g dry weight of the vegetative parts, respectively.

The interaction between rootstocks and amino acids solution had a significant impact on growth traits. The ROV1.75 treatment achieved the highest values for the number of primary branches (5.33 branch sapling-1), increase in the number of leaves (64.44 leaf sapling-1), leaves area (18.29 dm²), and dry weight of the vegetative parts (61.64 g). Meanwhile, the VOV1.75 treatment recorded the greatest branch length, reaching 20.83 cm. On the other hand, SOV0 noted lowest values .

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Table 3. Impact of rootstock type and amino solution foliar application and their interaction on number and length of primary branches, leaves number increment, leaves area, and vegetative system dry weight

	Number of main shoots (shoot $sapling^{-1}$)	Length of main shoots (cm)	Leaves number increment (leaf $sapling^{-1}$)	Leaves area (dm^2)	Vegetative system dry weight (g)
Rootstock type					
SO	2.88	11.35	28.56	9.19	31.60
RO	4.55	18.84	56.22	16.20	53.16
VO	3.88	18.31	51.75	15.04	49.59
RA	3.10	11.65	32.90	10.36	34.36
L.S.D.	0.44	0.79	2.38	1.72	1.27
Amino solution (V) ml L^{-1}					
V_0	2.99	11.95	31.67	9.99	33.12
$V_{1.50}$	3.66	15.56	43.30	12.92	42.79
$V_{1.75}$	4.16	17.61	52.09	15.19	50.63
L.S.D.	0.38	0.69	2.06	1.48	1.10
Rootstock type x Amino solution					
SOV_0	2.33	7.61	17.67	6.47	23.12
$SOV_{1.50}$	3.00	12.29	29.33	9.39	32.76
$SOV_{1.75}$	3.33	14.16	38.67	11.73	38.93
ROV_0	3.66	16.20	46.00	13.60	43.56
$ROV_{1.50}$	4.66	19.53	58.22	16.72	54.28
$ROV_{1.75}$	5.33	20.80	64.44	18.29	61.64
VOV_0	3.33	15.62	41.56	12.50	39.05
$VOV_{1.50}$	4.00	18.48	52.00	15.10	48.81
$VOV_{1.75}$	4.33	20.83	61.68	17.54	60.90
RAV_0	2.66	8.37	21.44	7.41	26.73
$RAV_{1.50}$	3.00	11.95	33.67	10.47	35.29
$RAV_{1.75}$	3.66	14.65	43.56	13.22	41.05
L.S.D.	0.77	1.38	4.12	2.97	2.20

The variation in the number and length of primary branches of local orange saplings grown on different citrus rootstocks is possibly due to the differences in the rootstock's genotype and their physiological status. This, in turn, affects the nature and vigor of the vegetative growth of the saplings. Rough lemon and Volkamer lemon are considered vigorous rootstocks with extensive and deep root systems [28,13], which can influence the transport of nutrients and growth-promoting substances, positively affecting the characteristics of the saplings

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grown on them. The difference in the leaves' number and area among rootstocks may be because of the difference in their influence on the number and length of the sapling's branches. The rise in the vegetative system dry weight, in addition to the percentage of carbohydrates in saplings grown on Rough lemon rootstock, can be attributed to vegetative growth's vigour and activity, which is evidenced by the increased leaves number and area (Table 3), as well as their higher content of total chlorophyll which enhances the effectiveness of photosynthesis and raises the production of carbohydrates, which ultimately leads to an increase in dry weight. These outcomes concur with the findings of [9] on orange saplings grown on two types of rootstocks, and with the results of [23] on mandarin saplings grown on 11 citrus rootstocks.

Foliar spraying with amino acid solution, particularly at 1.75 ml L-1 concentration, effectively enhanced vegetative growth traits (Table 3). This is due to the amino acids it contains (Table 2) and their vital role in supplying the plant with ready-made building blocks for proteins. Additionally, amino acids play a crucial role in metabolic processes, formation of nucleic acids, stimulating cell elongation and division, as well as contributing to the synthesis of secondary compounds and activating the plant's enzymatic system [25]. In addition to their role in the synthesis of various compounds such as vitamins, co-enzymes, and pigments [12], amino acids also enhance the photosynthesis efficiency, in addition, stimulate chlorophyll and carbohydrate biosynthesis, which contribute to increased vegetative growth. Furthermore, amino acids are involved in the biosynthesis of several plant hormones such as auxins, cytokinins, and polyamines, particularly tryptophan, phenylalanine, and arginine, which play significant and wide-ranging roles in plant growth and development [16]. In light of these functions and various physiological effects of the components of the amino acid solution, it is expected that the biological activity of saplings would increase, positively impacting the improvement of vegetative growth traits and their association with an increase in vegetative parts dry weight and branches content of carbohydrates. These outcomes agree with the results of [17] on trees of apricot when sprayed with amino acid solution Bioflow, and with the results of [2] when sprayed Amino plus TG solution on sweet orange saplings .

Chemical traits

The results in Table 4 indicate significant differences between rootstock types in terms of the percentage of total carbohydrates in branches, as well as the nitrogen, phosphorus, potassium, and total chlorophyll content in the leaves. The RO rootstock, which didn't differ substantially from the VO rootstock, showed a significant superiority over the other rootstocks, with the highest values recorded at 9.09%, 2.53%, 0.30%, 1.63%, and 1.37 mg g-1 fresh weight, respectively. In contrast, the SO rootstock recorded the lowest values, which were 8.85%, 2.40%, 0.22%, 1.38%, and 1.18 mg g-1 fresh weight, respectively.

amino acids foliar applied also revealed a significant rise, with the V1.75 concentration achieving the highest content of total carbohydrates as well as the highest leaves content of nitrogen, phosphorus, potassium, and total chlorophyll, reaching 9.08%, 2.51%, 0.28%, 1.60%, and 1.34 mg g-1 fresh weight, respectively. In contrast, the V0 level recorded the lowest values, which were 8.81%, 2.40%,

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0.23%, 1.38%, and 1.19 mg g-1 fresh weight, respectively.

The interaction between the study factors had a significant impact on the total carbohydrate percentage in the branches, and the nitrogen and potassium percentages in the leaves, as well as their total chlorophyll content. Notably, the ROV1.75 treatment recorded the highest values at 9.21%, 2.58%, 1.74%, and 1.44 mg g-1 fresh weight, respectively. On the other hand, SOV0 noted lowest values.

Table 4. Impact of rootstock type and amino solution foliar application and their interaction on the branches content of total carbohydrates, percentage of nitrogen, phosphorus, potassium in leaves, as well as their chlorophyll content

	Total carbohydrates (%)	N (%)	P (%)	K (%)	Total chlorophyll (mg g^{-1} F.W.)
Rootstock type					
SO	8.85	2.40	0.22	1.38	1.18
RO	9.09	2.53	0.30	1.63	1.37
VO	9.06	2.51	0.29	1.60	1.36
RA	8.85	2.41	0.23	1.39	1.20
L.S.D.	0.22	0.04	0.03	0.05	0.08
Amino solution (V) ml L^{-1}					
V_0	8.81	2.40	0.23	1.38	1.19
$V_{1.50}$	9.00	2.47	0.26	1.52	1.30
$V_{1.75}$	9.08	2.51	0.28	1.60	1.34
L.S.D.	0.19	0.03	0.02	0.04	0.07
Rootstock type x Amino solution					
SOV_0	8.67	2.33	0.19	1.27	1.11
$SOV_{1.50}$	8.88	2.41	0.23	1.41	1.20
$SOV_{1.75}$	9.01	2.46	0.25	1.48	1.25
ROV_0	8.95	2.48	0.27	1.52	1.29
$ROV_{1.50}$	9.13	2.55	0.31	1.65	1.40
$ROV_{1.75}$	9.21	2.58	0.33	1.74	1.44
VOV_0	8.93	2.44	0.26	1.50	1.28
$VOV_{1.50}$	9.09	2.53	0.29	1.61	1.38
$VOV_{1.75}$	9.16	2.57	0.32	1.69	1.44
RAV_0	8.71	2.36	0.20	1.25	1.11
$RAV_{1.50}$	8.90	2.42	0.24	1.42	1.23
$RAV_{1.75}$	8.95	2.45	0.25	1.51	1.26
L.S.D.	0.39	0.06	N.S.	0.09	0.14

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The variation in the impact of rootstocks on the nitrogen, phosphorus, and potassium content in leaves of orange saplings, particularly the superiority of the Rough lemon and Volkamer lemon, may be attributed to their role in enhancing the vegetative growth, such as increasing leaves number and leaves area and their association with an increase in carbohydrates (Table 4), part of which is utilized in building the root system and providing the necessary energy for the absorption of available minerals from the soil (Table 1.(

The rise in these elements' content because of foliar spraying with the amino solution could be related to the amino acids' role, particularly glutamic acid. Glutamic acid acts as an osmotic agent within the guard cells, which encourages stomatal opening [12,16]. This leads to an increased rate of transpiration, which in turn enhances the absorption and transport of mineral ions. Additionally, amino acids are an important source of organic nitrogen which increases the amount of energy supplied (ATP). This makes the roots more efficient in absorbing nutrients [19.[

The increase in total chlorophyll content of saplings grown on Rough lemon and Volkamer lemon rootstocks, as well as those treated with amino acids, possibly attributed to the study factors' impact on enhancing the saplings' nutritional status, particularly the nitrogen content in the leaves (Table 4). Nitrogen is essential in forming the porphyrin ring, a key component in chlorophyll pigment structure [31]. Additionally, the increase in chlorophyll content due to foliar spraying with the amino acid solution can be linked to the amino acids it contains, especially glycine and glutamic acid. These compounds are fundamental in the biosynthesis of chlorophyll pigment [16]. These outcomes concur with the results of [26] on orange saplings grown on five different rootstocks, where the Rough lemon rootstock achieved the highest content of nitrogen, phosphorus, and potassium in the leaves. Similarly, they align with the findings of [29] who reported a notable rise in the leaves content of N, and P in addition to total chlorophyll of lemon transplants grown on Swingle citrumelo rootstock compared to four other types of citrus rootstocks.

These results also align with those of [18], who observed a notable rise in the percentage of N, P, and K, as well as the total chlorophyll content in the leaves of navel orange trees when sprayed with the amino solution Bioflow. Additionally, they are consistent with the findings of [1], who reported a significant increase in the phosphorus and potassium percentage in leaves, along with total chlorophyll content, when almond saplings were foliar sprayed with the amino acid solution Aminoplasmal B Braun 10%.

Conclusion

The genetic variation among the citrus rootstocks revealed a significant impact on all attributes. The Rough Lemon rootstock excelled in most vegetative growth and chemical content traits, followed by the Volkamer Lemon rootstock, while the Sour Orange rootstock recorded the lowest values. Additionally, the growth traits of the local orange saplings significantly improved with increasing levels of foliar spraying with the amino acid solution, especially at the concentration of 1.75 ml L-1.

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.**References**

[1]
Abdul Qader, M. A., Ibrahim, Z. R. and Nabi, H. S. 2022. Response of almond seedling (Prunus amygdalus) to spray of aminoplasmal, humic acid, and boron. Iraqi Journal of Agricultural Sciences, 53(2): 415-428.

[2] Al-Janabi, A. M. I. 2020. Effect of shading, rootstock type and foliar spraying with amino acids on some growth traits of sweet orange (Citrus sinensis L. Osbeck) saplings. Biochem. Cell. Arch., 20(1): 1735-1744.

[3] Al-Karboli, L. H. A. and Al-Janabi, A. M. I. 2024. Effect of brassinolide and moringa leaf extract foliar application on growth and mineral content of local lemon transplants. Sabrao Journal of Breeding and Genetics, 56(1): 323-331.

[4] Alkhafaji, A. R. and Khalil, N. H. 2019. Effect of fertilization, rootstocks and growth stimulant on growth of Citrus limon L. sapling. Iraqi Journal of Agricultural Sciences, 50(4): 990-1000 .

[5] Al-Khafaji, M. A., Attra, S. O. and Abd El-Razaq, A. 1990. The Evergreen Fruits. Ministry of Higher Education and Scientific Research, University of Baghdad, Iraq.

[6] Al-Mineesy, F. A. 1975. Citrus. Scientific foundations of cultivation – 1st edition - New Publications House - Alexandria.

[7] Al-Mohammedi, S. H. M. and Al-Mohammadi, F. M. 2012. Statistics and Experiments Design. Dar Osama for Publishing and Distribution, Amman - Jordan.

[8] AOAC, 1980. Official methods of analysis. 13th ed. Association of Official Analytical Chemists. Washington, D.C.

[9] Ataweia, A. A., Bakry, K. H. A., Abd EL Aal, M. M. and Abo-Hamda, M. A. 2015. Physiological studies on Valencia orange transplants budded on different Citrus rootstocks I-vegetative growth measurements. Middle East Journal of Agriculture Research, 4(4): 1038-1046.

[10] Aubied, I. A., Al-Janabi, A. M. I. and Alkhafaji, Z. A. H. 2023. Effect of NPK fertilization and leaf/bunch ratio on fruit yield and quality of Khastawi date palm. Sabrao Journal of Breeding and Genetics, 55(4): 1443-1450.

[11] Bahargava, B. S. and Raghupathi, H. B. 1999. Analysis of plant materials for macro and micronutrients. Pp.49-82. In: Methods of analysis of soils, plants, water and fertilizers, Tandon, HLS (eds.), Binng Printers. L-14, Lajpat Nagar New Delhi.

[12] Bell, E. A. 2003. Nonprotien amino acids of plants: significance in medicine, nutrition, and agriculture. J. Agric. Food chem., 51(10): 2854-2865.

[13] Bowman, K. D. and Joubert, J. 2020. Citrus Rootstocks, In: The Genus Citrus. Talon, M, Caruso, M, and Gmitter FG (eds.), Elsevier Inc. pp. 105-127 .

[14] Chou, G. J. 1966. Anew method of measuring the leaf area of citrus. Acta Hort. Sci., 5: 7-20.

[15] CSO, 2020. Citrus Trees Production. Central Statistical Organization, Ministry of Planning, Iraq.

ISSN 2072-3857

[16] D'Mello, J. P. F. 2015. Amino acids in higher plants. Formerly Scottish Agriculture College, UK. 632P.
[17] El-Badawy, H. E. M. 2019. Effect of spraying amino acids and micronutrients as well as their combination on growth, yield, fruit quality, and mineral content of Canino apricot trees. Journal of Plant Production, 10(2): 125-132.
[18] El-Gioushy, S. F., El-Badawy, H. E. M. and Elezaby, A. A. 2018. Enhancing productivity, fruit quality and nutritional status of Washington Navel Orange trees by foliar applications with GA3 and amino acids. Journal of Horticultural Science & Ornamental Plants, 10(2): 71-80.
[19] Enders, L. and Mercier, H. 2003. Amino acid uptake and profile in bromeliads with different habits cultivated in vitro. Plant Physiol. Biochem., 41(2): 181-187.
[20] FAOSTAT, 2021. Food and Agriculture Organization of the United Nation. Available in: http://www.fao.org/faostat/en/#data/qc.
[21] Gogoi, M. and Basumatary, M. 2018. Estimation of the chlorophyll concentration in seven Citrus species of Kokrajhar district, BTAD, Assam, India. Tropical Plant Research, 5(1): 83-87.
[22] Hartmann, H. T., Kester, D. E., Davies, F. T. and Geneve, R. L. 2011. Hartmann and Kester's Plant Propagation: Principles and Practice, 8th ed. Pearson Education Inc., Publishing as Prentice Hall, One Lake Street, Upper Saddle River, NJ 07458.
[23] Hayat, F., Li, J., Liu, W., Li, C., Song, W., Iqbal, Sh., Khan, U., Javed, H. U., Altaf, M. A., Chen, P. T. J. and Liu, J. 2022. Influence of citrus rootstocks on scion growth, hormone levels, and metabolites profile of 'Shatangju' mandarin (Citrus reticulata Blanco). Horticulturae, 8(608): 1-17.
[24] Hayat, K. 2014. Citrus molecular phylogeny, antioxidant properties and medicinal uses, botanical research and practices. Nova Science Publishers, Inc. New York. 213p.
[25] Hildebrandt, T. M., Nesi, A. N., Araujo, W. L. and Braun, H. 2015. Amino acid catabolism in plants. Journal of Molecular Plant, 8: 1563-1579.
[26] Khan, M. N., Hayat, F., Asim, M., Iqbal, Sh., Ashraf, T. and Asghar, S. 2020. Influence of citrus rootstocks on growth performance and leaf mineral nutrition of 'Salustiana' sweet orange [Citrus sinensis (L). Osbeck]. Journal of Pure and Applied Agriculture, 5(1): 46-53.
[27] Kumar, S., Awasthi, O. P., Dubey, A. K. and Sharma, R. M. 2017. Effect of different rootstocks on growth, leaf sclerophylly and chlorophyll fractions of Kinnow mandarin. Indian J. Hort., 74(4): 505-509 .
[28] Lacey, K. 2012. Citrus rootstocks for WA. Department of Agriculture and Food. Farmnote, 155. Available from www.agric.wa.gov.au.
[29] Majeed, A. W. and Abood, M. R. 2021. Effect of rootstock type, organic fertilizer and irrigation intervals on growth of "Mahali" lemon transplants. Plant Archives, 21(Supplement 1): 1458-1462.
[30] Saunt, J. 2000. Citrus varieties of the world: an illustrated guide. 2nd ed., Norwich, England: Sinclair International Limited. 156p.
[31] Stefan, H. and Feller, U. 2001. Nitrogen metabolism and remobilization during senescence. Journal of Experimental Botany, 53(370): 927-937.

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