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Studies on foliar application of micronutrients and bio stimulants on storage attributes of rose onion

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Abstract

This research was done to investigate the studies on foliar application of micronutrients and bio stimulants on storage attributes of rose onion during *Late Kharif* of 2022-23 and 2023-24 at the Main Agricultural Research Station (MARS), University of Agricultural Sciences (UAS), Dharwad, Karnataka. It was undertaken with Complete Randomized Design, to study the application of different doses of foliar applications of micronutrients and bio stimulants with 12 treatment and 3 replications along with 25 t ha⁻¹ FYM. The results revealed significantly during 20, 40 and 60 days of storage studies of physiological loss in weight (2.67%, 9.20% and 15.18%), sprouting percentage (rotting percentage (0.57%, 1.49% and 7.77%), (0.73%, 2.04% and 7.76%) and marketable bulb (58.10%) were recorded at 100% RDF + humic acid of 2 kg ha⁻¹ + ZnSO₄ + FeSO₄ @ 25 kg ha⁻¹ each.

Keywords: Rose onion, micronutrients, seaweed extract, humic acid and storage

1. Introduction

Onion (*Allium cepa* L.) is an important culinary vegetable that belongs to the Alliaceae family, with a chromosome number of 2n = 16. It is native to South West Asia, from where it has spread around the world. This crop is mainly grown for local consumption and export. Onions are a versatile, bulbous crop with shallow roots. Although they are botanically classified as herbs, they are grown as annuals for bulb production and as biennials for seed. Onions can adapt to different climates, but they are long-day plants. Their growth under specific light and temperature conditions allows them to be divided into long, intermediate, and short-day categories. Onions primarily come in three skin colours: red, yellow, and white. Red onions are popular in cooking because they enhance flavors, while the milder yellow and white varieties are often used in salads and are preferred by processing industries for dehydrated products (Chavan *et al.*, 2024) [5].

This variety of onion known locally as "Gulabi eerulli" is grown in and around Bangalore, Karnataka. Rose onions are grown in Bangalore's urban, rural, Chikkaballapur, Kolar, Tumkur, Hassan, Davanagere, Dharwad and Bagalkot districts. In India, rose onions are not grown anywhere else. This kind of onions has spherical bulbs with a flat base. They are also distinctive because to their intense pungency, anthocyanin, phenols and deep scarlet red colour (Raghu, 2024) [17].

Rose onions are a short-duration crop, in contrast to normal onions. The crop can be harvested 110 days after sowing. It can be cultivated all year round. However, cold climates can produce high-quality bulbs with large yields, particularly in the winter. Approximately 4000 hectares of land, the most of which are under medium and small land holdings are used to grow the crop. Every year, about 70,000 tons of rose onions are produced and 40,000-45,000 tonnes of bulbs are exported, generating Rs. 60-70 crores in foreign exchange profits. 0.06 percent of the nation's total onion exports are rose onions. Malaysia, Indonesia, Singapore, Sri Lanka, Brunei, Bangladesh, Bahrain and Dubai are the top exporting destinations for Rose onion. Because of its high export potential, the Agricultural and Processed Food Products Export Development Authority (APEDA) and the Karnataka State Agricultural Produce Processing and Export Corporation (KAPEC) have been promoting rose onion exports and APEDA has established an Agri-export zone for rose onion in Karnataka (Shubha, 2023) [22].

Rose onion production heavily relies on mineral fertilizers, as increasing NPK levels has been shown to enhance mineral uptake by the plants. Yet, this benefit comes with a steep price: continuous fertilizer use causes environmental pollution and jeopardizes the sustainability of agricultural practices (Bagali *et al.*, 2012) [2]. Despite these risks, farmers frequently apply excessive amounts of fertilizer to boost their output. Such over use of chemical fertilizers creates significant damage to our ecosystem, atmosphere and human health (Mostafa *et al.*, 2021) [15], compounding the problems with higher costs and the degradation of soil health.

The foliar application of micronutrients like Zinc sulphate (ZnSO₄) and Ferrous sulphate (FeSO₄), combined with humic acid, has shown to promote better growth and higher yields in various vegetable crops (Zandonadi *et al.*, 2007) [23]. Zinc and Iron supports healthy plant growth and development (Atiyeh *et al.*, 2002) [1]. Humic acid offers many advantages for plants. It helps with nutrient uptake in vegetable crops (Cimrin and Yilmaz, 2005) [6], adjusts hormone levels by acting as a growth regulator, improves soil quality (Serenella *et al.*, 2002) [19], boosts photosynthesis and cell elongation.

One effective strategy to improve crop productivity and enhance rose onion quality is the foliar application of micronutrients paired with bio stimulants, such as seaweed extract (Datta *et al.*, 2003; Saravanan *et al.*, 2003) [7, 18]. Applying bio stimulants directly to leaves has shown to promote vegetative growth, increase yield and improve the quality of bulbs. Seaweed extract, a modern natural organic fertilizer, is exceptionally nutritious and positively impacts plant growth and development (Battacharyya *et al.*, 2015) [3], subsequently leading to higher yields (Dhargalkar and Pereira, 2005) [8]. Furthermore, seaweed is recognized as a rich source of both micronutrients and macronutrients (Shehata *et al.*, 2011) [21]. Specifically, seaweed extract serves as a fertilizer supplement containing modest amounts of macronutrients (nitrogen, potassium and phosphorus), alongside vital organic substances like amino acids, key plant growth regulators (auxin, cytokinin and gibberellins) and various trace elements (Begum *et al.*, 2018) [4].

2. Materials and Methods

Experimental site was conducted in the *Late Kharif* season during 2022-2023 and 2023-24 at All India Network Research Project on Onion and Garlic (AINRPOG) at the Main Agricultural Research Station (MARS), University of Agricultural Sciences (UAS), Dharwad. The site is located at Northern Transitional Zone (Zone VIII) of Karnataka state, situated at 15° 26' North latitude, 75° 07' East longitude and at an altitude of 678 meter above the mean sea level. The soil is deep black and well drained with uniform texture. The research was executed in a Complete Randomized Design (CRD) with three replications and twelve treatment combinations. The rose onion local variety was used, known for its deep scarlet red colour and high pungency. Harvesting was done uniformly at 110 days after sowing. Bulbs were harvested for storage assessments. two kg per treatment of bulbs were used for storage studies. Additionally, soil factors were evaluated both prior to and following harvest. Observations were recorded at 20, 40 and 60 days after storage on physiological loss in weight (%), sprouting percentage, rotting percentage and marketable bulb (%).

2.1 Physiological loss in weight (PLW) (%)

The cumulative loss in weight of the bulbs at different DAS was calculated and expressed as percent physiological loss in weight of bulbs using the formula given below:

$$\text{PLW (\%)} = \frac{(P_0 - P_1) \text{ or } (P_0 - P_2) \text{ or } (P_0 - P_3)}{P_0} \times 100$$

Where,

P₀ = Initial weight

P₁ = Weight after 30 days

P₂ = Weight after 40 days

P₃ = Weight after 60 days

2.2 Sprouting percentage (%)

During storage of bulbs which are showing at least one sprout longer than 0.5 mm size was counted as sprouted bulbs and sprouting percentage was calculated by following formula as mentioned below:

$$\text{Sprouting percentage (\%)} = \frac{\text{Number of bulbs sprouted}}{\text{Total number of bulbs stored}} \times 100$$

2.3 Rotting percentage (%)

During storage number of rotten bulbs was counted and decay percentage was calculated by following formula as mentioned below:

$$\text{Rotting percentage (\%)} = \frac{\text{Number of bulbs rotted}}{\text{Total number of bulbs stored}} \times 100$$

2.4 Marketable bulb (%)

At the end of storage period (60 DAS), the rotten and sprouted bulbs was separated and discarded. Only weight of healthy bulbs was recorded. The marketable bulb percentage was calculated by using the following formula as mentioned below:

$$\text{Marketable bulb (\%)} = \frac{\text{Weight of the healthy bulbs obtained}}{\text{Initial weight of bulbs stored}} \times 100$$

3 Results and Discussion

At 20 DAS (days after storage), significantly lower percentage of physiological weight loss of 2.87 and 2.48 percent for 2023 and 2024 respectively with an average of 2.67 percent was accounted with T₁₂ (T₁ + humic acid 2 kg ha⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each) followed by T₈ (T₁ + Seaweed extract of *Ascophyllum nodosum* 1.5 ml l⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each) with 3.12, 2.66 and averaging 2.89% during 2023 and 2024. The higher percentage of physiological weight loss of 4.15 and 3.46 percent for 2023 and 2024 respectively with an average of 3.80 percent was accounted with T₁ (RDF). At 40 DAS, the treatment T₁ exhibited the higher percentage of physiological loss of weight in both 2023 and 2024 season, with values of 12.13 and 10.37 percent, averaging 11.25 percent. T₁₂ had the lower physiological loss of weight, with values of 9.43 and 8.98 percent, resulting with an average of 9.20 percent followed by T₈ (10.19, 9.18 & 9.69%) and T₄ (10.33, 9.44 and 9.89%) respectively at 40 DAS. At 60

DAS, T_{12} maintained supremely by registering significant lower physiological weight loss of 15.39 and 14.97 percent for 2023 and 2024 respectively with an average of 15.18 percent. However, treatment T_1 noticed with higher physiological weight loss of 18.07 and 16.67 percent with an average of 17.37 percent respectively at 60 DAS. This implied the critical role of micronutrients and bio stimulants with their management in maintaining plant health and minimizing weight loss during the growth period. Absence of adequate fertilization, plants are more susceptible to stress factors such as drought and disease, leading to increased respiration rates and moisture loss, which contributes to a higher physiological weight loss in onion (Jinkovic *et al.*, 2016) ^[13]. The reduced PLW under these treatments is attributable to higher dry matter content, firmer bulb structure and thinner neck diameter, which collectively minimize water loss and respiration rates. Similar findings were reported by Sharma *et al.* (2014), who observed that balanced nutrient supplementation improved bulb firmness and reduced PLW in stored onions.

At 20 DAS (days after storage), significantly lower sprouting percentage of 0.58 and 0.56 percent for 2023 and 2024 respectively with an average of 0.57 percent was accounted with T_{12} (T_1 + humic acid 2 kg ha⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each) followed by T_8 (T_1 + Seaweed extract of *Ascophyllum nodosum* 1.5 ml l⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each) with 0.65, 0.59 and averaging 0.62%

during 2023 and 2024. The higher sprouting percentage of 1.29 and 1.23 percent for 2023 and 2024 respectively with an average of 1.26 percent was accounted with T_1 (RDF). At 40 DAS, the treatment T_1 exhibited the higher percentage of sprouting percentage in both 2023 and 2024 season, with values of 3.18 and 2.77 percent, averaging 2.98 percent. T_{12} had the lower sprouting percentage with values of 1.53 and 1.45 percent, resulting with an average of 1.49 percent followed by T_8 . At 60 DAS, T_{12} maintained supremely by registering significant lower sprouting percentage of 7.86 and 7.68 percent for 2023 and 2024 respectively with an average of 7.77 percent. However, treatment T_1 noticed with higher sprouting percentage of 8.98 and 8.51 percent with an average of 8.75 percent respectively at 60 DAS. The sprouting reduction can be linked to improved bulb dormancy, delayed physiological aging and enhanced accumulation of inhibitory compounds under humic acid and micronutrient-enriched conditions. Feibert *et al.* (2023) ^[11] reported that foliar application of humic substances reduced sprouting incidence in onion during storage. Nahar (2021) ^[16] similarly confirmed that balanced nutrient management delayed sprouting by improving bulb dormancy and reducing stress metabolism. Gupta *et al.* (2021) ^[12] also highlighted that the use of bio stimulants and micronutrients lowered sprouting incidence by strengthening bulb structure and delaying sprout initiation.

Table 1: Effect of foliar application of micronutrients and bio stimulants on physiological loss in weight of rose onion during 2023 and 2024

Treatment details		Physiological loss in weight (PLW) (%)								
		20 DAS			40 DAS			60 DAS		
		2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T_1	125:50:125 NPK kg ha ⁻¹ + 25 t FYM/ha (RDF)	4.15	3.46	3.80	12.13	10.37	11.25	18.07	16.67	17.37
T_2	T_1 + FeSO ₄ @ 25 kg ha ⁻¹	3.81	3.19	3.50	11.72	10.09	10.91	17.21	16.10	16.66
T_3	T_1 + ZnSO ₄ @ 25 kg ha ⁻¹	3.57	2.97	3.27	11.23	9.77	10.50	16.77	15.71	16.24
T_4	T_1 + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	3.19	2.78	2.98	10.33	9.44	9.89	15.94	15.21	15.58
T_5	T_1 + Seaweed extract of <i>Ascophyllum nodosum</i> 1 ml l ⁻¹	4.10	3.35	3.72	12.00	10.25	11.13	17.91	16.52	17.22
T_6	T_1 + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹	3.46	2.92	3.19	11.12	9.65	10.38	16.53	15.68	16.11
T_7	T_1 + Seaweed extract of <i>Ascophyllum nodosum</i> 2 ml l ⁻¹	3.72	3.11	3.42	11.65	9.87	10.76	17.13	15.92	16.53
T_8	T_1 + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	3.12	2.66	2.89	10.19	9.18	9.69	15.86	15.15	15.50
T_9	T_1 + Humic acid 1 kg ha ⁻¹	3.72	3.11	3.42	11.65	9.87	10.76	17.13	15.92	16.53
T_{10}	T_1 + Humic acid 2 kg ha ⁻¹	3.38	2.85	3.11	10.85	9.49	10.17	16.28	15.47	15.88
T_{11}	T_1 + Humic acid 3 kg ha ⁻¹	3.29	2.82	3.06	10.78	9.36	10.07	16.12	15.34	15.73
T_{12}	T_1 + Humic acid 2 kg ha ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	2.87	2.48	2.67	9.43	8.98	9.20	15.39	14.97	15.18
S.Em.±		0.18	0.15	0.13	0.53	0.48	0.43	0.83	0.70	0.65
C.D @ 1%		0.54	0.43	0.37	1.54	1.41	1.25	2.42	2.04	1.91
Note: DAS-Days after storage										

Table 2: Effect of foliar application of micronutrients and bio stimulants on sprouting percentage of rose onion during 2023 and 2024

Treatment details		Sprouting percentage (%)								
		20 DAS			40 DAS			60 DAS		
		2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T ₁	125:50:125 NPK kg ha ⁻¹ + 25 t FYM/ha (RDF)	1.29	1.23	1.26	3.18	2.77	2.98	8.98	8.51	8.75
T ₂	T ₁ + FeSO ₄ @ 25 kg ha ⁻¹	1.21	1.14	1.17	2.65	2.30	2.48	8.72	8.35	8.53
T ₃	T ₁ + ZnSO ₄ @ 25 kg ha ⁻¹	1.11	1.03	1.07	2.38	2.13	2.25	8.51	8.19	8.35
T ₄	T ₁ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	1.09	0.98	1.04	2.19	1.97	2.08	8.42	8.16	8.29
T ₅	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1 ml l ⁻¹	1.27	1.20	1.24	2.95	2.66	2.80	8.96	8.44	8.70
T ₆	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹	1.19	1.12	1.16	2.52	2.24	2.38	8.69	8.28	8.49
T ₇	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 2 ml l ⁻¹	0.84	0.75	0.79	1.76	1.65	1.70	8.08	7.91	8.00
T ₈	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	0.65	0.59	0.62	1.58	1.50	1.54	7.92	7.77	7.84
T ₉	T ₁ + Humic acid 1 kg ha ⁻¹	0.97	0.87	0.92	1.93	1.80	1.86	8.31	8.14	8.22
T ₁₀	T ₁ + Humic acid 2 kg ha ⁻¹	0.86	0.80	0.83	1.88	1.73	1.81	8.22	8.01	8.12
T ₁₁	T ₁ + Humic acid 3 kg ha ⁻¹	0.79	0.68	0.74	1.68	1.61	1.65	7.98	7.83	7.91
T ₁₂	T ₁ + Humic acid 2 kg ha ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	0.58	0.56	0.57	1.53	1.45	1.49	7.86	7.68	7.77
S.E.m.±		0.08	0.07	0.07	0.16	0.14	0.14	0.40	0.37	0.31
C.D @ 1%		0.23	0.21	0.21	0.47	0.41	0.42	1.17	1.08	0.91

Note: DAS-Days after storage

At 20 DAS (days after storage), significantly lower rotting percentage of 2.87 and 2.48 percent for 2023 and 2024 respectively with an average of 2.67 percent was accounted with T₁₂ (T₁ + humic acid 2 kg ha⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each) followed by T₈ (T₁ + Seaweed extract of *Ascophyllum nodosum* 1.5 ml l⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each) with 3.12, 2.66 and averaging 2.89% during 2023 and 2024. The higher rotting percentage of 4.15 and 3.46 percent for 2023 and 2024 respectively with an average of 3.80 percent was accounted with T₁ (RDF). At 40 DAS, the treatment T₁ exhibited the higher percentage of rotting percentage in both 2023 and 2024 season, with values of 12.13 and 10.37 percent, averaging 11.25 percent. T₁₂ had the lower rotting percentage with values of 9.43 and 8.98 percent, resulting with an average of 9.20 percent followed by T₈ (10.19, 9.18 & 9.69%) and T₄ (10.33, 9.44 and 9.89%) respectively at 40 DAS. At 60 DAS, T₁₂ maintained supremely by registering significant lower rotting percentage of 15.39 and 14.97 percent for 2023 and 2024 respectively with an average of 15.18 percent. However, treatment T₁ noticed with higher rotting percentage of 18.07 and 16.67 percent with an average of 17.37 percent respectively at 60 DAS. The reduced rotting can be attributed to firmer bulb texture, improved neck closure, higher antioxidant content (ascorbic acid) and enhanced plant defense mechanisms under humic acid and seaweed extract supplementation. El-Sawy *et al.* (2021) [10] reported that humic acid applications improved disease resistance in onions by enhancing bulb firmness and defense responses. Similarly, Gupta *et al.* (2021) [12] demonstrated that the combined use of seaweed extracts reduced storage rots in

onions by enhancing systemic resistance.

The treatment T₁₂ yielded significantly higher marketable bulb in 2023 and 2024 seasons with values of 57.15 and 59.05 percent, averaging 58.10 percent respectively, T₈ was statistically parallel with former and registered marketable bulb of 55.95 and 58.47 percent, averaging 57.21 percent. T₁ (RDF) was recorded lower marketable with the values of 46.46, 51.34 percent averaging 48.90 percent respectively in 2023 and 2024 and average of both years compared to all other treatments. The addition of micronutrients such as zinc and iron likely played a critical role in enhancing the physiological health of the plants, contributing to improved bulb quality and weight as documented by El-Hadidi *et al.* 2016 [9], which is in line with the result of current study. The synergistic effect of nutrient application helps in producing bulbs with better marketable quality. Next best treatment was T₈ with average marketable bulb content, indicating that the inclusion of seaweed extract along with the other nutrient strategies can also lead to favorable outcomes. The humic acid provides additional nutrients or bioactive compounds that enhance growth and quality. RDF was recorded lower of marketable bulb (average of 48.90%) as compared to all other treatments, which might be due to less number of additive factors (only NPK fertilizers). RDF recorded the lower number of marketable bulbs. The substantial disparity between the RDF and the treated groups underscores the critical role of nutrient management which plays important role in the production of market-quality onions and statement was endorsed with earlier researcher (Kumar *et al.*, 2018) [14].

Table 3: Effect of foliar application of micronutrients and bio stimulants on rotting percentage of rose onion during 2023 and 2024

Treatment details		Rotting percentage (%)								
		20 DAS [#]			40 DAS [#]			60 DAS [#]		
		2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T ₁	125:50:125 NPK kg ha ⁻¹ + 25 t FYM/ha (RDF)	1.38	1.28	1.33	5.15	4.11	4.63	9.23	8.23	8.73
T ₂	T ₁ + FeSO ₄ @ 25 kg ha ⁻¹	1.29	1.20	1.24	4.55	3.23	3.89	8.78	8.14	8.46
T ₃	T ₁ + ZnSO ₄ @ 25 kg ha ⁻¹	1.25	1.16	1.20	3.86	2.85	3.36	8.60	7.92	8.26
T ₄	T ₁ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	0.98	0.91	0.94	2.60	2.22	2.41	8.31	7.62	7.977
T ₅	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1 ml l ⁻¹	1.23	1.14	1.19	3.57	2.76	3.17	8.53	7.89	8.21
T ₆	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹	1.34	1.25	1.29	5.07	3.86	4.47	9.14	8.20	8.67
T ₇	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 2 ml l ⁻¹	1.28	1.18	1.23	4.19	3.12	3.65	8.75	8.11	8.43
T ₈	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	0.81	0.71	0.76	2.34	2.05	2.19	8.20	7.49	7.85
T ₉	T ₁ + Humic acid 1 kg ha ⁻¹	1.10	1.02	1.06	2.96	2.34	2.65	8.40	7.77	8.08
T ₁₀	T ₁ + Humic acid 2 kg ha ⁻¹	1.14	1.06	1.10	3.26	2.55	2.90	8.48	7.87	8.18
T ₁₁	T ₁ + Humic acid 3 kg ha ⁻¹	0.95	0.80	0.88	2.51	2.13	2.32	8.28	7.58	7.93
T ₁₂	T ₁ + Humic acid 2 kg ha ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	0.78	0.67	0.73	2.11	1.96	2.04	8.11	7.42	7.76
S.Em.±		0.07	0.07	0.07	0.21	0.16	0.15	0.47	0.42	0.31
C.D @ 1%		0.21	0.20	0.20	0.61	0.47	0.44	1.39	1.24	0.89

Note: DAS-Days after storage

Table 4: Effect of foliar application of micronutrients and bio stimulants on marketable bulb of rose onion during 2023 and 2024

Treatment details		Marketable bulb (%)		
		2023	2024	Pooled
T ₁	125:50:125 NPK kg ha ⁻¹ + 25 t FYM/ha (RDF)	46.46	51.34	48.90
T ₂	T ₁ + FeSO ₄ @ 25 kg ha ⁻¹	48.97	53.42	51.20
T ₃	T ₁ + ZnSO ₄ @ 25 kg ha ⁻¹	50.84	54.90	52.87
T ₄	T ₁ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	51.66	55.33	53.50
T ₅	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1 ml l ⁻¹	47.03	51.99	49.51
T ₆	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹	49.52	54.01	51.77
T ₇	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 2 ml l ⁻¹	54.62	57.42	56.02
T ₈	T ₁ + Seaweed extract of <i>Ascophyllum nodosum</i> 1.5 ml l ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	55.95	58.47	57.21
T ₉	T ₁ + Humic acid 1 kg ha ⁻¹	52.75	56.10	54.43
T ₁₀	T ₁ + Humic acid 2 kg ha ⁻¹	53.47	56.78	55.12
T ₁₁	T ₁ + Humic acid 3 kg ha ⁻¹	55.11	57.95	56.33
T ₁₂	T ₁ + Humic acid 2 kg ha ⁻¹ + FeSO ₄ + ZnSO ₄ @ 25 kg ha ⁻¹ each	57.15	59.05	58.10
S.Em.±		2.43	2.38	1.85
C.D @ 1%		7.09	6.95	5.39

Conclusion

The study clearly demonstrated that both micronutrients and bio stimulants significantly influence the storage attributes of rose onion. Minimum loss in physiological weight, sprouting percentage, rotting percentage and higher marketable bulb were achieved with 100% RDF (T₁) + Humic acid 2 kg ha⁻¹ + FeSO₄ + ZnSO₄ @ 25 kg ha⁻¹ each. Thus, for optimizing rose onion production, a combination of micronutrients and humic acid with 100% RDF is recommended to achieve the best balance between high productivity, superior quality and maximum marketable bulb. Future research could further explore the role of integrated nutrient management with organic sources to enhance sustainability in rose onion production.

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