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Impact of foliar application of kinetin and seaweed extract on some vegetative growth and physiological status of olive (*Olea europaea* L. cv. sourani) Saplings

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Abstract

Establishing 'Sourani' olive saplings (*Olea europaea* L.) in the calcareous soils of Iraq faces significant physiological challenges, including retarded growth and nutrient fixation. To overcome these bottlenecks, this study investigated the synergistic potential of foliar biofortification using Kinetin and *Ascophyllum nodosum* Seaweed Extract (SWE). A factorial experiment based on a Randomized Complete Block Design (RCBD) was conducted during the 2024 season in Kirkuk. Treatments included four Kinetin concentrations (0, 50, 100, and 150 mg L⁻¹) and four SWE levels (0, 2, 4, and 6 ml L⁻¹) applied to two-year-old saplings. Results demonstrated that the co-application of biostimulants elicited a superior physiological response compared to individual applications. The combination of 150 mg L⁻¹ Kinetin and 6 ml L⁻¹ SWE proved to be the optimal protocol, significantly maximizing vegetative vigor. This interaction yielded the highest plant height (36.57 cm), stem diameter (4.77 mm), and branch number (15.3 branches/sapling), alongside the highest total chlorophyll content (2.18 mg g⁻¹). Physiologically, the treatments optimized biomass partitioning; while the root-to-shoot ratio slightly decreased due to prioritized shoot expansion, the absolute root dry weight more than doubled (22.77 g) compared to the control (9.83 g). This indicates that the protocol enhances canopy development while maintaining a vigorous root system capable of supporting the plant. In conclusion, foliar application of Kinetin and SWE is a recommended strategy for producing high-quality, resilient olive saplings suitable for orchard establishment in semi-arid regions.

Keywords: *Olea europaea*, foliar biofortification, kinetin, seaweed extract, biomass partitioning

Introduction

1. General Background, Economic Significance, and Health Implications

The olive tree (*Olea europaea* L.), a quintessential xerophytic species, constitutes the cornerstone of agro-ecosystems in the Mediterranean basin and the Middle East. Beyond its socio-economic pivotal role in sustainable food security, it represents a biological model for resilience against climatic harshness [Fратиanni *et al.*, 2021; Jimenez-Lopez *et al.*, 2020] ^[1, 2]. The global trajectory of olive cultivation is driven by the escalating demand for virgin olive oil, a key component of the Mediterranean Diet, recognized for its potent nutraceutical properties. These health benefits are due to a unique set of bioactive secondary metabolites, especially phenolic compounds (like oleuropein and hydroxytyrosol) and monounsaturated fatty acids (like oleic acid). These compounds have strong antioxidant properties and can help fight chronic diseases [Servili, 2014; Visioli *et al.*, 2018] ^[3, 4]. In Iraq, the 'Sourani' cultivar is valorized as a premier indigenous genetic resource. It displays high phenotypic plasticity and dual-purpose productivity (oil and table olive), positioning it as a strategic candidate for horticultural expansion amidst challenging environmental constraints [Al-Ruqaie *et al.*, 2016] ^[5].

Despite the crop's hardiness, nursery propagation faces physiological bottlenecks that hamper initial seedling establishment. These challenges include retarded root system development and restricted nutrient uptake, significantly exacerbated by the calcareous nature of regional soils. Such edaphic conditions lead to high pH-induced nutrient fixation (precipitation) and low bioavailability of essential elements [Chatzistathis and Therios, 2013] ^[6]. Consequently,

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relying solely on soil fertilization is often insufficient to satisfy the accelerated metabolic demands of young, rapidly growing seedlings.

To circumvent these limitations, foliar biofortification has emerged as an indispensable agronomic strategy. This approach facilitates the direct delivery of nutrients and bioactive molecules to sink tissues, bypassing soil fixation and root transport lag phases [Fernández and Eichert, 2009] [7]. The efficacy of foliar sprays depends on solute permeation through the cuticle and stomata. Although the thick, waxy olive cuticle acts as a strong barrier, the presence of trichomes once wetted by surfactants can serve as preferential entry points [Fernández and Brown., 2013] [8].

Cytokinins such as Kinetin (N⁶-furfuryladenine) are pivotal in regulating plant morphogenesis. Kinetin promotes cytokinesis and cellular differentiation, effectively breaking apical dominance to induce lateral bud development a prerequisite for a well-branched seedling architecture [Kieber & Schaller, 2014; Ramlal *et al.*, 2024] [9, 10]. At the cellular level, Kinetin delays senescence by inhibiting the degradation of chlorophyll and proteins. Crucially, it enhances "sink strength," creating a metabolic gradient that mobilizes photo-assimilates towards active growing points [Zwack & Rashotte, 2015; Koprna *et al.*, 2016] [11, 12].

Parallel to hormonal regulation, seaweed extracts, particularly from *Ascophyllum nodosum*, have been widely adopted as sustainable biostimulants. They act as metabolic enhancers rich in bioactive moieties, including laminarins, alginates, and phytohormones [Battacharyya *et al.*, 2015] [13]. Foliar application of these extracts triggers physiological responses that maintain cell turgor and protect photosynthetic apparatuses, translating into superior biomass accumulation [Ali *et al.*, 2021] [14].

While the individual effects of Kinetin and seaweed extracts are documented, a knowledge gap exists regarding their

synergistic interplay on the 'Sourani' cultivar under nursery conditions. This study hypothesizes that the co-application of *A. nodosum* extract and Kinetin will elicit a synergistic physiological response, maximizing vegetative vigor and biomass accumulation. Therefore, this study aims to evaluate the vegetative, biomass, and physiological responses of olive saplings to this combined protocol to define an optimal strategy for high-quality nursery production.

Materials and Methods

Study Site and Plant Material

The experiment was conducted at the Qamar Extension Farm in Kirkuk city (Coordinates: 35.678483, 44.568570) during the 2024 growing season. The study aimed to investigate the physiological response of two-year-old 'Sourani' olive saplings (*Olea europaea* L.) to foliar application of Kinetin and seaweed extract (*Ascophyllum nodosum*). Uniform saplings, grafted onto local olive seedling rootstocks, were obtained from the Al-Hawija Horticulture Station. To minimize experimental error arising from the genetic variability of the seedling rootstocks, saplings were strictly selected for uniformity in height, canopy size, and stem diameter. They were transplanted into 10-kg plastic pots filled with a potting substrate consisting of river soil (loam) and sand at a ratio of 2:1 (v/v). Standard agricultural practices, including basal fertilization, irrigation and periodic pest control, were applied uniformly to all saplings. Irrigation was applied manually based on the visual monitoring of the saplings' water requirements to prevent water stress throughout the experimental period. Samples of the potting soil were analyzed to determine their physical and chemical properties. The analysis (Table 1) indicated that the soil texture was Sandy Loam with a pH of 7.5, which is typical for the region, and moderate fertility levels.

Table 1: Physical and chemical analysis of the potting soil.

Characteristic	Analysis	Characteristic	Analysis
EC ms. cm ⁻¹	1.878	TDS mg L ⁻¹	1115.310
pH	7.5	Clay %	3
N mg kg ⁻¹	1234.357	Silt %	42
P mg kg ⁻¹	14.302	Sand %	55
K mg kg ⁻¹	120.417	Tissue	Sandy Loam

Experimental Treatments and Design

The experiment was arranged as a factorial experiment based on a Randomized Complete Block Design (RCBD) with three replicates. The study comprised two factors:

- Kinetin Levels:** Four concentrations (0, 50, 100, and 150 mg L⁻¹). Kinetin was dissolved in minimal 1N NaOH, and the pH was adjusted to 6.5-7.0 prior to final volume adjustment.
- Seaweed Extract Levels:** Four concentrations of *Ascophyllum nodosum* extract (0, 2, 4, and 6 ml L⁻¹), prepared using distilled water.

The total number of saplings utilized was 48 (4 × 4 × 3 replicates)

Application Protocol

Treatments were applied in four intervals, commencing on March 15, 2024 (coinciding with sap flow and vegetative bud break), with a 21-day interval between applications.

Foliar spraying was conducted in the early morning until runoff using a 5-liter manual sprayer. A surfactant, (Tween-20®, 0.1%) from (Sigma-Aldrich) company, was added to all solutions, including the control, to ensure adhesion to the waxy cuticle.

Data Collection and Statistical Analysis

Measurements were recorded one month after the final application. Parameters included:

Vegetative Growth: Plant height increase (cm), Stem diameter increase (mm), Number of branches, Average branch length (cm), Number of leaves, and Leaf area (cm²) using ImageJ software.

Biomass: Fresh and Dry weights (g) for both leaves/shoots and roots. Samples were oven-dried at 70°C until constant weight.

Physiological Indices: Root-to-Shoot Ratio (calculated on a dry weight basis) and Total Chlorophyll Content (mg g^{-1}) using ethanol extraction (Knudson *et al.*, 1977)^[15].

Data were analyzed using CoStat software (version 6.303). Means were compared using the Least Significant Difference (L.S.D) test at $p \leq 0.05$.

Results

1. Plant height (cm): Data presented in Table (2) indicate that Kinetin application significantly enhanced sapling

height. Specifically, the 150 mg/L concentration yielded the maximum height (30.19 cm), significantly surpassing the control.

Seaweed extract treatments elicited a significant increase in plant height, with the 6 ml/L concentration registering the highest value (27.65 cm) compared to untreated saplings.

A significant synergistic effect was observed between the studied factors; the combined application of 150 mg/L Kinetin and 6 ml/L Seaweed extract resulted in the tallest plants (36.57 cm) relative to all other treatments.

Table 2: Effect of Kinetin and Seaweed extract on the plant height of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	14.83	17.80	20.77	23.50	19.23
2 ml/L	16.53	20.40	24.47	28.20	22.38
4 ml/L	17.90	22.80	27.83	32.50	25.26
6 ml/L	19.30	24.67	30.33	36.57	27.65
Mean Ki	17.14	21.42	25.85	30.19	
LSD SW: 0.15		LSD SW $\times$ Ki : 0.30			LSD Ki: 0.15

2. Stem diameter (mm)

As shown in Table (3), stem diameter was significantly influenced by Kinetin treatments. The application of 150 mg/L resulted in the thickest stems (3.81 mm) compared to the control.

Foliar spraying with Seaweed extract significantly promoted

secondary growth, where the 6 ml/L level produced the highest stem diameter (4.08 mm).

The interaction between Kinetin and Seaweed extract significantly maximized stem diameter, with the combination of 150 mg/L Kinetin and 6 ml/L Seaweed extract achieving the peak value of 4.77 mm.

Table 3: Effect of Kinetin and Seaweed extract on the stem diameter of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	1.97	2.3	2.7	2.9	2.48
2 ml/L	2.4	2.8	3.2	3.5	2.98
4 ml/L	2.8	3.3	3.8	4.03	3.48
6 ml/L	3.4	3.77	4.4	4.77	4.08
Mean Ki	2.64	3.04	3.53	3.81	
LSD SW: 0.06		LSD SW $\times$ Ki : 0.13			LSD Ki: 0.06

3: Branch Number

Kinetin treatments significantly induced lateral bud development (Table 4). The 150 mg/L concentration proved most effective, resulting in the highest branch number (12.3 branches) relative to the control.

The application of Seaweed extract led to a significant

proliferation of branches, with the 6 ml/L concentration recording a maximum of 10.8 branches.

A significant interaction was noted, where the co-application of 150 mg/L Kinetin and 6 ml/L Seaweed extract yielded the highest vegetative branching (15.3 branches).

Table 4: Effect of Kinetin and Seaweed extract on the branch number of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	3.7	5.7	7.3	9.3	6.5
2 ml/L	4.7	7.3	9.3	11.3	8.2
4 ml/L	5.3	8.3	11.3	13.3	9.6
6 ml/L	6.3	9.3	12.3	15.3	10.8
Mean Ki	5.0	7.7	10.1	12.3	
LSD SW: 0.38		LSD SW $\times$ Ki : 0.77			LSD Ki: 0.38

4: Average branch length (cm)

The results in Table (5) demonstrate that shoot elongation was significantly responsive to Kinetin, with the 150 mg/L treatment producing the longest average shoots (16.53 cm). Seaweed extract application significantly enhanced shoot extension, particularly at the 6 ml/L concentration, which

gave the highest value (15.90 cm).

The combined treatment (150 mg/L Kinetin + 6 ml/L Seaweed extract) significantly superiorized other interactions, recording the maximum average shoot length of 19.20 cm.

Table 5: Effect of Kinetin and Seaweed extract on the average shoot length of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	9.83	11.23	12.60	13.70	11.84
2 ml/L	10.83	12.50	14.27	15.70	13.33
4 ml/L	11.53	13.80	15.83	17.50	14.67
6 ml/L	12.43	14.83	17.13	19.20	15.90
Mean Ki	11.16	13.09	14.96	16.53	
LSD SW: 0.09		LSD SW × Ki : 0.18			LSD Ki: 0.09

5: Number of leaves: Table (5) reveals that Kinetin application significantly increased leaf abundance. The 150 mg/L concentration resulted in the highest leaf count (164.92 leaves) compared to the control. Spraying with Seaweed extract significantly improved leaf

production, with the 6 ml/L level achieving the maximum number of leaves (155.58 leaves).

The interaction effect was significant, with the combination of 150 mg/L Kinetin and 6 ml/L Seaweed extract producing the densest canopy (205.00 leaves).

Table 6: Effect of Kinetin and Seaweed extract on the number of leaves of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	78.67	95.67	112.33	127.67	103.67
2 ml/L	88.33	110.33	132.67	151.33	120.83
4 ml/L	98.33	125.67	151.33	175.67	137.92
6 ml/L	108.33	138.33	169.67	205.00	155.58
Mean Ki	93.42	117.50	141.50	164.92	
LSD SW: 0.98		LSD SW × Ki : 1.95			LSD Ki: 0.98

6: Leaf area (cm²)

Leaf expansion was significantly affected by Kinetin (Table 6). Interestingly, the 100 mg/L concentration not the highest dose recorded the maximum leaf area (4.54 cm²).

Seaweed extract treatments significantly enlarged leaf surface area, with the 6 ml/L concentration yielding the

highest value (4.81 cm²).

The interaction between the two biostimulants significantly maximized leaf area, reaching 5.6 cm² under the combination of 150 mg/L Kinetin and 6 ml/L Seaweed extract.

Table 7: Effect of Kinetin and Seaweed extract on the leaf area of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	3.43	3.8	4.07	4.4	3.93
2 ml/L	3.67	4.07	4.5	4.77	4.25
4 ml/L	3.93	4.37	4.77	5.2	4.57
6 ml/L	4.2	4.6	4.83	5.6	4.81
Mean Ki	3.81	4.21	4.54	4.10	
LSD SW: 0.09		LSD SW × Ki : 0.19			LSD Ki: 0.09

7. Leaf fresh weight (g)

Kinetin application significantly enhanced fresh biomass accumulation in the shoot system (Table 7), with the 150 mg/L concentration producing the highest weight (76.31 g). A significant increase in shoot fresh weight was observed

with Seaweed extract, peaking at 75.76 g under the 6 ml/L treatment.

The combined application of 150 mg/L Kinetin and 6 ml/L Seaweed extract exhibited a significant synergistic effect, yielding the maximum shoot fresh weight (92.73 g).

Table 8: Effect of Kinetin and Seaweed extract on the fresh weight of Shoot System of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	44.57	50.57	55.90	60.47	52.88
2 ml/L	49.50	56.87	64.47	70.80	60.41
4 ml/L	54.40	63.37	72.43	81.23	67.86
6 ml/L	59.60	69.80	80.90	92.73	75.76
Mean Ki	52.02	60.15	68.43	76.31	
LSD SW: 0.37		LSD SW × Ki : 0.74			LSD Ki: 0.37

8. Leaf dry weight (g): Data in Table 8 indicate that Kinetin significantly promoted dry matter accumulation in shoots. The highest dry weight (25.49 g) was recorded at the 150 mg/L concentration. Seaweed extract significantly influenced shoot dry weight,

with the 6 ml/L concentration resulting in the highest value (25.28 g).

The interaction treatment of 150 mg/L Kinetin and 6 ml/L Seaweed extract significantly outperformed other

treatments, achieving a maximum shoot dry weight of 30.93 g.

Table 9: Effect of Kinetin and Seaweed extract on the dry weight of Shoot System of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	14.87	16.83	18.63	20.13	17.62
2 ml/L	16.50	19.03	21.53	23.77	20.21
4 ml/L	18.20	21.20	24.37	27.13	22.73
6 ml/L	19.83	23.23	27.10	30.93	25.28
Mean Ki	17.35	20.08	22.91	25.49	
LSD SW: 0.15		LSD SW × Ki : 0.30			LSD Ki: 0.15

9. Root fresh weight (g)

Root system fresh weight was significantly increased by Kinetin application (Table 9), reaching a maximum of 50.03 g at the 150 mg/L concentration.

Seaweed extract treatments significantly enhanced root fresh

biomass, with the 6 ml/L level recording the highest weight (55.84 g).

The combination of 150 mg/L Kinetin and 6 ml/L Seaweed extract resulted in the most vigorous root system, with a significant maximum fresh weight of 63.60 g.

Table 10: Effect of Kinetin and Seaweed extract on the fresh weight of Root System of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	29.47	32.50	34.47	36.27	33.18
2 ml/L	35.50	39.50	42.47	45.63	40.78
4 ml/L	41.57	46.50	50.60	54.63	48.33
6 ml/L	47.60	53.60	58.57	63.60	55.84
Mean Ki	38.53	43.03	46.53	50.03	
LSD SW: = 0.22		LSD SW × Ki : 0.44			LSD Ki: 0.22

10. Root dry weight (g)

As shown in Table 10, Kinetin application significantly increased root dry matter. The 150 mg/L concentration yielded the highest value (17.63 g).

Root dry weight was significantly positively affected by Seaweed extract, peaking at 19.67 g under the 6 ml/L

treatment.

The interaction between the two factors maximized root biomass; the combination of 150 mg L⁻¹ Kinetin and 6 ml L⁻¹ Seaweed extract recorded the highest root dry weight (22.77 g), which is more than double the value of the control treatment (9.83 g).

Table 11: Effect of Kinetin and Seaweed extract on the dry weight of Root System of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	9.83	10.83	11.53	12.13	11.08
2 ml/L	11.90	13.50	14.87	15.93	14.05
4 ml/L	14.13	16.23	17.83	19.67	16.97
6 ml/L	16.17	18.80	20.93	22.77	19.67
Mean Ki	13.01	14.84	16.29	17.63	
LSD SW: 0.10		LSD SW × Ki : 0.22			LSD Ki: 0.10

11. Root-to-Shoot Ratio: Significant variations were observed in biomass partitioning (Table 12). Saplings treated with Seaweed extract generally maintained higher root-to-shoot ratios compared to Kinetin-treated saplings. Specifically, the 6 ml L⁻¹ Seaweed level recorded a ratio of 0.79. Conversely, higher Kinetin concentrations resulted in a lower ratio compared to the control (0.74), reflecting a shift

in biomass allocation towards the shoot system.

The interaction data reveals that while the highest biological yield was found in the combination treatment (K3+S3), the highest root-to-shoot ratio (0.82) was recorded in saplings treated with 6 ml L⁻¹ Seaweed extract alone (without Kinetin), indicating different allocational strategies driven by the treatments.

Table 12: Effect of Kinetin and Seaweed extract on the Root/Shoot Ratio of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	0.66	0.64	0.62	0.60	0.63
2 ml/L	0.72	0.71	0.69	0.67	0.70
4 ml/L	0.77	0.77	0.73	0.72	0.75
6 ml/L	0.82	0.81	0.77	0.74	0.79
Mean Ki	0.74	0.73	0.70	0.68	
LSD SW: 0.002		LSD SW × Ki : 0.003			LSD Ki: 0.002

12. Total Chlorophyll Content (mg g⁻¹)

Table 12 demonstrates that Kinetin significantly enhanced photosynthetic pigment content. The 150 mg/L concentration yielded the highest total chlorophyll content (1.93 mg/g).

Foliar application of Seaweed extract significantly improved

leaf greenness, with the 6 ml/L concentration recording the highest chlorophyll content (1.78 mg/g).

A significant interaction was observed regarding biochemical attributes; the combined application of 150 mg/L Kinetin and 6 ml/L Seaweed extract resulted in the maximum total chlorophyll content (2.18 mg/g).

Table 13: Effect of Kinetin and Seaweed extract on the Total Chlorophyll Content of 'Sourani' olive saplings.

Sea Weed	Kinetin				Mean SW
	0.0	50 mg/L	100 mg/L	150 mg/L	
0.0	1.18	1.35	1.52	1.68	1.43
2 ml/L	1.25	1.45	1.65	1.85	1.55
4 ml/L	1.32	1.55	1.78	2.02	1.67
6 ml/L	1.38	1.65	1.92	2.18	1.78
Mean Ki	1.28	1.50	1.72	1.93	
LSD SW: 0.001		LSD SW × Ki : 0.002			LSD Ki: 0.001

Discussion

The results obtained in this study demonstrate that the foliar biofortification of 'Sourani' olive saplings with Kinetin and *Ascophyllum nodosum* seaweed extract (SWE) elicits a significant synergistic response. This combined protocol effectively overcame the growth limitations typically associated with nursery establishment in semi-arid regions.

1. Enhancement of Vegetative Growth and Branching Architecture

The remarkable increase in plant height and, particularly, the number of branches (Table 4) driven by Kinetin application can be physiologically attributed to its role in modulating apical dominance. Exogenous cytokinins antagonize the inhibitory effect of auxins transported from the apical bud, thereby releasing lateral buds from dormancy and stimulating axillary shoot proliferation (Kieber and Schaller, 2014) [9]. Furthermore, Kinetin promotes cytokinesis in the Shoot Apical Meristem (SAM), translating into increased shoot length and leaf number.

This hormonal signal was supported by the metabolic fuel provided by the Seaweed Extract. The extract's richness in macro- and micronutrients, alongside auxin-like compounds and betaines, likely maintained cell turgor pressure the biophysical force driving cell expansion (Battacharyya *et al.*, 2015) [13]. The synergy observed (K3+S3) suggests that while Kinetin triggered the "signal" for branching, the nutrient-rich SWE provided the "substrate" to sustain this vigorous growth, preventing nutrient depletion.

2. Physiological Efficiency: Chlorophyll Content and Leaf Area

The significant rise in chlorophyll content (Table 13) is a classic manifestation of the "Richmond-Lang effect," where Kinetin delays senescence by inhibiting chlorophyllase activity and maintaining chloroplast ultrastructure (Zwack and Rashotte, 2015) [11]. Simultaneously, SWE contributed to this "greening effect" by supplying Magnesium (central to chlorophyll) and Iron (a biosynthesis cofactor). Additionally, the antioxidants in seaweed extracts likely protected the photosynthetic apparatus from photo-oxidation, a common stressor in the study region. The consequent increase in Leaf Area Index (LAI) and chlorophyll density maximized the Net Assimilation Rate (NAR), leading to the observed surge in biomass.

3. Biomass Accumulation and Resource Partitioning

A critical analysis of the Root-to-Shoot (R/S) ratio (Table 12) reveals an adaptive physiological adjustment. Although the R/S ratio slightly decreased in the combined treatments, the absolute root biomass more than doubled compared to the control (22.77 g vs. 9.83 g). This result aligns with the "Functional Equilibrium" hypothesis. When plants receive abundant nutrition and hormonal signals via foliar biofortification, the pressure on roots to forage for nutrients is alleviated. Consequently, the plant allocates more photo-assimilates to shoot expansion to maximize light interception (Fernández and Brown, 2013) [8].

However, the crucial finding is that the root system did grow vigorously enough (due to the auxin-like compounds in SWE) to mechanically and hydraulically support the larger canopy, ensuring a balanced and resilient sapling. (Arioli *et al.*, 2015) [16].

Conclusion

This study provides empirical evidence that combining Kinetin (150 mg L⁻¹) with *Ascophyllum nodosum* Seaweed Extract (6 ml L⁻¹) constitutes an optimal foliar protocol for 'Sourani' olive nurseries. This treatment acts synergistically to:

- **Overcome physiological bottlenecks:** By enhancing sink strength and nutrient availability.
- **Optimize architecture:** By promoting lateral branching and stem thickening.
- **Ensure quality:** By producing saplings with a robust root system (high absolute mass) and a vigorous canopy.

Therefore, adopting this protocol is recommended to accelerate the production cycle and ensure the availability of resilient planting material suitable for orchard establishment in calcareous, semi-arid soils.

Recommendation

Based on these findings, it is recommended to adopt this combined foliar protocol (Kinetin 150 mg L⁻¹ + SWE 6 ml L⁻¹) in olive nurseries. This strategy not only accelerates the production cycle but also ensures the production of high-quality, resilient saplings suitable for orchard establishment in semi-arid regions. Future research should investigate the long-term field performance of these biofortified saplings and the cost-benefit analysis of this protocol on a commercial scale.

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