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Summary of Deliverable D4.2 – Fresh Biomass from Organic Sea Fennel Crops	This deliverable reports the first quantitative results of field trials, measuring the edible aerial biomass of sea fennel cultivated under organic conditions across Italy, Croatia, Tunisia, and Türkiye. The findings demonstrate the crop's adaptability but also reveal how strongly growth is influenced by local climate and cultivation practices. In Italy, trials showed clear benefits from sustainable inputs. Plants treated with biofertilizers or irrigation produced significantly more biomass than untreated controls, with yields more than doubling at later growth stages. Mediterranean ecotypes generally outperformed Atlantic ones, though both showed potential for cultivation. At the Croatian site, comparisons between the local Korčula ecotype and the Atlantic type revealed variability in plant size and flowering time, reflecting their adaptation to different climates. The Korčula ecotype produced larger plants, while the Atlantic type flowered earlier, underlining the importance of matching germplasm to environmental conditions. In Tunisia, early cultivation attempts in 2023 failed due to extreme heat, but renewed trials in 2024 succeeded. Biomass production increased significantly by the January 2025 harvest, especially in the local ecotype, confirming that sea fennel can adapt when conditions are favorable. In Türkiye, drip-irrigated and biofertilized plots performed best, with edible biomass increasing by nearly 70% in the second year. Among the three tested populations, the Atlantic type again showed the highest yields. Importantly, biochemical analyses revealed rich profiles of antioxidants, flavonoids, carotenoids, and vitamin C, further confirming the nutritional value of sea fennel.

Versioning and Contribution History

Version	Date	Modified by	Modification reason
v1.0	20/04/2023	Branimir Ulrich	First version
v2.0	01/01/2025	Branimir Ulrich	Comments after peer reviewing process.

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1. Fresh biomass (edible aerial parts) from the new organic sea fennel crops

Objective

Measurement of fresh biomass of sea fennel crop cultivated at demo and open field.

1.1 Italian site

Materials and methods

The epigeal biomass was cut with scissors at 5 cm from the ground level and after plant sampling, the leaves and branches were separated and carefully cleaned from soil residues, limiting the loss of leaves as much as possible. Each fresh plant was separately weighed using a laboratory balance to assess the fresh weight. After that, the biomass was placed in an oven at 105° C for two days, after which its dry weight was determined. Samples were taken in a randomised manner. The biomass of the plant was collected at three distinct phenological stages: Side Shot formation, Vegetative parts development, Flower buds visible; for each treatment studied: biostimulated, irrigated and control.



Weighing of fresh biomass

Results

Biomass data refer only for Mediterranean population. Results collected at the Italian demo field in Agugliano (AN) in 2023 are reported below.

Treatment	BBCH	UFW (g plant ⁻¹)	TFW (t ha ⁻¹)	UDW (g plant ⁻¹)	TDW (t ha ⁻¹)
CT	20-29	95.3(±24.8) b	9.3(±2.4) a	14.0(±2.5) b	1.4 (±0.4) b
BIO	20-29	151.1(±41.4) a	14.8(±4.1) a	27.4(±2.6) a	2.7(±0.3) a
IRR	20-29	141.6(±24.1) a	13.9 (±2.4) a	24.1(±4.0) a	2.4(±0.4) a
Mean 20-29		129.3(±38.9)	12.7(±3.8)	21.9(±6.5)	2.1 (±0.6)
CT	40-49	380.7(±32.1) c	37.3(±3.2) c	59.4(±8.6) b	5.8(±0.8) b
BIO	40-49	548.6 (±39.8) b	53.8(±3.9) b	86.6(±7.9) a	8.5(±0.8) a
IRR	40-49	596.8(±37.9) a	58.4(±3.7) a	88.0(±12.0) a	8.6 (±1.2) a
Mean 40-49		508.7(±100.8)	49.9(±9.9)	78.0(±16.3)	7.6 (±1.6)
CT	51	523.7(±28.2) c	51.3(±2.8) c	88.1(±7.5) c	8.6(±0.7) c
BIO	51	936.1(±70.6) a	91.7(±6.9) a	153.7(±19.0) a	15.1(±1.9) a
IRR	51	820.4(±35.0) b	80.4(±3.4) b	122.9(±9.3) b	12.0(±0.9) b
Mean 51		760.1(±183.0)	74.5(±17.9)	121.6(±30.0)	11.9 (±2.9)

Means (+/- standard deviation) within each column followed by different letters are significantly different (ANOVA, $p < 0.05$).

BIO: Biofertilized

IRR: Irrigated

CT: Control (no treatment)

BBCH = phenological phase 20-29 Side shoots formation; 40-49 Vegetative parts development; 51 Flower buds visible

UFW Unit Fresh Weight

TFW Total Fresh Weight

UDW Unit Dry Weight

TDW Total Dry Weight

Results collected in Agugliano (AN) in 2024 are reported below, the data refers for Mediterranean and Atlantic populations.

BBCH	Treatment	Ecotype	UFB g pt ⁻¹	TFB t ha ⁻¹	UDB g pt ⁻¹	TDB t ha ⁻¹
20-29 (side shoots formation)	Biostimulated		1.76(±0.44) a	0.172(±0.043) a	0.26(±0.07) a	0.025(±0.007) a
		AT	1.88(±0.51)	0.184(±0.050)	0.28(±0.06)	0.028(±0.006)
		ME	1.64(±0.32)	0.161(±0.031)	0.24(±0.07)	0.023(±0.007)
	Irrigated		1.77(±0.50) a	0.173(±0.049) a	0.28(±0.10) a	0.029(±0.010) a
		AT	1.82(±0.53)	0.179(±0.052)	0.28(±0.10)	0.029(±0.010)
		ME	1.71(±0.48)	0.168(±0.047)	0.29(±0.11)	0.029(±0.011)
	Control		1.67(±0.40) a	0.163(±0.039) a	0.29(±0.09) a	0.028(±0.008) a
		AT	1.79(±0.45)	0.176(±0.044)	0.29(±0.10)	0.028(±0.009)
		ME	1.54(±0.33)	0.151(±0.032)	0.30(±0.08)	0.028(±0.008)
	Mean 20-29		1.73(±0.44)	0.170(±0.043)	0.28(±0.09)	0.027(±0.009)
40-49 (vegetative parts development)	Biostimulated		23.80(±3.62) a	2.332(±0.355) a	3.43(±0.64) a	0.336(±0.063) a
		AT	23.64(±3.36)	2.317(±0.329)	3.19(±0.40)	0.313(±0.039)
		ME	23.96(±4.01)	2.348(±0.393)	3.66(±0.77)	0.359(±0.075)
	Irrigated		23.01(±4.31) a	2.255(±0.423) a	3.27(±0.68) a	0.320(±0.066) a
		AT	23.00(±5.07)	2.254(±0.497)	3.31(±0.83)	0.324(±0.082)
		ME	23.01(±3.63)	2.255(±0.355)	3.23(±0.51)	0.317(±0.050)
	Control		14.28(±4.94) b	1.399(±0.484) b	2.43(±0.97) a	0.238(±0.095) a
		AT	14.03(±4.39)	1.375(±0.430)	2.32(±0.71)	0.228(±0.070)
		ME	14.52(±5.62)	1.423(±0.551)	2.54(±1.19)	0.249(±0.117)
	Mean 40-49		20.36(±6.09)	1.995(±0.597)	3.04(±0.88)	0.298(±0.086)
51 (visible flower buds)	Biostimulated		107.05(±35.03) a	10.491(±3.433) a	16.35(±5.46) a	1.602(±0.535) a
		AT	110.25(±32.03)	10.804(±3.139)	15.10(±4.42)	1.479(±0.434)
		ME	103.86(±40.62)	10.178(±3.980)	17.61(±6.49)	1.725(±0.636)
	Irrigated		89.49(±21.40) a	8.770(±2.097) a	13.29(±3.28) ab	1.303(±0.322) ab
		AT	89.87(±17.79)	8.807(±1.744)	12.78(±2.39)	1.253(±0.234)
		ME	89.11(±25.31)	8.732(±2.481)	13.80(±4.03)	1.352(±0.395)
	Control		42.89(±13.36) b	4.203(±1.309) b	7.64(±3.16) b	0.749(±0.310) b
		AT	40.30(±13.27)	3.949(±1.300)	7.18(±3.06)	0.704(±0.300)
		ME	45.48(±13.51)	4.457(±1.324)	8.10(±3.33)	0.794(±0.326)
	Mean 51		74.36(±34.40)	7.287(±3.372)	11.64(±5.08)	1.141(±0.498)

AT = Atlantic population

ME = Mediterranean population,

UFB = Unit Fresh Biomass,

TFB = Total Fresh Biomass,

UDB = Unit dry biomass,

TDB = Total Dry Biomass,

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Values are shown as mean ± standard deviation.

1.2 Croatian site

Materials and methods

After transplanting in May 2023 plants were irrigated once a week over the summer, but overall growth was slow until September, so harvest was not done until end of October 2023.

Harvest was done on two ecotypes/ populations, French - Atlantik and Croatian - Korčula. The edible biomass of the plant was collected at phenological stage of full umbell development for only one treatment studied: unfertilized (control). Plants were divided in 3 parts: leaves, stem and flower, weighed fresh and dried at 70 C to calculate dry mass percentage of each plant organ/parts.



Harvest of sea-fennel plant

Results

Results are shown in the following Table. Differences in fresh and dry weight, as also dry weight percentage were not significant between ecotypes due to high variability of plants.

Significant between ecotypes due to high variability of plants.								
Ecotype	Plant		Leaves		Stem		Flover	
	Fresh weight (g/plant)							
Atlantik	216,4	± 19,1	120,2	± 10,4	62,1	± 6,7	34,1	± 6,9
Korčula	198,4	± 18,4	93,2	± 11,2	73,9	± 7,5	31,2	± 6,7
	Dry weight (g/plant)							
Atlantik	41,8	± 4,5	21,8	± 1,9	12,5	± 1,8	7,5	± 1,6
Korčula	39,1	± 3,8	17,3	± 2,1	15,4	± 1,6	6,3	± 1,3
	Dry weight percentage (%)							
Atlantik	19	± 0,7	18,2	± 0,6	19,3	± 0,9	22,1	± 1,7
Korčula	19,6	± 0,4	18,5	± 0,3	20,5	± 0,8	19,9	± 1,1

Sea fennel plants harvested in October 2023; fresh and dry weight, and dry weight percentage

Means are shown as +/- standard error

Next harvest was done in July 2024 what can be consider as first standard harvest in period when sea fennel plants leaves were collected for future use and processing.

Ecotype Korčula had bigger plants than ecotype Atlantik, but no differences were found in dry weight percentage between ecotypes. Differences were found for weight of flowers as Atlantic ecotype started earlier with flowering phase and flowers with stems were more developed in harvest time. That can be explained due to differences in climatic conditions in Croatian site with warm, hot Mediterranean climate comparing from conditions in north-west part of France where is origin of Atlantic ecotype.

Seafennel plants harvested in July 2024 - fresh and dry weight, and dry weight percentage

Ecotype	Plant	Leaves	Stem	Flover
Fresh weight (g/plant)				
Atlantik	212 ± 22,1	85,3 ± 8,46	67,4 ± 9,1	59,4 ± 7,1
Korčula	374 ± 29,0	189 ± 18,2	159 ± 11,9	24,5 ± 4,8
Dry weight (g/plant)				
Atlantik	58,1 ± 5,7	23,5 ± 2,1	18,8 ± 2,4	15,7 ± 1,6
Korčula	97,5 ± 7,5	48,1 ± 4,5	42,9 ± 3,4	6,5 ± 1,3
Dry weight percentage (%)				
Atlantik	27,7 ± 0,4	28,1 ± 0,5	28,3 ± 0,5	26,9 ± 0,5
Korčula	26,1 ± 0,3	25,6 ± 0,3	26,8 ± 0,4	27,1 ± 0,6

1.3 Tunisian sites

The cultivation of sea fennel for last year (2023) failed due to high temperatures, the cultivation will be renewed in the year 2024.

Materials and methods

The harvest of sea fennel started from september 2024. Harvest was done on two ecotypes, French - Atlantic and Tunisian-Tabarka. After harvest, the leaves and branches were separated, cleaned and than weighed using a balance to determine the fresh weight. The plant material was then introduced into an oven until reaching a constant weight for the determination of the dry matter content.



Sea fennel in the field (Left picture), weight of fresh biomass (right picture)

Results

The results showed in the following table correspond to the averages of fresh and dry biomass of plants edible parts compared to the hole harvested plants. Values correspond to two harvesting periods (September 2024 and January 2025)

Averages of Fresh-Biomass (g/plant) of edible parts of sea fennel samples

Ecotype	Treatment	Harvest period	Total plant fresh biomass (g)	Edible fresh mass (g)	% of edible (FW)
Tunisia	NPK	Sep-24	15.38±10.80	3.36±1.51	48%±39%
Tunisia	Control	Sep-24	8.03±9.60	2.6±2.13	49%±28%
Atlantic	NPK	Sep-24	3.36±1.63	3.36±1.63	100%

Ecotype	Treatment	Harvest period	Total plant fresh biomass (g)	Edible fresh mass (g)	% of edible (FW)
Atlantic	Control	Sep-24	1.92±1.17	1.92±1.17	100%
Tunisia	NPK	Jan-25	179.11±148.83	16.21±11.86	9%±3%
Tunisia	Control	Jan-25	103.36±98.33	13.34±12.33	14%±6%
Atlantic	NPK	Jan-25	24.78±7.20	2.56±0.66	11%±2%
Atlantic	Control	Jan-25	4.06±3.38	0.61±0.42	19%±8%

1.4 Turkish sites

Materials and methods

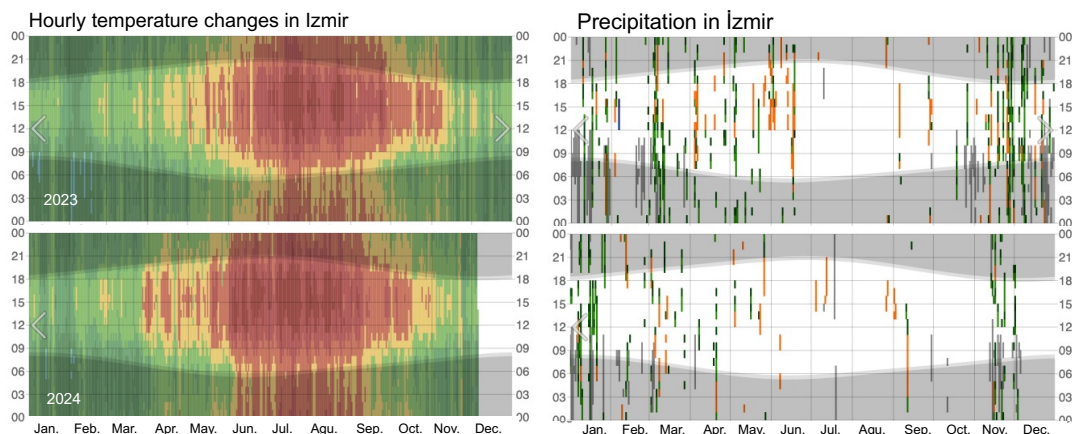
Soil samples (0–30 cm depth) were collected from the experimental site before transplanting. The samples were analyzed for various physicochemical properties, including soil texture, pH, organic matter content, electrical conductivity, total nitrogen (N), available phosphorus (P), exchangeable calcium (Ca), potassium (K), sodium (Na), iodine (I), magnesium (Mg), and major anions. Throughout the growing period, irrigation was carried out using a drip irrigation system. Field observations confirmed that sea fennel plants were unable to survive under rainfed conditions at the experimental site. Weed management was performed through mechanical removal, targeting *Sorghum halepense* L., the predominant weed species in the field. Hourly average temperature and total precipitation data for 2023 and 2024 at the experimental site (İzmir-Bornova) are presented in the Figure below. Mean temperatures in 2024 were recorded as 1.2°C (7.2%) higher than in 2023. Total precipitation in 2023 was 780 mm higher than long-term averages, while precipitation levels in 2024 were projected to be at least 20% lower by the end of the year.

Plant sampling and harvesting were conducted on October 5. The aerial parts of sea fennel were separated into two categories: edible portions (sprouts, tender young leaves, and stems) and refuse (older leaves and fibrous stems). Both fractions were stored at +4°C immediately after harvesting for subsequent analysis and utilization.

Soil

pH	7.88
Org.(%)	1.99
Salinity (%)	0.09
CaCO ₃ (%)	14.2
Structure	Clay-loamy
Sand (%)	42
Silt (%)	21
Clay (%)	37
N (%)	0.05
P (ppm)	6.75
K (ppm)	506
Fe (ppm)	0.18
Cu (ppm)	1.10
Mg (ppm)	367
Zn (ppm)	1.95
Na (ppm)	73
Mn (ppm)	1.17

Physicochemical properties of the soil sampled from the experimental site in Izmir. The samples were collected before the sea fennel seedlings transplanted to the demo field trail (2023).



Hourly average temperature and total precipitation during 2023 and 2024 at the experimental site (İzmir-Bornova).

Some plant samples were stored in liquid nitrogen and subsequently transferred to -70°C for further chemical analysis. For dry matter determination, plant material was dried in a forced draft oven at 105°C until a constant weight was achieved. Dry matter content was expressed as g per 100 g fresh weight (FW). Additionally, leaf area (m^2) and color measurements were performed using the CIE Lab* color scale to assess lightness (L^*), redness (a^*), and yellowness (b^*). Several biochemical properties of sea fennel samples were analyzed using spectrophotometric methods (UV-VIS Cary 50 spectrophotometer), as high-performance liquid chromatography (HPLC) and gas chromatography-mass spectrometry (GC-MS) were not available in the laboratory.



*Sampling of sea fennel (*Crithmum maritimum* L.) plants on October 5th (left photo). Storing plant samples in liquid nitrogen (right-down photo).*

Antioxidant activity was determined using the Ferric Reducing Antioxidant Power (FRAP) assay as described by Benzie and Strain (2009). Plant samples (0.5 g) were extracted with 20 mL of 80% (v/v) ethanol and centrifuged for 20 min at 4°C. The reaction was initiated by adding 0.05 mL of the extract to 1.50 mL of FRAP reagent and 0.15 mL of distilled water. Absorbance was measured spectrophotometrically at 593 nm, and results were expressed as μ moles FRAP per gram of dry matter.

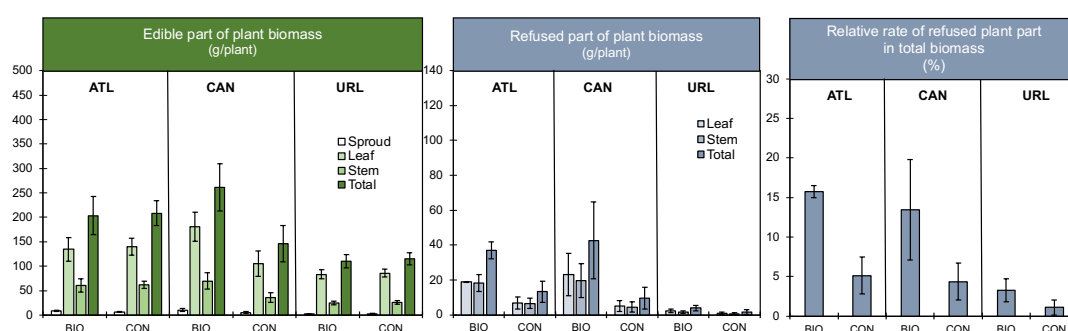
Total flavonoid content was measured using the aluminum chloride colorimetric assay (Zhinsel et al., 1999). Extracts were treated with NaNO_2 , AlCl_3 , and NaOH solutions before incubation in darkness for 30 min. Absorbance was measured at 510 nm, with results expressed as mg rutin per gram of dry matter.

Antiradical activity was determined following the method of Brand-Williams et al. (1995). A 0.1 mL extract was mixed with 3.9 mL of DPPH• solution, and absorbance at 515 nm was recorded over 10 min. The efficient concentration (EC_{50}) was calculated as the amount of antioxidant required to reduce the initial DPPH• concentration by 50%.

Carotenoid analysis of sea fennel leaves was performed using a solvent extraction method followed by UV-Vis spectrometric detection, according to Biswas et al. (2011). All analyses were conducted using validated spectrophotometric techniques, ensuring reliable quantification of the biochemical parameters assessed in this study.

Results

Effect of bio-fertilizer application versus no fertilization on the biomass distribution of sea fennel in 2023, including edible and refused (leaf, stem, and total) plant fractions, as well as the relative proportion of refused plant parts in the total biomass of three populations, are shown in Figure below. Considering the average biomass values of the edible parts of all three populations, a 19% increase was observed in the plots with biological fertilizer application, yielding 191 g/plant, compared to the 160 g/plant from the control plots. When considering the refused parts of the plant, the effect of biological fertilization was more pronounced, resulting in a 3.5-fold increase compared to control plots. The biomass of the refused parts was 28 g/plant in the biologically fertilized plots, compared to 8 g/plant in the unfertilized plots.

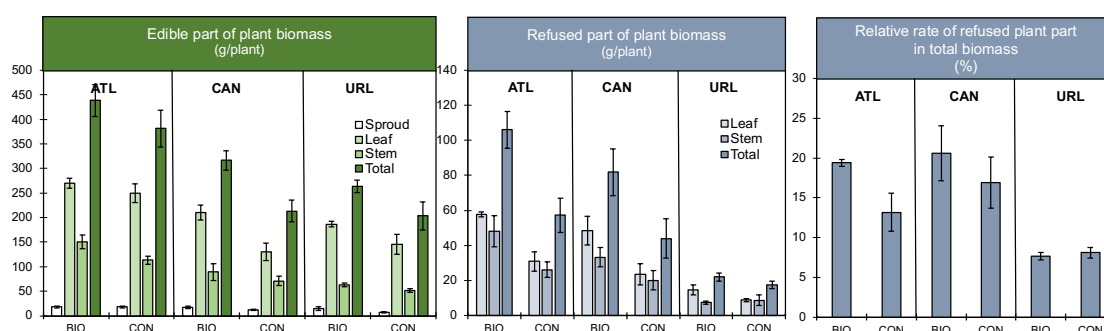


Effect of bio-fertilizer application versus no fertilization on the biomass distribution of sea fennel (*Crithmum maritimum* L.) in 2023, including edible (sprout, leaf, stem, and total) and refused (leaf, stem, and total) plant fractions, as well as the relative proportion of refused plant parts in the total biomass of three populations (ATL: Atlantis, CAN: Çandarlı, and URL: Urla).

The highest biomass values were recorded in the ATL and CAN populations, with 206 g/plant and 204 g/plant, respectively, followed by the URL population with 130 g/plant. The lowest proportion of refused parts was observed in the URL population (2%). Moreover, biological fertilization increased the ratio of refused plant parts in the total biomass by an average of 7%.

In the second year of the field trial (2024), an average 68% increase in the edible biomass was recorded. The effect of biological fertilizer application was further enhanced, with 340 g/plant of edible biomass obtained in fertilized plots and 266 g/plant in unfertilized plots, resulting in a 28% increase due to fertilization. On the other hand, the biomass of the refused plant parts increased by 75% in the fertilized plots, reaching 70 g/plant, compared to 40 g/plant in the unfertilized plots.

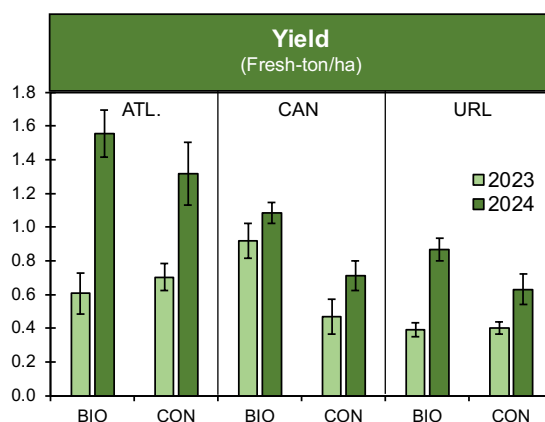
The highest biomass value in 2024 was recorded in the ATL population, with 410 g/plant, followed by the CAN and URL populations with 265 g/plant and 234 g/plant, respectively. The lowest proportion of refused parts was observed in the URL population (8%). Additionally, biological fertilization increased the ratio of refused plant parts in total biomass by an average of 3%.



Effect of bio-fertilizer application versus no fertilization on the biomass distribution of sea fennel (*Crithmum maritimum* L.) in 2024, including edible (sprout, leaf, stem, and total) and refused (leaf, stem, and total) plant fractions, as well as the relative proportion of refused plant parts in the total biomass of three populations (ATL: Atlantis, CAN: Çandarlı, and URL: Urla).

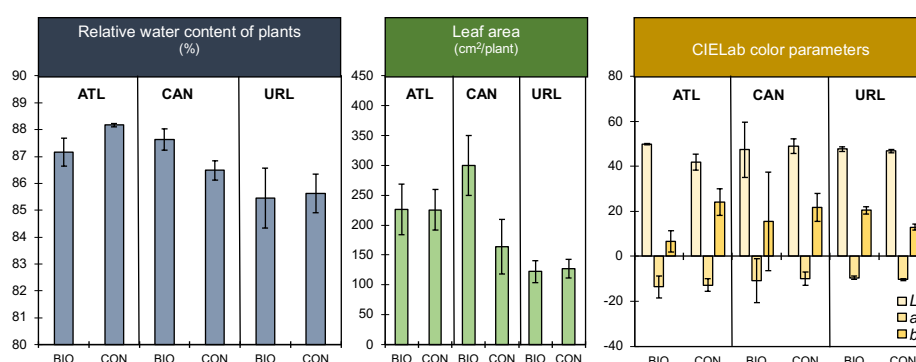
According to the results from the field trials, the average fresh yield in 2023 was recorded at 0.58 tons/ha, with a 76% increase in 2024, reaching 1.02 tons/ha. When considering the average yields over both trial years, the ATL population exhibited the highest yield at 1.05 tons/ha, followed by the CAN and URL populations with yields of 0.80 tons/ha and 0.57 tons/ha, respectively.

In 2023, biological fertilization resulted in a significant yield increase of 96% in the CAN population, whereas no notable effect was observed in the other populations. In 2024, biological fertilization positively impacted all populations, with an average yield increase of 32%.



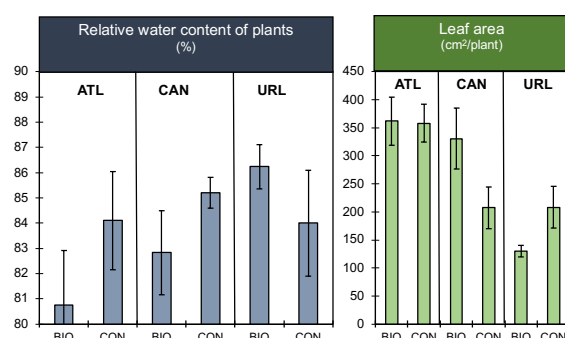
Effect of bio-fertilizer application versus no fertilization on the fresh yield of three sea fennel (*Crithmum maritimum* L.) populations (ATL: Atlantis, CAN: Çandarlı, and URL: Urla) during the 2023 and 2024 growing seasons.

The average relative water content (RWC) of the harvested sea fennel plants in 2023 was 87%, with no statistically significant differences observed between the populations in terms of RWC. In the same year, the average leaf area did not exhibit significant variation between the ATL and CAN populations, which measured 226 cm² and 232 cm², respectively. However, the leaf area of the URL population was significantly lower than the other two, at 125 cm². Additionally, bio-fertilization led to an 83% increase in the leaf area of the CAN population. According to the results obtained from the CIELab color analysis, the average L (lightness) value of sea fennel plants was recorded as 47.1. The highest L value was observed in the ATL population treated with biological fertilizer (BIO), at 49.9, while the lowest value was obtained from the ATL population under control conditions (CON), at 41.9.



Effect of bio-fertilizer application versus no fertilization on relative water content of plants, leaf area and CIELab color of three sea fennel (*Crithmum maritimum* L.) populations (ATL: Atlantis, CAN: Çandarlı, and URL: Urla) in 2023.

Regarding the a (redness/greenness) values, the ATL population with BIO treatment exhibited the lowest value (-13.5), indicating greater greenness, whereas the URL population with BIO treatment showed the highest value (-9.5). As for the b (yellowness) values, the highest measurement (24.1) was obtained from the ATL population under control conditions (CON), whereas the lowest measurement (6.7) was recorded for the ATL population under BIO treatment. Overall, biological fertilizer application did not result in consistent or significant changes across the CIELab color parameters in sea fennel populations.



Effect of bio-fertilizer application versus no fertilization on relative water content of plants and leaf area of three sea fennel (*Crithmum maritimum* L.) populations (ATL: Atlantis, CAN: Çandarlı, and URL: Urla) in 2023.

In the second year of the study (2024), the relative water content (RWC) of sea fennel plants decreased by 3.5% compared to the first year, reaching 84%. However, greater variation was observed between populations and treatments. The highest RWC value was recorded in the URL population treated with biological fertilizer at 86%, while the lowest RWC was observed in the ATL population under the same treatment at 81%. Leaf area measurements showed a similar trend to the first year, with the highest values

recorded in the ATL and CAN populations, reaching 360 cm² and 270 cm², respectively. The leaf area of the URL population was lower, measured at 169 cm².

According to the biochemical analyses of sea fennel populations, total antioxidant activity (FRAP) values ranged from 112 to 177 µmol FRAP/g DW (Table 2). The highest antioxidant activity was recorded in the flowers samples of URL population (URL-F) (177 µmol FRAP/g DW), while the lowest was in leaf samples of CAN population (CAN-L) (112 µmol FRAP/g DW). Total flavonoid content varied significantly among samples, with the highest value observed in leaf samples of ATL population (ATL-F) (11.2 mg/g DW) and the lowest in CAN-L (2.71 mg/g DW).

Antiradical activity (DPPH) ranged from 66 to 265 µg/mL. The lowest IC₅₀ value, indicating the highest antiradical activity, was observed in leaf samples of URL population (URL-L) (66 µg/mL), while the highest IC₅₀ was recorded in URL-F (265 µg/mL). Total carotenoid content was highest in URL-L (113.1 mg/g DW) and lowest in flower samples of CAN population (CAN-F) (28.6 mg/g DW).

Total antioxidant activity, total flavonoids, antiradical activity, total carotenoids, total phenolic compounds, total tocopherol and vitamin C content of leaves (L) and flowers (F) of three sea fennel (Crithmum maritimum L.) populations (ATL: Atlantis, CAN: Çandarlı, and URL: Urla).

Ecotypes	[1] Total antioxidant activity µmol FRAP/g DW	[2] Total flavonoids mg/g DW	[3] Antiradical activity DPPH as IC ₅₀ , µg/mL	[4] Total carotenoids mg/g DW	[5] Total phenolic compounds mg/g DW	[6] Total tocopherol mg/kg DW	[7] Vitamin C mg/g DW
ATL-L	172.5 ±28.2	2.89 ±0.88	136.0 ±23.3	86.2 ±22.5	6.12 ±2.13	369 ±19.4	1.72 ±0.19
ATL-F	146.5 ±32.1	11.2 ±1.66	243.8 ±40.6	47.7 ±13.6	16.2 ±3.18	23.9 ±8.8	1.80 ±0.09
CAN-L	112.3 ±24.1	2.71 ±1.04	87.7 ±18.2	48.3 ±17.4	2.10 ±0.98	218 ±15.7	1.19 ±0.24
CAN-F	154.0 ±17.0	6.03 ±1.12	220.1 ±27.0	28.6 ±12.7	10.8 ±2.44	44.0 ±3.45	0.92 ±0.16
URL-L	163.8 ±18.8	3.44 ±1.29	66.3 ±12.4	113.1 ±33.6	2.84 ±0.34	143 ±16.6	2.04 ±0.37
URL-F	177.2 ±27.3	3.82 ±0.78	265.1 ±31.5	50.4 ±12.7	8.79 ±2.05	14.9 ±3.02	1.86 ±0.11

[1]AO-Benzie and Strain (2009), [2]FLV-Zhishen et al. (1999), [3]AR-Brand-Williams et al. (1995), [4]TC-Arnon and Copper (1949), [5]TPC-Singleton et al.(1999), [6]TTC-Biswas et al (2011), [7]VC-Asghari et al. (2015)

Total phenolic compounds ranged from 2.10 to 16.2 mg/g DW. ATL-F had the highest phenolic content (16.2 mg/g DW), whereas CAN-L had the lowest (2.10 mg/g DW). Tocopherol content varied significantly, with ATL-L showing the highest level (369 mg/kg DW) and URL-F the lowest (14.9 mg/kg DW). Vitamin C content ranged from 0.92 to 2.04 mg/g DW. The highest vitamin C content was detected in URL-L (2.04 mg/g DW), while the lowest was in CAN-F (0.92 mg/g DW).

Overall, biochemical profiles varied notably across ecotypes and plant parts, indicating both genetic and treatment-related differences in the accumulation of bioactive compounds.