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Saline Water Irrigation Effect on Oil Yield and Quality of Argan Trees Domesticated in Laâyoune, Morocco †

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Abstract: Salinity is one of the major severe constraints that limit crop productivity in 40% of the land surface, notably in the Mediterranean region. In this study, we worked in an argan orchard located in Laâyoune, Morocco. The orchard is characterized by a saline soil and trees that are irrigated with highly saline water. The study aimed to evaluate the effect of irrigation with saline water on oil yield, total phenolic content, flavonoid content, antioxidant activity, and fatty acid composition. The results show that saline water irrigation has a no significant effect on oil yield and most oil quality parameters, yet has a highly significant effect on total polyphenols, flavonoid content as well as two saturated acids (C16:0 and C20:0).

Keywords: salinity; argan; oil yield; total polyphenol; flavonoid content; antioxidant activity; fatty acids

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1. Introduction

Around the world, it is estimated that approximately 20% of irrigated cultivated lands since 1990 are affected by salinization [1]. The growing demand for water and the climate change shift seem to increasingly limit crop production, making the issues even worse [2]. Agriculture will then increasingly be forced to use low-quality waters such as brackish water or reclaimed effluent which in turn increases the risks of soil salinization and yield reduction [3]. The introduction of plant species that are tolerant to salt stress of great socio-economic values is one of the possible approaches to promote salt-affected soils and tackle this major abiotic factor that reduces agricultural yield [4]. The approach would improve the vegetation cover and solve the regeneration of particular forest species, such as the argan tree (Argania spinosa) that occurs in a restricted arid areas and which certainly represents a threatened ecological wealth in Southwestern Morocco [3].

Adult argan trees are adapted to aridity and are able to survive long drought periods. They can produce leaves, branches and fruits under as little as 100 mm rainfall [5]. It was shown that the argan tree could tolerate water salinity at germination stage and at the first phases of its in vitro growth [4]. Yet, the majority of studies consider the vegetative parameters, germination or oil quality of argan trees. Despite this knowledge, little is known about the effect of salinity on argan oil quality, and such understanding could help mitigate and buffer extreme events caused by climate change. Therefore, we conducted a comprehensive study on the quality of argan oil obtained from trees domesticated under saline constraints in the Saharan climate in Laâyoune.

2. Materials and Methods

2.1. Site and Plant Materials

The study was carried out in a 700 m^2 orchard in Laâyoune, Morocco. Twelve argan trees were investigated, eight of which were at production stage during the sampling period (Figure 1). The trees have been planted since 1996 at a density of 5 × 5 m and have been irrigated twice a month with 40 L of saline well water per tree. The soil is a sandy-loamy-clayey texture on a limestone slab, with a pH of 7.95, an electrical resistivity of 7.64 dS m^{-1} and a 108 ppm Na+. As for the irrigation water, the pH, the electrical conductivity and the sodium content were 7.27, 16.45 dS m^{-1} and 3083 ppm, respectively (experimental INRA-field, Laâyoune data).

Figure 1. The argan orchard design with the twelve domesticated trees at experimental INRA-field, Laâyoune.

The kernels were recovered from the ripped fruits and grinded. The powder was fried down for 24 h at 40 °C to eliminate all traces of humidity

2.2. Extraction

Once oven dried, a 10 g mass was mixed with 80 mL hexane then poured in a 100 mL flask. The mixture was then exposed to an ultrasonic bath set at 50 ± 1 C for 45 min at a frequency of 28 kHz.

2.3. Physico-Chemcial and Biochemical Study

The extraction of phenolic compounds was achieved following the method of polarity [6]. The determination of the total polyphenol and flavonoid content was carried out by colorimetry using the Folin–Ciocalteu reagent [7], and the aluminum trichloride (AlCl3) and sodium nitrite (NaNO2) [8] methods, respectively. To study the anti-radical activity of the different extracts, the method based on diphenyl picryl-hydrayl (DPPH) as a relatively stable free radical was used according to the protocol described by [9]. The International Organization for Standardization (ISO 5509:2009) [10] method was used for fatty acid composition. Data were analyzed using analysis of variance (ANOVA). Statistica software version 10 was used to assess the statistical significance of mean variations in terms of the effect on the quality of oil. The threshold for significance was set at <0.05 p values.

3. Results

Table 1 shows that the mean oil yields ranged from 37.04% to 47.60%. The total polyphenols and flavonoids ranged from 0.075 to 0.094 and 1.749 to 2.494, respectively. The antioxidant activity varied between 22.80% and 46.17%. As for the fatty acid profiles, the results show variations between 12.82 and 15.1 in C16:0, 0.1 and 0.14 for C16:1, 5.36 and 7.9 for C18:0, 44.33 and 53.66 for C18:1, 25.27 and 34.78 for C18:2, 0.06 and 0.1 for C20:0 and 0.02 and 0.04 for C20:1. From the table, we observe that the results obtained show an interesting aspect in terms of the several analyses carried out.

Table 1. Analysis of variance data of oil yield and quality under highly saline water irrigation.

Tree Code	Oil Yield (%)	TPC (mg EAG/g oil)	FC (mg EQ/g Oil)	AOA (%)	C16:0	C16:1	C18:0	C18:1	C18:2	C20:0	C20:1
A1	43.02	0.094	2.194	31.95	14.39	0.11	6.44	53.66	25.27	0.08	0.04
A2	37.58	0.075	2.466	22.80	15.10	0.14	6.02	51.67	26.97	0.08	0.02
A3	46.12	0.077	2.449	41.33	13.74	0.1	6.93	44.33	34.78	0.08	0.03
B1	44.73	0.080	2.255	46.12	12.82	0.11	7.90	49.69	29.38	0.06	0.03
B2	43.02	0.077	2.416	40.68	12.94	0.14	5.36	46.65	34.80	0.08	0.04
C1	47.60	0.084	2.494	45.85	14.22	0.12	6.27	50.31	28.96	0.08	0.04
C2	41.80	0.093	1.933	39.08	13.16	0.11	7.30	48.02	31.27	0.10	0.04
C4	37.04	0.081	1.749	46.17	13.92	0.13	5.79	48.5	31.53	0.09	0.04
Mean	42.61	0.083	2.245	39.25	13.79	0.12	6.50	49.10	30.37	0.08	0.04
Marge	37.04 −47.60	0.075–0.094	1.749 −2.494	22.80 −46.17	12.82 −15.10	0.10 −0.14	5.36 −7.90	44.33 −53.66	25.27 −34.80	0.06 −0.10	0.02 −0.04
F value	6.162	9.130	650.025	0.355	21.792	0.000	2.141	3.265	0.451	1017.679	3.764
LSD (0.05)	0.005 ns	0.004 *	0.000 ***	0.554 ns	0.000 ***	1.000 ns	0.150 ns	0.077 ns	0.505 ns	0.000 ***	0.059 ns

TPC: Total polyphenol content; EAG: Equivalent gallic acid; FC: Flavonoid content; EQ: Equivalent quercetin; AOA: Antioxidant activity; LSD: Least significant differences; * significant at $p < 0.05$; *** significant at $p < 0.001$; ns:no significant.

Table 1 also shows that irrigation with highly saline water has no significant effect on oil yield, a highly significant effect on the content of both total polyphenols and flavonoids, a non-significant effect on the antioxidant activity relative to the control treatments. For the fatty acid, the ANOVA showed a highly significant effect of saline irrigation water on two saturated acids which are palmitic C 16:0 and arachidic acid C20:0, for the rest of the fatty acids, the results shows that there is no significant effect.

4. Discussion

Soil and water of the orchards were classified as moderately and highly saline, respectively [1,11]. We observed that the mean of the oil yield of trees irrigated with saline water is lower than that in the previous findings of Charrouf, Kouidri and Mechqoq [12–14], who reported an oil yield with solvent ranging between 50–55%, a yield of 55.94% and a yield of 57.12%, respectively. This could be explained by the fact that the yields obtained by those authors were extracted using the Soxhlet method, which generally gives better yield than UAE. However, the total polyphenol content for all irrigated trees with highly saline water was higher than the values obtained by Sour and Demnati [15,16], 0.083 mg EGA/g oil vs. 0.0563 and 0.0724 mg EGA/g oil, respectively. The high stress phase of argan trees under high saline conditions in our orchards would stimulate the production of the secondary metabolites and therefore explain their high values. Similar higher values were obtained for flavonoids, relative to the control. The antioxidant activity values were slightly lower than those of the control yet both are lower than the value obtained by [17], who reported 86.45% antioxidant activity for non-irrigated, old trees. Perhaps the antioxidant activity difference is mostly due to the climate or tree age. Chromatographic profiles showed that the results are overly within the ranges given by the Moroccan standers [18] except for some slight variation, for example in A2 for C16:0, B1 and C2 for C18:0, A1, A2, B1 and C1 for C18:1 and C18:2, all trees for C20:0 and C20:1 (except A2 for the last acid).

5. Conclusions

Our results suggest that except the secondary metabolites, all parameters are either genetically controlled by the tree treats or are affected biotic/abiotic factors such as soil type, climate, age, extraction methods, etc. For a better understanding of those interactions, a profound study on different concentrations, different soils and climates should be conducted.

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