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Effects of irrigation and fertilization on the growth of juniper seedlings

Der Einfluss von Bewässerung und Düngung auf das Wachstum von Wacholdersämlingen

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Keywords: seedling quality, plant nutrition, evaporation, leachate, chlorophyll

Abstract

Juniper has recently become one of the most common species in forest nurseries throughout Turkey; however, issues related to cultural treatments have not been fully resolved yet. This project was implemented to determine the growth and nutritional responses of containerized Crimean juniper (*Juniperus excelsa* Bieb.) seedlings to irrigation (full vs. limited irrigation) and fertilization (unfertilized vs. fertilized) treatments. Results showed that the fertilization treatment significantly increased above-ground development in terms of height, root collar diameter, shoot and total dry weight but didn't affect root dry weight. Consequently, shoot/root and height/diameter ratios also increased. Moreover, both shoot and root N and shoot

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chlorophyll concentrations were also increased by fertilization. The effects of fertilization were either absent or very limited on other nutrients. Irrigation, on the other hand, had no effect on most seedling attributes. However, the amount of leachate increased significantly as a result of full irrigation. Similarly, EC and nitrate concentration increased in leachate in the fertilized treatments. Therefore, loss of nitrate in leachate was greatly elevated when full irrigation is combined with fertilization. These findings indicated that over-irrigation might lead to loss of nutrients and didn't necessarily produce larger or healthier seedling; therefore, limited irrigation with fertilization may be more beneficial for juniper production.

Zusammenfassung

Obwohl Wachholder (*Juniperus*) inzwischen eine gewöhnliche Pflanze in den Forstbaumschulen der Türkei ist, gibt es trotzdem einige ungelöste Probleme bezüglich der Pflanzenbehandlung. Nachfolgend wird über ein Experiment berichtet, das die Reaktion von Sämlingen des Krim-Wachholders (*Juniperus excelsa* Bieb.) auf Bewässerung (volle vs. eingeschränkte Bewässerung) sowie auf Düngung (ungedüngt vs. gedüngt) untersucht. Die Ergebnisse zeigen, dass die Düngung die Sproßentwicklung in Bezug auf Höhe, Wurzelhalsdurchmesser, Sproß- und Gesamttrockengewicht signifikant verbessert, nicht aber die das Wurzel-Trockengewicht. Auch das Sproß-Wurzel-Verhältnis sowie der Höhen-Durchmesser-Quotient nahmen zu. Die Effekte der Düngung fehlten oder waren nur sehr begrenzt bei anderen Nährelementen nachweisbar. Allerdings nahm die Menge des Sickerwassers infolge von „voller Bewässerung" signifikant zu. Ebenso nahm die Konzentration von EC und Nitrat im Sickerwasser der gedüngten Versuchsvariante zu. Konsequenterweise war die Ausschwemmung an Nitrat im Sickerwasser erheblich erhöht für die Behandlungskombination „gedüngt und volle Bewässerung". Die Ergebnisse deuten darauf, dass übermäßige Bewässerung zu Närstoff-Ausschwemmung führt und nicht unbedingt größere oder vitalere Sämlinge liefert. Eine eingeschränkte Bewässerung kombiniert mit Düngung wird daher für die Produktion von Sämlingen bei *Juniperus excelsa* empfohlen.

1. Introduction

Turkey has developed large-scale afforestation and rehabilitation programs in the last decade and most of these activities have been carried out on coniferous species in addition to the multi-purpose broadleaved species (MEF 2007). Annual production of seedlings has been raised to more than 500 million in order to supply the demand for these activities, (FS 2011). Among the conifers, Crimean juniper (*Juniperus excelsa* Bieb.) has become one of the most demanded forest tree species for afforestation due to its resistance to harsh environmental conditions. However, there is still lack of information about the cultural practices related to nursery production and the target seedling attributes for junipers in Turkey.

A successful nursery management needs to combine various cultural treatments in the most effective way to achieve the target seedling quality. Seedlings with well-developed root systems and smaller shoot/root ratio are commonly recommended for harsh-dry sites, since they usually have a better chance to survive in the field (Haase 2007). Contrary to this common belief, recent findings suggest that larger seedlings with higher nutrient reserves are more likely to have better survival and growth rates in Mediterranean climate (Luis et al. 2009; Oliet et al. 2009, 2013; Puertolas et al. 2003; Villar-Salvador et al. 2012). Therefore, nurseries may need to rearrange their traditional practices for a new target seedling attribute in order to have a better establishment of a plantation.

Among various nursery treatments, irrigation and fertilization are perhaps the most common and influential ones which directly affect seedling attribute (Landis 1989a, 1989b). Dose and timing of irrigation depend on the type of seedling and its development stage, along with environmental conditions such as temperature, wind speed and relative humidity. While lack of humidity results in reduced availability of nutrients and water for photosynthesis and growth, over-irrigation may lead to excessive water and nutrient consumption, leaching of nutrients from the growing medium, creating environmental pollution and conditions favorable for diseases (Juntunen et al. 2003; Mexal and Khadduri 2011).

Fertilization also alters availability of the nutrients and thus not only affects vegetative growth but also changes physiological status, which may in turn influence the field performance of the seedlings (Landis 1985; Rook 1991; van den Driessche 1991). While lack of available nutrients may result in stunted growth; over-fertilization may lead to unbalanced seedlings with larger shoots and relatively smaller roots, waste of nutrients and money, and it can even cause death of seedlings at excessive doses.

Although junipers are considered as slow-growing and less-demanding tree species, they can respond well to irrigation and fertilization under nursery conditions (Eser 2007). Considering that they have indeterminate growth habit, they can keep growing as long as they find sufficient resources and suitable environmental conditions (Thomas 2000; Dumrose et al. 2009; Landis and Luna 2009). In this research, we investigated the response of containerized Crimean juniper seedlings to irrigation and fertilization treatments under open-field conditions. Specifically, we tested the effects of two levels of irrigation (100 % vs. 60 % of pan evaporation) and two levels of fertilization (no fertilization vs. water soluble 20-20-20 compound fertilizer) on seedling growth and nutrition. We also determined quantity and quality of leachate after irrigation and fertilization treatments.

2. Material and Methods

2.1 Nursery treatments and design of the experiment

The study was carried out in university nursery with 1+0 year-old Crimean juniper seedlings obtained from the Eğirdir State Nursery. Seedlings were containerized with polyethylene plastic bags with a size of 10x25 cm and a volume of approximately 1 L. A standard potting mixture (soil+humus) was used as a growing medium, which had high amount of organic matter and were slightly alkaline (Table 1). Healthy and morphologically similar seedlings were selected from a large batch and placed tightly in a new seedling bed, where a nylon cover was laid out at the bottom of the bed to collect leachate from the beds. All treatments were launched by the end of spring rains and finalized by autumn.

Tablo 1: Characteristics of potting mixture

Parameter	Organic Matter	pH	EC	$CaCO_3$	NH_4^+	NO_3^-	P	K	CA	Mg	Fe	Cu	Mn	Zn
	mg g^{-1}		µS cm^{-1}	mg g^{-1}	mg g^{-1}									
Value	75.1	7.65	400	23.9	184	89	16	232	4552	587	27	0.77	23.47	1.51

Two levels of irrigation and two levels of fertilization with three replications were applied in a completely randomized design. First level of irrigation treatment was set to 100 % of evaporation (called full irrigation), while the second level received irrigation water equal to 60 % of evaporation (limited irrigation) on weekly basis. Evaporation was measured with a class-A evaporation pan (120 cm width and 25 cm depth) located nearby the experimental site within the nursery (Table 2). Irrigation water was applied every other day in the mornings with mini-sprinklers. Timing and amount of water was controlled with battery-powered irrigation controller (Rainbird WP-1) which delivered 15 mm water in full irrigation and 9 mm water in limited irrigation treatments in 20 minutes. In addition, 3 sensors (Decagon EM50, 5TE sensor) were placed at the center of central containers in each irrigation treatment to measure and record temperature and moisture of growing medium during the study. Irrigation water was slightly alkaline, with relatively high concentrations of Ca, Mg, carbonate and bicarbonate (Table 3).

Table 2: Meteorological parameters from the State Meteorological Station of Isparta for the year 2012, with the amount and duration of irrigation during summer

Month	Temperature max (°C)	Temperature min (°C)	Temperature ort (°C)	Humidity max (%)	Humidity min (%)	Humidity ort (%)	Sunshine duration (hr day^{-1})	Wind speed (m s^{-1})	Monthly precipitation (mm)	Monthly evaporation (mm)	Monthly irrigation (full/ limited) mm
1	8.4	-12.9	-0.5	97	32	74.1	3.6	1.9	148.0		
2	12.9	-11.4	0.3	93	31	67.6	5.6	2.1	88.6		
3	17.7	-8.3	5.1	90	24	57.6	7.1	2.1	20.8	127.2	
4	25.3	-0.1	12.3	88	20	55.2	7.5	2.6	53.2	122.1	
5	26.1	6.2	14.7	94	22	64.0	5.7	1.9	107.4	232.9	
6	33.6	6.1	22.9	81	19	43.6	10.6	1.9	18.1	276.6	337.5/202.5
7	39.2	12.5	25.9	75	17	39.7	11.4	2.1	0.8	232.8	232.5/139.5
8	35.1	9.9	23.1	81	15	41.4	10.6	2.0	34.6	189.6	168.8/101.3
9	34.1	7.2	20.2	96	16	43.8	10.5	1.6	16.4	94.3	116.3/69.8
10	29.8	3.7	14.4	91	26	65.1	7.1	1.8	38.8		
11	22.5	-3.4	8.9	94	40	70.6	3.8	1.5	25.9		
12	16.6	-5.9	4.5	95	37	74.3	0.3	1.8	70.3		

Table 3: Chemical features of the irrigation water used in the nursery.

Parameter	pH	EC	Na	K^+	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^-	NO_3^-	ZN	MN	B
		µS cm^{-1}	mg L^{-1}									
Value	7.91	620	7.1	1.8	56.1	80.2	6.0	322.1	13	0.507	0.023	0.074

Fertilization treatment included no fertilization vs. water soluble 20-20-20 compound fertilizer (Table 4). Seedlings assigned to the fertilization treatment group received 16 applications of fertilizer at weekly intervals. At each application, fertilizer was dissolved in water (2 g per L) in a watering can and applied to the seedlings manually. Same amount of water with no fertilizer was also given to the other seedlings. At the end of the study, a total of 100 g of fertilizer (20 g N, 20 g P_2O_5, 20 g K_2O) per square meter was applied. With the addition of the fertilizer, pH of the irrigation water was reduced by approximately one unit to 6.89, EC and NO_3^- concentration was increased to 1990 µS cm^{-1} and 615 mg L^{-1}, respectively.

Table 4: Composition of the fertilizer (Nutribella®, NPK 20-20-20 + TE).

Nutrients	Total N	NH_4^+-N	NO_3^--N	Urea-N	P_2O_5	K_2O	Cu	Fe	Mn	Zn	B	Mo
Content (%)	20	3,4	5,3	11,3	20	20	0,02	0,08	0,03	0,03	0,02	0,002
Trace elements are water soluble, EDTA chelated (chelate is stable between pH 2-6.5 for Fe; pH 2-11 for Cu, Mn, Zn)												

2.2 Seedling characteristics

Twenty seedlings were extracted from each treatment plot in November and their morphological characteristics (height, root collar diameter) were measured. Then, seedlings were oven-dried at 70° C for 48 hours and their shoot and root masses were measured. Other morphological indices, such as shoot/root ratio, height/diameter ratio and Dickson's quality index (DQI = seedling dry mass in g / [height in cm / diameter in mm + shoot dry mass in g / root dry mass in g]) were also calculated (Thompson, 1985; Haase 2007).

Dried samples were pooled for each treatment and then analyzed for mineral nutrients at Fruit Research Laboratory of General Directorate of Agricultural Research and Policy in Eğirdir. Total N was analyzed by Kjeldahl method using steam distillation system (Gerhardt Vapodset 40), and other nutrients were analyzed after dry-ashing by using inductively coupled plasma (ICP-AES Perkin-Elmer Optima 2100 DV) according to Ryan et al. (2001).

Chlorophyll concentrations were determined on 5 fresh seedlings taken from each treatment. Approximately 2-cm-long pieces were clipped from tips of the branches, where central woody tissue is smaller than 1 mm in diameter, and these clippings were further cut into smaller pieces. Subsample of approximately 0.25 g cut tissue was extracted in 10 mL of methanol for 24 hours at room temperature under dark conditions. The solution was analyzed with UV-VIS spectrophotometer (PG instruments, T80+) and the chlorophyll concentrations were calculated as follows (Dere et al. 1998):

Chlorophyll a (μg / mL) = 15.65 A666 – 7.34 A653

Chlorophyll b (μg / mL) = 27.05 A653 – 11.21 A666

Total chlorophyll = chlorophyll a + chlorophyll b

2.3 Collection and analysis of leachate

Leachate samples were taken four times in August, after the seedlings were allowed to settle at their new seedling beds. Leachate samples were collected in PET bottles attached to an inlet at each treatment plot approximately 2 hours after an irrigation event. Samples were analyzed for total volume, pH, EC and nitrate concentration shortly after collection in the field using portable devices (ExStik EC500 by Extech Instruments, Cardy Twin Nitrate Meter by Horiba).

2.4 Data analysis

The effects of treatments were compared through the analysis of variance using a split plot model, where irrigation treatment was assigned as whole plot while fertilization was assigned as subplot. When significant differences were observed, LSMEANS statement was also used to make multiple comparisons of the treatment means. $p \leq 0.05$ was considered as significant for all analyses. Vector analysis was also performed to demonstrate the effects of treatments on seedling nutrition and growth (Haase and Rose 1995).

3. Results

3.1 Temperature and moisture of the growing medium

Temperature of the growing medium in the pot ranged from 8.5°C in November to 27.5°C in August (Fig. 1). Moisture of the medium ranged from 0.13 to 0.32 $m^3\ m^{-3}$ throughout the study. This data showed that both temperature and moisture variables were almost identical for both irrigation treatments during the growing season. It also indicated that both irrigation treatments had considerable higher levels of moisture content for the first half of the season whereas afterwards the moisture decreased.

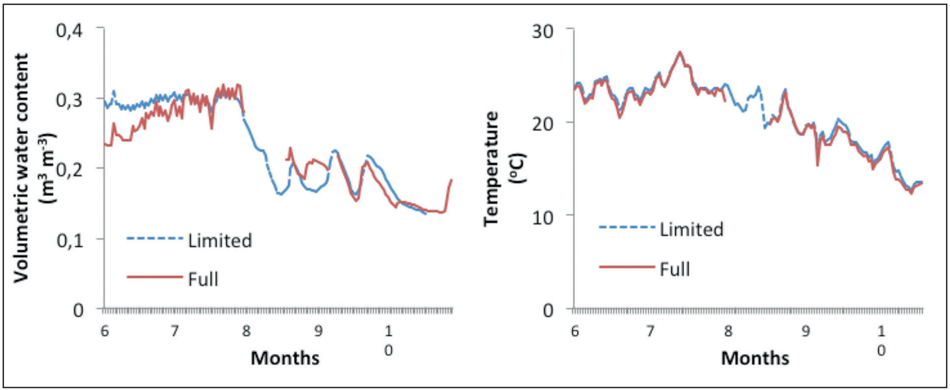

Fig. 1: Temperature (a) and moisture (b) of the growing medium at the university nursery (Some data is missing for full irrigation due to sensor malfunction).

3.2 Morphological characteristics of seedlings

While fertilization usually produced larger seedlings, irrigation had no significant effect on morphological parameters of seedlings (Table 5). On average, fertilization appeared to increase seedling height by 3.5-5.2 cm and diameter by 0.2-0.5 mm. Seedling height was more responsive to fertilization than diameter; therefore, height/diameter ratio also increased. Dry weights of the seedling were also 1.0 to1.6 g greater after fertilization, but this was mainly due to faster shoot growth rather than root growth. In turn, shoot/root ratio rose from 1.4-1.5 in unfertilized seedlings to 1.9 in fertilized seedlings. Seedling quality index, which incorporates other variables in a single value, was not affected by any of the treatments.

Table 5: Morphological characteristics (mean±sd) of Crimean juniper seedling grown under different irrigation and fertilization treatments. Means with same letter are not significantly different (p<0.05) for a given parameter.

Treat-ment	Height cm	Diameter mm	Root DW g	Shoot DW g	Seedling DW g	Shoot/root ratio	Height/ diameter ratio	Dickson's Quality index
I0F0	18.9±0.5b	4.1±0.2b	2.0±0.2	3.0± 0.4b	5.1±0.5b	1.5±0.1b	46.6±1.1b	0.84±0.09
I0F1	22.4±2.1a	4.3±0.2ab	2.1±0.1	3.9± 0.7a	6.0±0.7ab	1.9±0.3a	52.7±3.7a	0.85±0.05
I1F0	19.4±1.0b	4.1±0.1b	2.1±0.3	2.9± 0.3b	5.0±0.6b	1.4±0.0b	47.5±1.6b	0.83±0.10
I1F1	24.1±0.3a	4.6±0.2a	2.3±0.2	4.3± 0.2a	6.6±0.3a	1.9±0.1a	53.7±2.9a	0.95±0.10
P-values								
I	0.2093	0.2377	0.1193	0.6118	0.4412	0.5977	0.6166	0.3535
F	**0.0042**	**0.0400**	**0.3841**	**0.0038**	**0.0126**	**0.0049**	**0.0063**	0.3133
I*F	0.4475	0.2778	0.6344	0.2802	0.3534	0.7244	0.9503	0.4397

I: irrigation; F: fertilization; IOF0: limited irrigation plus no fertilization; I0F1: limited irrigation plus fertilization; I1F0: full irrigation plus no fertilization; I1F0: full irrigation plus fertilization

3.3 Seedling nutrition

The effects of treatments on seedling nutrition seemed to be limited to only N and, to some extent, B and Mn concentrations of the seedlings (Table 6). Fertilization treatment significantly raised N concentration by 46 % in the shoots and 33 % in the roots in comparison to unfertilized seedlings. Full irrigation appeared to have a negative effect on B concentration of the shoots (12 % reduction) and positive effect on Mn concentration of the roots (15 % increase), but these observed changes were relatively small. Neither irrigation nor fertilization had any significant effect on other nutrient concentrations. It was also apparent that concentrations of N, P and K were greater in shoots than in roots, while concentrations of some other nutrients including Ca, Mn, Fe and B were greater in roots.

Since the seedlings in fertilization treatments were heavier and had greater N concentrations, they also had greater nitrogen content (Table 7). In fact, fertilized seedlings had up to 148% more N concentration and 185 % more N content in comparison to the seedlings receiving limited irrigation with no fertilization. This indicated that N was the most responsive nutrient (Fig. 2). P, K and Mg contents of the seedlings were also significantly affected by fertilization but the magnitude of the change was relatively small.

Tablo 6: Nutrient concentrations (mean±sd) of shoots and roots of Crimean juniper seedlings grown under different irrigation and fertilization treatments (treatment codes are given in table 5). Means with same letter are not significantly different ($p<0.05$) for a given parameter.

Treat-ment	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	B
	g kg^{-1}					mg kg^{-1}				
Shoot										
I0F0	9.2±0.1b	1.8±0.1	5.6±0.2	10.9±0.1	2.1±0.1	162±12	10.8±1.0	35.9±2.3	29.2±2.1	17.2±1.0a
I0F1	14.1±0.8a	1.6±0.1	5.5±0.3	10.4±0.6	2.1±0.1	137±18	8.3±1.6	36.3±2.0	25.9±1.5	15.4±0.7b
I1F0	9.4±0.4b	1.6±0.1	5.4±0.4	10.5±1.0	1.9±0.1	140±19	9.2±2.8	32.7±1.1	28.0±2.9	14.4±0.5b
I1F1	13.0±0.9a	1.7±0.1	5.5±0.3	10.1±0.7	2.2±0.1	159±43	10.9±3.3	35.8±3.7	27.4±2.9	14.1±0.8b
P-values										
I	0.5076	0.7676	0.7433	0.3921	0.2879	0.9943	0.5453	0.2299	0.7279	0.0107
F	0.0001	0.4353	0.8512	0.3749	0.0913	0.8177	0.8405	0.3000	0.3600	0.0643
I*F	0.0176	0.0602	0.2341	0.9701	0.0913	0.1450	0.3013	0.4266	0.5289	0.1562
Root										
I0F0	7.7±0.2b	1.1±0.1	3.3±0.3	13.2±0.6	2.0±0.2	639±30	12.4±2.1	49.4±4.8	23.0±3.6	18.6±0.3
I0F1	9.9±0.7a	1.0±0.1	3.4±0.4	13.6±1.7	1.9±0.2	663±119	10.9±3.3	50.8±9.4	18.1±3.0	18.9±1.9
I1F0	7.5±0.7b	1.0±0.0	3.2±0.2	13.5±0.4	2.0±0.2	723±79	12.2±0.6	58.9±4.4	24.7±1.4	19.4±1.5
I1F1	10.3±0.3a	1.1±0.0	3.8±0.2	14.8±0.5	2.1±0.1	647±26	11.0±0.3	56.3±3.2	20.9±2.2	17.7±0.4
P-values										
I	0.7764	0.3739	0.5445	0.1690	0.0533	0.3695	0.9632	0.0356	0.1279	0.7078
F	0.0009	0.7247	0.0671	0.2323	0.8993	0.6368	0.1620	0.8958	0.0799	0.4082
I*F	0.4572	0.1318	0.1630	0.4845	0.3987	0.3777	0.8100	0.6548	0.7810	0.2740

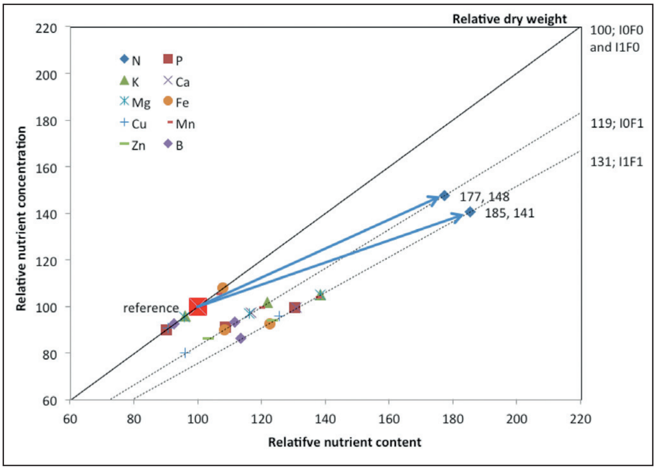

Fig. 2: Vector diagram on response of *Juniperus excelsa* seedlings to irrigation and fertilization treatments. Irrigation plus no fertilization treatment (I0F0) was taken as the reference treatment for comparison with other treatments and shown with the big square. Note that I0F0 overlaps I1F0. Numbers next to N points (diamonds) indicate proportional increase in N content and concentration, respectively.

Tablo 7: Nutrient contents (mean±sd) of Crimean juniper seedlings grown under different irrigation and fertilization treatments (treatment codes are given in table 5). Means (mg seedling-1) with same letter are not significantly different (p<0.05) for a given parameter.

Treat-ment	N	P	K	Ca	Mg	Fe	Cu	Mn	Zn	B
I0F0	43.1±3.5b	7.5±1.2b	23.5±2.0bc	59.7±6.1	10.3±0.8b	1.8±0.1	0.06±0.01	0.21±0.02	0.14±0.03	0.09±0.01
I0F1	76.5±13.5a	8.2±1.2ab	28.6±4.3ab	69.5±11.5	12.1±1.6b	1.9±0.4	0.06±0.01	0.25±0.04	0.14±0.02	0.10±0.02
I1F0	43.5±3.9b	6.8±1.1b	22.5±2.5c	59.5±10.1	9.9±1.2b	1.9±0.1	0.05±0.01	0.22±0.03	0.13±0.02	0.08±0.01
I1F1	79.9±6.8a	9.9±0.8a	32.5±2.3a	77.9±5.5	14.3±0.6a	2.2±0.2	0.07±0.01	0.29±0.03	0.17±0.01	0.10±0.01
P-values										
I	0.7398	0.5371	0.4691	0.4377	0.2847	0.2005	0.3739	0.1688	0.2241	0.1000
F	0.0009	0.0328	0.0070	0.0534	0.0083	0.1743	0.3046	0.0623	0.3068	0.0907
I*F	0.7161	0.1042	0.1721	0.4593	0.0925	0.6681	0.1917	0.4977	0.3068	0.3295

3.4 Chlorophyll concentrations

Chlorophyll concentration of the juniper shoots ranged from 2.77 to 3.64 mg g^{-1} among treatments and it was affected significantly by fertilization (Fig. 3). Effects of the fertilization were more apparent when the seedlings had limited irrigation. In addition, chlorophyll concentrations were also highly correlated with shoot N concentrations (R^2 = 0.59, p = 0.003).

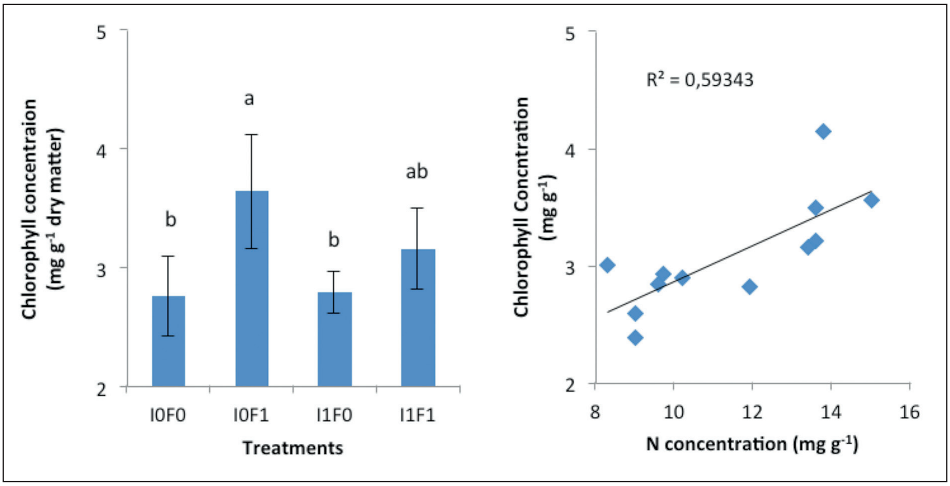

Fig. 3 Total chlorophyll (chlorophyll a + chlorophyll b) concentrations of *Juniperus excelsa* seedlings grown under different irrigation and fertilization treatments and its relationship with N concentration (error bars represent ±1 standard deviation).

3.5 Leachate

Leachate amount and chemistry was significantly affected by the treatments (Table 8). Amount of leachate increased from 76-83 mL m^{-2} in limited irrigation to 950-983 mL m^{-2} in full irrigation treatments. Nitrate concentrations of the leachate were also 4-5 times greater in fertilized treatments. Therefore, full irrigation plus fertilization had an interaction with the amount of leached nitrate, which rose from 4 mg m^{-2} in limited irrigation plus no fertilization to 161 mg m^{-2} in full irrigation plus fertilization treatment. This amount corresponds to approximately 4.0 % of the applied nitrate (1.1 % of the applied nitrogen) in limited irrigation treatment and 38.9 % of the applied nitrate (10.3 % of applied nitrogen) in full irrigation treatment. pH of the leachate seemed to be lowered by 0.29 unit in full irrigated treatment while EC seemed to be elevated by fertilization.

Table 8: Amount of leachate per irrigation event and its chemistry (mean±sd).

Treatment	Amount of leachate mL m^{-2}	pH	EC	NO_3^- mg L^{-1}	NO_3^- mg m^{-2}	Leached/applied NO_3^- ratio %
I0F0	83±77b	8.37±0.13a	685±41c	44±6b	4±3c	-
I0F1	76±91b	8.23±0.17ab	947±27a	203±53a	16±21bc	4.0
I1F0	950±207a	8.06±0.10bc	693±24c	52±13b	51±25b	-
I1F1	983±208a	7.99±0.02c	846±25b	161±17a	161±28a	38.9
P-values						
I	**0.0019**	**0.0285**	**0.0356**	0.1010	**0.0040**	
F	0.7841	0.0600	**0.0001**	**0.0039**	**0.0008**	
I*F	0.6782	0.6182	**0.0339**	0.2570	**0.0021**	

4. Discussion

Relatively smaller seedlings are usually preferred in drier areas in Mediterranean counties; therefore growers are usually hesitant about over irrigation and the use of fertilizers in Turkish forest nurseries. But recent findings indicate that strong seedlings with balanced nutrition are more likely to perform better even in dry sites (Puertolas et al. 2003; Luis et al. 2009; Oliet et al. 2009, 2013; Villar-Salvador et al. 2012). Therefore, current cultural practices should be reevaluated to be able to achieve the target seedling quality that performs better under Mediterranean conditions.

Junipers are generally considered as drought and cold tolerant species and this feature makes it a very good alternative for plantings on difficult sites (Chambers et al. 1999; Gültekin and Gültekin 2007; Karatepe and Gürlevik 2011). They are also traditionally considered as slow-growing species. According to Turkish standards for coniferous seedlings, first class juniper seedlings should be at least 2 mm in diameter regardless of age or type of seedling, and the stem height should be at least 4 cm at age 1, 8 cm at age 2 and 13 cm at age 3 (TS2265 1988). However, current nursery practices indicate that junipers can grow much faster than initially thought. They have an indeterminate growth habit, which means that they can continue growing even during the fall and winter as long as environmental factors are favorable (Thomas 2000; Dumrose et al. 2009; Landis and Luna 2009). It is reported that in Turkish nurseries *J. excelsa* can easily grow 12-19 cm in height and 2.2-3.5 mm in root collar diameter in one year both in bare-root and containerized propagation (Gülcü et al. 2005, 2010; Eser 2007; Deligöz 2012). In fact, Gültekin and Gültekin (2007) suggest that a first class juniper seedling should have a minimum height of 15 cm and diameter of 2 mm in the light of current research and practices.

Irrigation can significantly affect plant growth and also physiology (Landis 1989a; Kozlowski ve Pallardy 1997; Akça and Yazıcı 1999). In our study, however, full and limited irrigation treatments had no significant impact on seedling growth and nutrition. Such absence of influence may be due to the fact that two irrigation doses had almost similar moisture contents for most of the growing season in this trial. This similarity in soil moisture contents is partly due to greater leaching losses in full irrigation than in limited irrigation (approximately 6-7 % vs. less than 1 % of the applied water). So, actual difference in terms of applied water is not 40 % but around 34 percent.

There are many ways to determine the amount of irrigation water for a particular plant or environment. While some of these methods rely on soil water content, others rely on direct measurements of plant water status (Jones 2004). However, most of these methods require expensive instruments and user experience. Pan evaporation method is perhaps the cheapest and easiest method that combines environmental factors such as solar radiation, air temperature, moisture and wind speed (Hillel 1997). It is recommended that irrigation amount should be set near or slightly above the amount of evaporation in the Mediterranean region (Kılcı et al. 1999). However, this method usually overestimates the actual water requirement of a plant by 33 % or more, depending on the crop type and development stage of the plants (Hillel 1997; Mexal and Khadduri 2011) since open water surfaces may evaporate more water than an area with full plant coverage. Therefore, even the limited irrigation in this trial may have provided sufficient amount of water to the seedlings.

Moreover, plants can exhibit optimum growth in wide range of soil moisture contents and they respond to moisture only after a certain point in soil moisture content (Landis 1989a; Mexal and Khadduri 2011). The research showed that water potentials of soil and plant sharply declined when the soil water content fell below 20-30 percent and water contents more than 30 % didn't produce a positive response in plant water potential, transpiration and photosynthesis (Havranek and Benecke 1978). This pattern of response was also confirmed in other applied research trails. Lamhamedi et al. (2001) applied four different doses of irrigation (15, 30,40, 60 % substrate water content, v/v) to *Picea glauca* (Moench) Voss seedlings and showed that only the lowest dose resulted in reduced growth.

In principle, fertilization adds the limiting nutrients to the growing medium, which increases nutrient availability and uptake by plants. Increased uptake, in turn, usually results in faster growth. In our study, in fact, fertilizer application significantly increased shoot growth but did not affect root growth, resulting in increased shoot/root ratio (from 1.4 to 1.9). However, Dickson's quality index, which incorporates seedling dry mass, shoot/root ratio and sturdiness (height/diameter) ratio, indicated that the increased shoot growth did not create an imbalanced seedling. Positive effects of fertilizers were also shown in other studies. Eser (2007) reported that height growth of fertilized bare rooted 1+0 *J. excelsa* seedlings responded positively to N (ammonium sulfate) fertilization on slightly alkaline soils (pH 7.8), while diameter growth was controlled by seedling density.

Fertilizer treatment also affected seedlings' nutrition and physiology. N concentrations and contents of the seedlings elevated significantly but other nutrient concentrations did not change. Furthermore, fertilization increased the chlorophyll concentration significantly and it was significantly correlated with N concentration; which was not surprising considering that N is one of the main constituents of the chlorophyll molecule (Tam and Magistad 1935; Linder 1980; von Wettstein et al. 1995; van den Berg and Perkins 2004). However, it is not clear why compound fertilizer application didn't affect other nutrients in the seedlings. This lack of fertilizer effect on other nutrients was also observed in another study on the same species in state forest nursery (unpublished results). We can speculate that although junipers are usually known as salt tolerant species (Valdez-Aguilar et al. 2011), high lime content of the soil and high concentrations of salt, carbonate and bicarbonate in irrigation water create alkaline conditions which in turn limit availability of nutrients. High carbonate and bicarbonate content was apparently visible as white deposits on seedlings by the end of the summer in our trial. It is also already known that P availability is very limited in alkaline soils where there is plenty of lime that forms insoluble calcium phosphate (Hopkins and Ellsworth 2005). Moreover, application of K, Ca and Mg with fertilizer doesn't really change anything for the plants, since local soils or potting mixture already have considerable concentrations of these nutrients. It has been reported that plants growing on poor acidic soils are more likely to respond to fertilization than productive calcareous soils (Berger and Glatzel 2001).

Leaching of fertilizer nutrients can be considered as loss of money and it can also create serious environmental problems (Juntunen and Rikala 2001). While high irrigation dose significantly increased the amount of leachate, fertilization resulted in significantly elevated electrical conductivity and nitrate levels in leachate in this study. When fertilizer application was accompanied with high dose of irrigation, the loss of nitrate was even greater while more than 1/3 of applied nitrate leached. We did not quantify other nutrients in leachate, but we can expect that at least some amount of organic N, ammonium-N and other nutrients also leached, considering that our potting mixture had high concentrations of organic matter and the nutrients in the fertilizer were in readily soluble form. To reduce the amount of leaching losses, timing and application method of irrigation and fertilizer can be adjusted according to the requirements of the plant (Landis 1989a, 1989b). Controlled-release fertilizers may be useful to reduce total fertilizer use and leaching losses (Trenkel 1997; Oliet et al. 2004). However, significant amount of nutrients can still leach, especially at the early stages of seedling development (Juntunen et al. 2003). Another possible alternative would be exponential application of liquid fertilizer where the dose of fertilizer is increased as the seedling grows larger during the season (Dumrose 2003, Hawkins 2011). In addition, some reports suggest that organic sources of nitrogen (such as arginine amino acid) can also be used as an affective N fertilizer with higher recovery by seedlings and reduced leaching losses (Öhlund and Näsholm 2002).

5. Conclusion

Although better nutritional status of a seedling doesn’t always guarantee better survival in the field (Landis 1985), recent findings indicate that larger seedlings can survive and grow better under Mediterranean conditions (Puertolas et al. 2003; Luis et al. 2009, Oliet et al. 2009, 2013); therefore, we may need to reconsider our target seedling standards. Both irrigation and fertilization have a potential to affect seedling quality significantly. Our research indicated that greater irrigation didn’t always produce larger seedlings while fertilization could lead to greater seedlings with higher nutrient and chlorophyll contents. It was also very obvious that higher dose of irrigation could lead to significant losses of nutrients. Under these circumstances, we can recommend reduced irrigation levels with sufficient doses of fertilizers. In this way, it may be possible to grow strong seedlings with greater nutrient reserves and hopefully they can survive and grow well after outplanting. However, before a final conclusion can be drawn, nursery trials should be supported by outplanting trials in which different qualities of juniper seedling are investigated for their performance.

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