

Investigation of Feeding Activities for *Juniperus* and *Picea* Species Grown in Turkish Forest Nurseries

Türkiye Orman Fidanlıklarında Yetiştirilen Ardıç (*Juniperus* spp.) ve Ladin (*Picea* spp.) Türlerine Yönelik Gerçekleştirilen Bitki Besleme Faaliyetlerinin İncelenmesi

Hakan LEVENTOĞLU*¹ 

¹Isparta University of Applied Sciences, Graduate Education Institute, Isparta

¹Agricultural Engineer, Sakarya

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*Sorumlu yazar/Corresponding author

Hakan LEVENTOĞLU

e-mail: hleventolu@gmail.com

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Abstract

This study investigates plant nutrition practices and fertilizer usage during the seedling production phase in Turkish forest nurseries. Seedlings of *Juniperus* spp. and *Picea* spp. were sampled from nine nurseries selected based on their geographical distribution and high production capacity of the target species. To evaluate the seedlings' growth and nutritional status, morphological measurements and nutrient content analyses were conducted. The proportional distribution of nutrient concentrations in coniferous leaves per 100 units of nitrogen was determined as follows: 11–22 units of phosphorus, 23–49 units of potassium, 5–28 units of magnesium, 11–303 units of calcium, 4–10 units of sulfur, 6–36 units of iron, 0.21–1.46 units of zinc, 0.28–3.54 units of copper, 0.39–3.84 units of manganese, and 0.38–8.72 units of sodium. The total nutrient amounts extracted from the soil by each set of seedlings (20 seedlings) were calculated and extrapolated to determine nutrient removal per unit area. Findings revealed that fertilization practices in most nurseries predominantly rely on conventional routines rather than soil analysis data, potentially compromising efficiency and sustainability. This study underscores the necessity of scientifically guided nutrient management strategies to enhance seedling quality and ecological compatibility in nursery operations.

Öz

Bu çalışma, Türkiye'deki orman fidanlıklarında iğne yapraklı fidanların üretim sürecinde uygulanan bitki besleme yöntemlerini ve gübre kullanım düzeylerini incelemektedir. Coğrafi temsiliyeti yüksek ve hedef türlerde üretim kapasitesi fazla olan dokuz orman fidanlığında *Juniperus* spp. ve *Picea* spp. türlerine ait fidan örnekleri alınmıştır. Fidanların gelişim ve beslenme durumları, morfolojik ölçümler ve besin element analizleri ile değerlendirilmiştir. 100 birim azot başına yapraklardaki besin element konsantrasyonlarının oransal dağılımı şu şekildedir: 11–22 birim fosfor, 23–49 birim potasyum, 5–28 birim magnezyum, 11–303 birim kalsiyum, 4–10 birim kükürt, 6–36 birim demir, 0.21–1.46 birim çinko, 0.28–3.54 birim bakır, 0.39–3.84 birim mangan ve 0.38–8.72 birim sodyum. Her bir fidan setinin (20 fidan) topraktan uzaklaştırdığı toplam besin miktarı hesaplanmış ve birim alana genellenerek söküm sonrası toprağa yeniden kazandırılması gereken besin miktarları belirlenmiştir. Fidanlıklarda gübrelemenin çoğunlukla toprak analizlerine değil, geleneksel uygulamalara dayalı olduğu saptanmıştır. Bu çalışma, fidan kalitesini ve ekolojik uyumu artırmak amacıyla bilimsel temelli besleme stratejilerinin gerekliliğini vurgulamaktadır.

INTRODUCTION

Türkiye's diverse geography, comprising seven distinct regions, presents varying microclimates and ecological conditions that significantly affect plant production practices. This variability in soil and climatic factors necessitates region-specific strategies in nursery operations. Nutrient requirements and soil nutrient depletion rates differ among species and growing conditions; however, these parameters remain largely undefined due to limited data. Insufficient knowledge and experience in plant nutrition can adversely affect seedling growth, quality, and survival, often resulting in inefficient labor use and increased production costs. In all cultivation systems—whether commercial or non-commercial inputs such as soil, nutrients, and water form an integrated framework and must be evaluated holistically. This applies both to large-scale afforestation initiatives and to controlled-environment crop production. While the biological processes from seed to sapling remain consistent, the ecological requirements of species vary according to their morphological characteristics. Given the broad range of species cultivated under the authority of the General Directorate of Forestry (OGM), more precise and scientifically grounded approaches are essential. Accordingly, this study aims to assess the fertilization and plant nutrition practices in forest nurseries across Türkiye, especially during the seedling production

phase. The study compares these practices against technical, economic, and scientific standards, with the goal of preventing the indiscriminate application of uniform feeding regimes. The ultimate objective is to recommend regionally adapted, data-driven nutrition strategies (Leventođlu 2024).

As of 2021, OGM oversees 28 regional directorates, 84 operational nursery units, and 102 nursery chiefdoms. These nurseries produce seedlings for OGM itself, as well as for other public and private stakeholders. Forest nurseries are defined as areas—either open or enclosed—designed for the production of seedlings to be transplanted for specific forestry purposes (Yahyaođlu 1993, Anonymous 1996). Two main types of nurseries exist under OGM: permanent and temporary forest nurseries (Ürgenç 1991). State Forest Nursery Enterprises (DOFIs) play a central role in the propagation of forest tree species. Therefore, aligning feeding practices in these institutions with modern silvicultural standards is essential (Ayan 2007). Nursery activities have also contributed to increased awareness of species-specific morphological and physiological variation (Gültekin 2005). At this stage, emphasis should be placed not on maximizing production, but on ensuring healthy, standard-compliant seedlings (Kalıpsız 1970). As Tolay (1983) noted, the success of afforestation projects is highly dependent on seedling quality, which is shaped by both biological and environmental interactions.

Morphological Characteristics

Morphological characteristics evaluated in this study include root collar diameter, total height, root dry weight, stem dry weight, leaf dry weight, total dry weight of the seedling, the stem-to-root weight ratio, and the leaf-to-total weight ratio. These parameters were measured to assess overall plant development and structural allocation among different organs.

Physiological Characteristics

Physiological characteristics were evaluated based on the content and concentration of essential plant nutrients in vegetative tissues. The fundamental principle of plant nutrition is the timely and adequate supply of nutrients to meet species-specific demands during critical growth phases. If the soil lacks sufficient nutrients to fulfill these requirements, external fertilization must be applied to prevent deficiencies that could lead to reduced growth or quality (Karaöz 1992). According to Gezer (1986), fertilization is a key component in producing robust seedlings capable of adapting to open-field afforestation sites and achieving vigorous growth. During the seedling cultivation phase, the nutrients extracted by millions of plants can only be compensated through fertilization practices that are correctly timed and dosed. Seedlings grown under such conditions tend to exhibit improved physiological traits and are better adapted to post-transplantation environments.

MATERIAL AND METHOD

Material

This study aimed to evaluate the development and nutritional status of *Juniperus* L. and *Picea* A. Dietr. seedlings commonly produced in forest nurseries. In selecting the nurseries for sampling, those with high production capacities and located in regions where these species are intensively cultivated were prioritized. Seedlings were collected from a total of nine forest nurseries across different geographical regions of Türkiye, as shown in Figure 1.



Figure 1. Geographical distribution of forest nurseries where seedlings were sampled in Türkiye

Method

Among the species produced in forest nurseries, 1+0 aged *Juniperus* and *Picea* seedlings being the most widely cultivated were selected. Sampling included three seedling types: bare-rooted, polyethylene-tubed, and enso-coated. Species and nursery selections were based on ecological prevalence and high production volumes. Data on seedling production were retrieved from the General Directorate of Forestry Seedling Stocks Database for the year 2019. Sampling was conducted at five nurseries for *Juniperus* and four nurseries for *Picea*.

Seedling Sampling

The most commonly cultivated *Juniperus* species (Gray, Thorny, and Fragrant) and *Picea* species (*Blue, Eastern, and Western*) were sampled for morphological and physiological evaluations. A total of 280 seedling samples (20 seedlings per species per nursery) were analyzed.

- **Morphological Measurements:** Some morphological measurements of 1+0 aged conifer seedlings were initiated in 2019. Sampling was conducted in August–September, when physiological maturity was reached. For each *Juniperus* and *Picea* type, 20 seedlings were collected from each respective nursery. Bare-rooted seedlings were carefully uprooted from a depth of 25–30 cm. Tubed and enso-coated seedlings were sampled directly from the production beds. Samples were packed in protective containers (telhis) and sent to the laboratory for analysis. Morphological measurements were performed at the Gübre Fabrikaları A.Ş. Samsun Regional Laboratory.

Seedlings were washed under medium-pressure water to remove soil and debris. The following parameters were measured: Root collar diameter: measured using a digital caliper (± 0.1 mm), Seedling height: distance from root collar to top bud (cm), Stem dry weight: dry weight (65°C for 48 h) of above-ground parts (g), Root dry weight: dry weight (65°C for 48 h) of roots cut at collar level (g), Leaf dry weight: dry weight (65°C for 48 h) of leaves (g), from these data. Total seedling dry weight=stem + root + leaf dry weights Stem-to-root dry weight ratio and leaf-to-total dry weight ratio were calculated. They were dried in a drying cabinet at 65°C for about 48 hours until they reached constant weight (Genç and Yahyaoglu 2007).



Figure 2. Morphological measurement procedures conducted before laboratory analysis

- **Nutrient Element Analyses:** Root, stem, and leaf samples, for which morphological measurements had been taken, were ground, labeled, and sealed in plastic bags before being sent to the Eskişehir Forest Soil and Ecology Research Institute Laboratory. For each species, 20 seedlings were analyzed. Nutrient concentrations were multiplied by the dry mass of the respective organs to determine total nutrient uptake. The nutrient contents of root, stem, and leaf were summed to estimate the total nutrient removal per seedling. In Table 1, the analytical methods used for macro and microelement analyses are presented.

Table 1. Plant analysis methods

Abbreviation	Analysis Name	Analysis Method
N	Nitrogen	Kjeldahl Method
P	Phosphorus	Ammonium Meta Vanadate Yellow Color Method in P Spectrophotometer
K	Potassium	Flame Photometric Method
Ca	Calcium	AAS Method
Mg	Magnesium	AAS Method
S	Sulfur	Turbidimetric barium sulfate method

Data Analysis and Evaluation

Morphological data were evaluated using analysis of variance (ANOVA). Differences among packaging types (bare-rooted, tubed, enso-coated) were tested using the SPSS software package. Post hoc comparisons were performed using the Tukey test at a significance level of $p < 0.05$. Statistically significant differences were indicated with Latin letters above the means (Kalıpsız 1981, Özdamar 2002, 2004).

Fertilization Practices in the Nurseries

Table 2 provides a comparative overview of fertilizer application rates (kg/da) by seedling type and fertilizer category. The data reveal that both fertilizer type and nursery production method substantially influence application quantities. In bare-root systems, nitrogen-rich fertilizers such as Ammonium Nitrate (AN: 45 kg/da), Monoammonium Phosphate (MAP: 50 kg/da), and Slow-Release Fertilizers (SRF: 50 kg/da) are applied at notably higher doses compared to other seedling types. This is likely due to the greater soil contact and more expansive root systems of bare-root seedlings, necessitating greater nutrient availability in open field conditions. In contrast, container and tubular systems display significantly reduced fertilizer dosages.

This trend reflects the limited substrate volume in containerized media and the need to prevent salt accumulation and root stress. Moreover, the use of slow-release fertilizers and organo-mineral formulations (e.g., OMF, MF, CF) across all systems indicates an emphasis on sustained nutrient supply and support for soil microbiota. Notably, manure (MF) and compost (CF) fertilizers are applied at very high rates (>1000–2000 kg/da), especially in bare-root and tubular systems.

This highlights a clear strategy to enhance soil organic matter content and improve nutrient-holding capacity, both of which are essential for long-term soil fertility. Furthermore, the implementation of green manuring (GF) across all seedling types underscores a commitment to ecological sustainability and soil health management in nursery practices.

Table 2. Organic and inorganic fertilizer application rates by seed type (kg/da)

Fertilizer Type	Bare-root	Tubular	Container-grown	Tall Seedling
UREA	18.15	15.0	11.25	11.25
AS (Ammonium Sulfate)	22.5	15.0	12.5	12.5
AN (Ammonium Nitrate)	45.0	27.5	20.0	20.0
NSP (Nitrate Superphosphate)	33.25	26.25	16.25	13.75
TSP (Triple Superphosphate)	28.75	16.25	17.5	17.5
DAP (DiammoniumPhosphate)	37.5	30.0	-	-
MAP (MonoammoniumPhosphate)	50.0	20.0	16.25	13.75
K ₂ SO ₄ (Potassium Sulfate)	32.5	13.75	16.25	22.5
NPK (e.g., 15-15-15)	37.5	11.5	12.5	18.75
SRF* (Slow-release Fertilizer)	50.0	30.0	16.5	21.25
OMF** (Organo-mineral Fertilizer)	27.5	18.75	12.0	-
MF*** (Manure Fertilizer)	>2000	>1500	>1000	>1000
CF**** (Compost Fertilizer)	>1500	>1000	>800	>800
GF***** (Green Manuring)	Yes	Yes	Yes	Yes

RESULTS

Morphological Characteristics of Juniper (*Juniperus* spp.) Seedlings

The morphological measurement results of *Juniperus* seedling samples obtained from different nurseries and packaging types are presented in Table 3. Evaluation of the data revealed that seedling height, root collar diameter, and the dry weights of root, stem, leaf, and total plant varied depending on species, growing medium, and nursery conditions. Among bare-rooted seedlings, height values ranged from 34.10 cm to 60.25 cm. The tallest average height was recorded in Grey juniper (*J. excelsa*) seedlings grown in Malatya Forest Nursery (60.25 cm). The lowest collar diameter (1.28 mm) was found in Grey juniper seedlings from Niksar Forest Nursery. Leaf dry weights varied between 1.29 and 2.05 g. The highest leaf weight was observed in Grey juniper seedlings cultivated in polyethylene tubes in Olcay Nursery (2.05 g). In general, tubed seedlings exhibited higher leaf and root dry weights compared to bare-rooted seedlings. For example, root dry weight in tubed Grey juniper seedlings grown in Gülek Nursery was measured as 1.92 g. The total dry weights of seedlings varied between 3.72 g and 5.58 g depending on species and cultivation conditions. The lowest value was recorded in Thorny juniper (*J. oxycedrus*) seedlings from Eğirdir (3.72 g), while the highest total dry weight belonged to tubed Grey juniper seedlings from Olcay Nursery (5.58 g). The stem/root dry weight ratios ranged from 0.82 to 1.11. This ratio reflects the extent of shoot development relative to root growth. The highest ratio was observed in Grey juniper seedlings from Niksar Nursery (1.11), indicating a relatively greater stem development. The leaf/total dry weight ratios were consistent across samples, ranging between 0.34 and 0.37, suggesting a uniform contribution of foliage to total seedling biomass.

Table 3. Morphological characteristics of Scented, Thorn and Gray juniper seedlings

Species	Packaging	Nursery	Quantity	Diameter (mm)	Height (cm)	Root (g)	Stem (g)	Yaprak (g)	Whole plant	Stem/root	Leaf Ratio
Scented Juniper	Bare root	Eğirdir	20	2.00	34.10	1.44	1.45	1.51	4.40	1.01	0.34
Grey Juniper	Bare root	Malatya	20	1.98	60.25	1.47	1.46	1.52	4.46	0.99	0.34
Grey Juniper	Bare root	Niksar	20	1.28	44.45	1.23	1.36	1.49	4.07	1.11	0.37
Thorn Juniper	Bare root	Eğirdir	20	1.58	38.40	1.18	1.25	1.29	3.72	1.06	0.35
Grey Juniper	Bare root	Eğirdir	20	1.68	37.34	1.46	1.49	1.65	4.59	1.02	0.36
Grey Juniper	Tubular	Olcay	20	2.06	43.10	1.95	1.59	2.05	5.58	0.82	0.37
Grey Juniper	Tubular	Gülek	20	1.23	38.61	1.92	1.59	1.96	5.47	0.83	0.36
Grey Juniper	Tubular	K.hamam	20	1.70	40.14	1.30	1.35	1.37	4.02	1.04	0.34

Morphological Characteristics of Spruce (*Picea* spp.) Seedlings

Table 4 presents the morphological traits of *Picea* seedlings, including Eastern spruce (*Picea orientalis*), Western spruce, and Blue spruce (*Picea pungens*), sampled from different nurseries and packaging types. The data indicate notable differences in diameter, height, and dry weights of root, stem, leaf, and total biomass among species and treatments. Among bare-rooted seedlings, the Eastern spruce seedlings from Kurşunçal Nursery had the lowest mean root collar diameter (0.35 mm) and the shortest height (14.44 cm), while those from Kemerköprü Nursery showed significantly greater dimensions (diameter: 0.67 mm, height: 25.57 cm). The highest total dry weight (6.50 g) among all spruce samples was also observed in seedlings from Kurşunçal, primarily due to higher root and stem biomass. Enso-pot seedlings exhibited greater stem diameters overall, with the Western spruce seedlings from Of Nursery reaching 2.21 mm. In contrast, Blue spruce seedlings had a relatively moderate collar diameter (1.43 mm) but demonstrated the highest leaf dry weight (1.50 g), resulting in the highest leaf-to-total biomass ratio (0.39) across all spruce samples. Stem/root dry weight ratios varied between 0.98 and 1.06. The highest value was recorded in Eastern spruce seedlings from Kemerköprü Nursery, suggesting relatively greater shoot development compared to root biomass. Leaf biomass contribution to total dry matter ranged from 0.27 to 0.39, indicating species-specific differences in foliage allocation. These findings highlight that both species-specific traits and nursery practices, including packaging type, substantially influence the morphological development of spruce seedlings.

Table 4. Morphological characteristics of Eastern, Western and Blue spruce seedlings

Species	Packaging	Nursery	Quantity	Diameter (mm)	Height (cm)	Root (g)	Stem (g)	Leaf	Whole plant	Stem/root	Leaf Ratio
Eastern Spruce	Bare root	Kurşunçal	20	0.35	14.44	2.34	2.20	1.96	6.50	0.98	0.30
Eastern Spruce	Bare root	Kemerköprü	20	0.67	25.57	1.67	1.75	1.25	4.67	1.06	0.27
Western Spruce	Enso-pot	Of	20	2.21	28.20	1.30	1.36	1.19	3.85	1.05	0.31
Blue Spruce	Enso-pot	Of	20	1.43	23.75	1.19	1.20	1.50	3.88	1.01	0.39
Eastern Spruce	Enso-pot	Of	20	1.13	22.40	1.13	1.11	1.08	3.33	0.98	0.33
Eastern Spruce	Enso-pot	K.hamam	20	1.61	25.40	1.21	1.21	1.07	3.49	1.00	0.31

In Table 5, this study revealed that packaging type significantly affected the morphological traits of seedlings, as demonstrated by the results of the Tukey HSD multiple comparison test ($p < 0.05$). The packaging systems analyzed were bareroot, tubular, and Enso-pot types. A one-way ANOVA was conducted to evaluate the effects of packaging type on various morphological traits. Post-hoc comparisons using Tukey's HSD test were performed to detect group differences. The results are statistically interpreted as follows:

Diameter: There were statistically significant differences in seedling diameter among packaging types. Tubular and Enso-pot systems resulted in higher stem diameters, while bareroot seedlings had significantly lower values (1.36b). This could be attributed to improved nutrient and water availability in containerized systems. • A significant difference was detected among packaging types ($p < 0.05$). Tubular (1.67a) and Enso-pot (1.59a) formed a homogeneous group, while Bareroot (1.36b) was significantly lower. This suggests that container systems enhance diameter growth through improved water and nutrient availability.

Stem Biomass: The bareroot system showed the highest stem biomass (1.57a), followed by tubular (1.51b), while Enso-pot yielded the lowest values (1.22c). The dry conditions associated with bareroot systems may promote stem lignification. Significant differences observed ($p < 0.05$). Bareroot (1.57a) had the highest stem biomass, while Enso-pot (1.22c) was the lowest. Tubular (1.51b) fell in an intermediate group. Possibly, dry-root environments promote stem lignification in bareroot seedlings.

Height: Tubular containers produced the tallest seedlings (40.61a), outperforming both bareroot (36.36b) and Enso-pot (24.93c) types. The superior performance in height may be attributed to greater root volume and favorable aeration. Differences in height were statistically significant ($p < 0.05$). Ranking: Tubular (40.61a) > Bareroot (36.36b) > Enso-pot (24.93c). The superior height in tubular may be due to optimized substrate conditions.

Leaf Biomass: Leaf weight was highest in seedlings grown in tubular containers (1.80a), followed by bareroot (1.52b) and lowest in Enso-pot systems (1.21c). This suggests that container size and media composition may strongly affect foliage development. Leaf weight differed significantly across packaging types ($p < 0.05$). Tubular (1.80a) was significantly greater than Bareroot (1.52b) and Enso-pot (1.21c). Nutrient retention capacity and container size likely contribute to this effect.

Root Biomass: Significant differences in root biomass were found, with tubular packaging promoting the most robust root development (1.72a), followed by bareroot (1.54b) and Enso-pot (1.21c). Aeration and substrate composition likely contributed to this result. The tubular system yielded the highest root biomass (1.72a), followed by bareroot (1.54b), and Enso-pot (1.21c) ($p < 0.05$). This underlines the effect of container design on root development.

Total Biomass: When evaluating the overall biomass, tubular seedlings exhibited the highest values (5.02a), indicating superior holistic growth performance, followed by bareroot (4.63b) and Enso-pot (3.63c). A statistically significant order was found: Tubular (5.02a) > Bareroot (4.63b) > Enso-pot (3.63c) ($p < 0.05$). Tubular containers clearly support overall seedling biomass production. General Interpretation: Packaging type is a critical factor in seedling quality. The tubular system consistently outperformed other systems in nearly all morphological categories. These results suggest that container systems with better substrate structure and root space lead to improved seedling growth. Nevertheless, economic feasibility and field performance must also be considered when selecting nursery practices. These statistical data clearly demonstrate that the type of packaging has a direct and significant effect on seedling development. In particular, the tubular system exhibited significantly superior performance across all morphological variables. This is an important indicator of seedling quality and serves as a direct guide for selecting optimal packaging systems in forest nurseries.

Table 5. Tukey HSD results for morphological traits by packaging type

Tukey HSD ^{a,b,c}		Diameter			Tukey HSD ^{a,b,c}		Stem		
Packaging	Quantity	Subset			Packaging	Quantity	Subset		
		1	2	3			1	2	3
Bareroot	140	1.36b			Enso-pot	80	1.22c		
Enso-pot	60	1.59a			Tubular	60	1.51b		
Tubular	80	1.67a			Bareroot	140	1.57a		

Tukey HSD ^{a,b,c}		Height			Tukey HSD ^{a,b,c}		Leaf		
Packaging	Quantity	Subset			Packaging	Quantity	Subset		
		1	2	3			1	2	3
Enso-pot	80	24.93c			Enso-pot	80	1.21c		
Bareroot	140	36.36b			Bareroot	140	1.52b		
Tubular	60	40.61a			Tubular	60	1.80a		

Tukey HSD ^{a,b,c}		Root			Tukey HSD ^{a,b,c}		All plant		
Packaging	Quantity	Subset			Packaging	Quantity	Subset		
		1	2	3			1	2	3
Enso-pot	80	1.21c			Enso-pot	80	3.63c		
Bareroot	140	1.54b			Bareroot	140	4.63b		
Tubular	60	1.72a			Tubular	60	5.02a		

Analysis Results

Table 6 reveals significant variation in macro- and micronutrient accumulation in the leaf tissues of coniferous seedlings, shaped by species, nursery sites, and packaging systems. Key nutrients assessed include nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), and trace elements (Fe, Zn, Cu, Mn, Na). Nitrogen concentrations ranged from 11.59 g/1000 seedlings (Enso-pot, Eastern Spruce, Kızılcahamam) to 34.57 g/1000 seedlings (Bareroot, Grey Juniper, Malatya), with elevated N levels in Grey Juniper from Malatya and Niksar possibly indicating high uptake capacity or over-fertilization consistent with Reich et al. (1997), who emphasized nitrogen's role as a limiting growth factor in forest species. Phosphorus peaked in Eastern Spruce seedlings from Kurşunçal (Bareroot, 5.21 g/1000), likely due to moderate soil pH and improved P bioavailability. In contrast, lower P concentrations in Kızılcahamam and Gülek samples may result from P fixation in alkaline or calcium-rich soils, as noted by Kurtaran (2012). Potassium levels varied widely, from 11.42 g/1000 seedlings (Grey Juniper, Malatya) to 2.99 g/1000 seedlings (Eastern Spruce, Enso-pot, Kızılcahamam), reflecting both species-specific demands and packaging-related nutrient limitations, consistent with Moshki and Lamersdorf (2011). Scented Juniper seedlings from Eğirdir showed the highest Mg (5.78 g/1000) and Ca (32.85 g/1000) concentrations, while Eastern Spruce from Kemerköprü exhibited the lowest (Mg: 1.11, Ca: 2.67 g/1000).

These trends reflect potential antagonistic interactions, where excessive K suppresses Mg and Ca uptake, as described by Bergmann (1992). Among micronutrients, Fe levels were highest in Scented Juniper (8.86 g/1000), possibly due to acidic soils or Fe chelate use. Zn and Cu accumulation was greatest in tubular-grown Grey Juniper (Olçay Nursery; 0.37 and 0.90 g/1000 respectively), underscoring efficient nutrient retention in confined root environments (Landis et al. 2005). Mn content peaked in Eastern Spruce (Enso-pot) at over 0.6 g/1000 seedlings, likely influenced by mildly acidic substrates. Sodium concentrations remained low overall but reached 1.00 g/1000 seedlings in Eastern Spruce (Enso-pot, Kızılcahamam), possibly due to localized salinity or irrigation practices—conditions that, if unmanaged, may impair seedling vigor.

Table 6. Average amounts of plant nutrients in leaves of different species (g/1000 seedlings)

Nursery	Packaging	Species	Organ	N	P	K	Mg	Ca	S	Fe	Zn	Cu	Mn	Na
Eğirdir	Bareroot	Scented Juniper	Leaf	24.30	3.68	9.74	5.78	32.85	1.75	8.86	0.09	0.08	0.46	0.19
Malatya	Bareroot	Grey Juniper	Leaf	34.57	3.78	11.42	3.49	16.13	1.27	3.24	0.08	0.15	0.21	0.05
Niksar	Bareroot	Grey Juniper	Leaf	32.54	3.82	8.83	2.73	14.14	2.06	2.00	0.07	0.09	0.13	0.15
Eğirdir	Bareroot	Thorn juniper	Leaf	20.86	2.81	8.97	2.49	13.67	1.34	1.99	0.06	0.28	0.18	0.11
Eğirdir	Bareroot	Grey Juniper	Leaf	26.52	4.26	10.62	4.46	26.02	1.94	4.79	0.20	0.33	0.29	0.16
Olçay	Tubular	Grey Juniper	Leaf	25.36	3.94	10.14	4.49	24.22	2.50	2.41	0.37	0.90	0.23	0.10
Gülek	Bareroot	Grey Juniper	Leaf	15.08	2.19	4.66	4.27	45.65	0.63	2.94	0.20	0.32	0.19	0.14
K.hamam	Tubular	Grey Juniper	Leaf	15.86	2.52	6.78	2.67	19.66	0.86	2.33	0.08	0.07	0.18	0.25
Kurşunçal	Bareroot	Eastern Spruce	Leaf	30.43	5.21	9.33	2.82	11.73	2.51	3.70	0.12	0.16	0.53	0.21
K.köprü	Bareroot	Eastern Spruce	Leaf	24.59	3.42	5.65	1.11	2.67	1.57	2.58	0.16	0.10	0.47	0.06
Of	Enso-pot	Western Spruce	Leaf	19.22	3.89	7.65	1.47	8.35	1.50	1.54	0.16	0.13	0.42	0.45
Of	Enso-pot	Eastern Spruce	Leaf	23.63	4.49	7.42	2.18	8.48	1.96	3.39	0.11	0.15	0.66	0.12
Of	Enso-pot	Blue Spruce	Leaf	15.37	2.74	7.55	1.58	7.76	1.16	1.29	0.11	0.10	0.43	0.13
K.hamam	Enso-pot	Eastern Spruce	Leaf	11.59	2.58	2.99	1.68	17.56	0.51	1.73	0.10	0.12	0.45	1.00

Table 7 presents the average nutrient concentrations in the stem tissues of various coniferous seedlings cultivated under different nursery and packaging conditions. The data reveal considerable variation in both macro- (e.g., N, K, Ca, Mg) and micro-nutrient (e.g., Fe, Zn, Cu) accumulation, influenced by nursery practices, species, and packaging systems. *Eastern spruce* seedlings from Kurşunçal and Kemerköprü nurseries exhibited notably high nitrogen (27.61 g/1000 seedlings) and phosphorus (5.48 g/1000 seedlings) levels, indicating a more balanced or effective fertilization regime. In contrast, *juniper* seedlings from nurseries such as Gülek and Kızılcahamam showed low potassium and calcium but elevated iron and copper levels, possibly reflecting nutrient antagonisms—such as K-induced suppression of Ca and Mg uptake—previously reported by Bergmann (1992), or an imbalanced fertilization strategy. Nutrient accumulation in stem tissues is particularly important, as it plays a vital role in translocation dynamics and structural biomass formation.

Seedlings grown in tubular systems (e.g., Olcay and Kızılcahamam) generally exhibited higher concentrations of micronutrients, particularly Zn and Cu, likely due to enhanced nutrient retention and controlled release. Conversely, spruce seedlings cultivated in Enso-pot systems tended to accumulate fewer nutrients, suggesting limited nutrient availability or uptake efficiency in this packaging method.

These findings underscore the importance of tailoring fertilization strategies to species-specific nutrient demands and packaging-related dynamics. Fertilizer programs based on organ-level nutrient partitioning and nursery-specific conditions may significantly enhance seedling quality and field performance.

Table 7. Average amounts of plant nutrients in the stems of different species (g/1000 saplings)

Nursery	Packaging	Species	Organ	N	P	K	Mg	Ca	S	Fe	Zn	Cu	Mn	Na
Eğirdir	Bareroot	Scented Juniper	Stem	12.62	3.23	9.35	2.51	25.90	0.76	7.57	0.11	0.14	0.20	0.16
Malatya	Bareroot	Grey Juniper	Stem	20.64	2.92	9.44	4.02	42.94	1.44	16.30	0.25	0.46	0.44	0.16
Niksar	Bareroot	Grey Juniper	Stem	20.88	2.55	7.38	2.13	24.49	1.27	6.68	0.14	0.22	0.11	0.37
Eğirdir	Bareroot	Thorn juniper	Stem	14.90	3.00	9.39	2.05	22.71	1.36	6.34	0.08	0.16	0.21	0.18
Eğirdir	Bareroot	Grey Juniper	Stem	14.61	2.78	9.61	2.88	36.35	1.32	9.40	0.16	0.22	0.23	0.42
Olcay	Tubular	Grey Juniper	Stem	12.89	1.99	6.45	2.24	28.19	0.95	5.78	0.49	1.77	0.10	0.08
Gülek	Bareroot	Grey Juniper	Stem	7.32	0.90	2.59	2.37	66.26	0.76	11.96	0.24	0.38	0.18	0.16
K.hamam	Tubular	Grey Juniper	Stem	6.62	1.31	2.70	1.72	9.00	0.67	12.94	0.23	0.33	0.35	0.36
Kurşunçal	Bareroot	Eastern Spruce	Stem	27.61	5.48	7.94	2.14	6.38	1.83	3.41	0.15	0.15	0.73	0.26
K.köprü	Bareroot	Eastern Spruce	Stem	24.21	4.41	6.33	1.45	4.98	1.58	4.64	0.11	0.09	0.71	0.26
Of	Enso-pot	Western Spruce	Stem	23.84	4.21	8.78	1.59	3.35	1.32	0.71	0.13	0.09	0.30	0.08
Of	Enso-pot	Eastern Spruce	Stem	13.52	2.95	4.32	1.34	3.55	0.91	0.54	0.09	0.10	0.31	0.11
Of	Enso-pot	Blue Spruce	Stem	12.48	2.18	4.51	1.38	3.20	0.89	0.35	0.10	0.07	0.28	0.06
K.hamam	Enso-pot	Eastern Spruce	Stem	10.00	2.05	4.35	1.78	11.98	0.95	2.63	0.08	0.08	0.12	0.58

Table 8 presents nutrient accumulation in root tissues of various conifer species across different nurseries and packaging systems. The findings reveal that both species traits and cultivation conditions significantly influence macro- and micro-nutrient levels in roots. *Picea orientalis* seedlings from Kurşunçal nursery exhibited the highest nitrogen content (23.37 g/1000 seedlings), suggesting effective fertilization or favorable soil fertility. Conversely, seedlings in Enso-pot systems showed markedly lower N levels, indicating potential limitations in nitrogen availability. Potassium was highest in juniper seedlings from Malatya and Olcay (9.29 and 8.55 g/1000), while calcium peaked in Gülek (35.96 g/1000), implying a K–Ca antagonism (Bergmann 1992). Magnesium, crucial for root vigor, was also elevated in Malatya and Olcay (4.89 and 4.02 g/1000), likely due to the nutrient-retentive nature of tubular systems. Among micronutrients, iron levels were highest in Malatya and Gülek (21.81 and 20.02 g/1000), possibly due to soil pH or parent material. Zn and Cu levels were also higher in tubular-grown seedlings, highlighting the role of packaging in micronutrient uptake. In summary, nutrient accumulation in roots is shaped by species-specific physiology, nursery management, and packaging type. Customizing fertilization based on species needs, soil characteristics, and packaging systems is essential to optimize nutrient uptake and seedling quality.

Table 8. Average amounts of plant nutrients in the roots of different species (g/1000 seedlings)

Nursery	Packaging	Species	Organ	N	P	K	Mg	Ca	S	Fe	Zn	Cu	Mn	Na
Eğirdir	Bareroot	Scented Juniper	Root	14.39	3.07	8.55	2.85	22.87	0.98	7.04	0.07	0.15	0.28	0.32
Malatya	Bareroot	Grey Juniper	Root	14.73	2.86	9.29	4.89	37.55	2.23	21.81	0.29	0.35	1.16	0.45
Niksar	Bareroot	Grey Juniper	Root	12.27	2.32	8.55	2.27	23.69	0.81	4.44	0.06	0.08	0.10	0.54
Eğirdir	Bareroot	Thorn juniper	Root	11.78	2.57	7.83	3.00	24.53	1.03	7.86	0.09	0.21	0.33	0.31
Eğirdir	Bareroot	Grey Juniper	Root	14.56	2.67	6.48	2.42	22.83	0.91	6.13	0.21	0.44	0.19	0.43
Olcay	Tubular	Grey Juniper	Root	19.45	2.24	8.55	4.02	42.30	1.20	12.78	0.29	1.54	0.41	0.50
Gülek	Bareroot	Grey Juniper	Root	19.23	1.38	5.83	4.33	35.96	2.00	20.02	0.25	0.52	0.52	0.45
K.hamam	Tubular	Grey Juniper	Root	13.00	1.98	4.00	2.67	14.10	0.97	15.42	0.32	0.49	0.56	0.60
Kurşunçal	Bareroot	Eastern Spruce	Root	23.37	5.41	6.57	2.04	9.07	1.80	2.17	0.07	0.09	0.15	0.19
K.köprü	Bareroot	Eastern Spruce	Root	16.66	4.00	5.89	1.72	6.62	1.50	2.20	0.09	0.09	0.31	0.18
Of	Enso-pot	Western Spruce	Root	13.03	3.00	6.48	1.64	4.36	1.68	2.47	0.11	0.09	0.21	0.08
Of	Enso-pot	Eastern Spruce	Root	11.86	2.44	4.59	1.44	4.43	1.60	2.40	0.08	0.09	0.18	0.23
Of	Enso-pot	Blue Spruce	Root	11.33	2.05	5.20	1.77	3.32	1.35	2.30	0.11	0.09	0.16	0.10
K.hamam	Enso-pot	Eastern Spruce	Root	12.08	1.94	5.20	1.92	13.11	0.39	4.71	0.10	0.09	0.11	0.65

Nutrient Element Ratios in Leaves of Coniferous Species

The nutrient element concentration ratios in the leaves of coniferous species are given in Table 9. The values in the Table 9 are the element ratios calculated based on 100 units of N. In all nurseries and species, leaves contain 11-22 units of P, 27-49 units of K, 5-28 units of Mg, 11-303 units of Ca and 5-10 units of S for 100 units of N. When analyzed in terms of microelements, it was determined that the species with the highest amount of Fe in the leaf organs for 100 units of nitrogen was Fragrant Juniper from Eğirdir nursery with bare root packaging structure. This value was 1.46 for Zn, 3.54 for Cu, 3.87 for Mn and 8.72 for sodium.

Table 9. Nutrient concentration ratios in leaves of coniferous species averages

Nursery	Packaging	Species	Organ	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	S (%)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Na (ppm)
Eğirdir	Bareroot	Scented Juniper	Leaf	100	15	40	24	135	7	36	0,36	0.34	1.91	0.80
Malatya	Bareroot	Grey Juniper	Leaf	100	11	33	10	47	4	9	0.23	0.43	0.60	0.15
Niksar	Bareroot	Grey Juniper	Leaf	100	12	27	8	43	6	6	0.21	0.28	0.39	0.46
Eğirdir	Bareroot	Thorn juniper	Leaf	100	13	43	12	66	6	10	0.28	1.36	0.88	0.51
Eğirdir	Bareroot	Grey Juniper	Leaf	100	16	40	17	98	7	18	0.75	1.23	1.08	0.60
Olca	Tubular	Grey Juniper	Leaf	100	16	40	18	96	10	10	1.46	3.54	0.90	0.38
Gülek	Bareroot	Grey Juniper	Leaf	100	15	31	28	303	4	19	1.35	2.12	1.24	0.95
K.hamam	Tubular	Grey Juniper	Leaf	100	16	43	17	124	5	15	0.51	0.43	1.13	1.59
Kurşunçal	Bareroot	Eastern Spruce	Leaf	100	17	31	9	39	8	12	0.41	0.52	1.76	0.68
Kemerköprü	Bareroot	Eastern Spruce	Leaf	100	14	23	5	11	6	10	0.63	0.42	1.92	0.26
Of	Enso-pot	Western Spruce	Leaf	100	20	40	8	43	8	8	0.86	0.65	2.18	2.33
Of	Enso-pot	Eastern Spruce	Leaf	100	19	31	9	36	8	14	0.48	0.62	2.80	0.52
Of	Enso-pot	Blue Spruce	Leaf	100	18	49	10	50	7	8	0.71	0.62	2.77	0.86
K.hamam	Enso-pot	Eastern Spruce	Leaf	100	22	26	15	153	4	15	0.84	1.07	3.87	8.72

DISCUSSION

Afforestation is an essential ecological and economic investment, relying heavily on the quality of nursery-grown seedlings, which is largely shaped by fertilization practices. This study found that most nurseries apply fertilizers—especially nitrogen—at levels far above recommended doses, often disregarding their own soil analysis results. While nursery staff claim to follow these analyses, nutrient accumulation in seedlings suggests otherwise. This supports Reich et al. (1997), who stressed nitrogen's role as a limiting factor in tree growth and the need for precise fertilization.

Elevated nitrogen accumulation was associated with better morphological traits, particularly in tubular systems. Yet, as Kurtaran (2012) warned, conventional fertilization may be ineffective in calcareous or alkaline soils, where Ca^{2+} binds essential nutrients like P, Fe, Zn, and Cu, reducing their availability. In such cases, foliar feeding proves more effective, as observed in this study. Another key factor is soil organic matter. As noted by OGM (1986), its deficiency in Turkish nurseries limits microbial activity and nutrient retention. Akgül (1985) advocated for compost and green manure over synthetic inputs. Our findings support this, as nurseries using compost showed better alignment between applied fertilizers and plant uptake.

Bergmann (1992) highlighted nutrient antagonisms—particularly between K and Ca/Mg. Our data confirmed that excessive K suppressed Ca and Mg uptake, especially in potassium-rich nurseries, reducing seedling quality. Moshki and Lamersdorf (2011) reported foliar K levels of 0.6–1.6% in black locust. Our Juniper and Spruce samples fell within this range, although packaging systems like enso-pot and tubes showed lower K accumulation, likely due to reduced root-soil interaction.

Copper (Cu) concentrations also exceeded optimal levels (3–5 ppm per Proe 1994), possibly due to overapplication or specific soil conditions. Since excessive Cu is phytotoxic, this highlights the need for caution and monitoring. Nutrient accumulation patterns varied across organs, packaging systems, and nurseries, reflecting local environmental and

management conditions. Although nutrient-rich seedlings had better morphology, imbalances in K, Ca, Mg, and Cu could impair field performance. Therefore, fertilization must be tailored using regular diagnostics and organ-level feedback.

Finally, fertilizer input-output analysis showed widespread overapplication—especially NPK rates of 300–500 kg/ha/year—without adjustments for soil fertility. Nurseries like Eğirdir and Malatya exceeded uptake capacity, risking leaching. In contrast, Kemer Köprü and Kurşunçal showed more balanced practices.

In conclusion, improving nursery fertilization requires integrated nutrient management, organ-specific strategies, and sustainable soil amendments. These improvements are essential for producing high-quality seedlings and ensuring the long-term success of afforestation initiatives.

CONCLUSION

This study clearly demonstrates that fertilization practices in Turkish forest nurseries significantly influence both the morphological development and nutrient dynamics of *Juniperus* and *Picea* seedlings. A comprehensive evaluation of leaf, stem, and root nutrient accumulation data revealed that packaging systems, nursery-specific fertilization regimes, and species-specific physiological traits jointly shape the nutritional composition of seedlings. Notably, seedlings grown in tubular packaging systems exhibited superior morphological performance and more balanced nutrient profiles, suggesting a positive synergy between packaging design and nutrient uptake efficiency. Despite the critical importance of soil and tissue analyses, the findings indicate a disconnect between actual fertilizer applications and soil diagnostic data. In several nurseries, especially Eğirdir and Malatya, nitrogen-based fertilizers were applied in excessive quantities (often exceeding 300–500 kg/ha annually), without proper calibration to soil nutrient status or species needs.

This leads to inefficient nutrient use, potential toxicity (particularly Cu and K accumulation), and risks of environmental degradation due to nutrient leaching. Antagonistic interactions, especially between potassium and calcium/magnesium, were evident in the data and may impair seedling quality if unregulated. These findings highlight the necessity of transitioning from generic, high-input fertilization models to tailored, evidence-based feeding programs. Emphasis should be placed on integrating organic matter amendments, adopting slow-release or organomineral fertilizers, and applying foliar feeding in alkaline or nutrient-immobilizing soils. The study further underscores the importance of organ-specific nutrient analysis in guiding fertilization, rather than relying solely on soil data. Future nursery practices must incorporate adaptive fertilization strategies, linked to both species-specific nutrient demands and packaging type, to ensure high-quality, field-ready seedlings.

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