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ORIGINAL ARTICLE

Afforestation of the Biosphere Reserve of Iraq with Norway Spruce (*Picea abies*) and Austrian Pine (*Pinus nigra*) Seedlings: a Quantitative and Qualitative Study

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A R T I C L E I N F O

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A B S T R A C T

In the western Iranian provinces of Kurdistan and Kermanshah as well as the northern Kurdistan Region of Iraq, there is a hilly terrain called Hawraman. It's called the biosphere reserve of Iraq due to its high biodiversity. In this study, the planting of saplings of the Norway spruce (*Picea abies*) and Austrian pine (*Pinus nigra*) species was investigated quantitatively and qualitatively using 20 square sample plots with measurements of 12×12 meters that were randomly chosen in the selection area. The diameter of the collar, the overall height, the freshness of the seedlings, and the survival indicators were evaluated and measured in each sample plot. *Picea abies* outperformed *Pinus nigra* in terms of diameter and height, according to a statistical comparison between the two species in the same direction and slope (*Picea abies*: 1.34 cm and 0.32 m, *Pinus nigra*: 0.71 cm and 0.21 m). There was no significant difference in the percentage of survival between the two species. In terms of freshness, a comparison of these two species revealed that the *Picea abies* species had a higher level of freshness than the *Pinus nigra* species.

Introduction

The importance and position of forestry are made obvious by the country's growing population and the resulting rise in their needs, as well as the steadily declining area of its natural resources (Harpold *et al*., 2015; Forrester *et al*., 2018; Mahmoudi Meymand *et al*., 2022). Nobody can deny the significance of forestry in terms of influencing the climate, increasing rainfall, preventing erosion, producing industrial wood products, as well as the matter of forest tourism (Sun *et al*., 2015; Zhang *et al*., 2015; Malvar *et al*., 2017; Aryal *et al*., 2020). In these circumstances, forestry can be done while preserving the existing species and introducing

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new ones. The impact of forestry on human life is significant, including (Aboutalebi Jahromi and Hosseini Farahi, 2016; Kumar *et al*., 2019; Vahdati *et al.*, 2019; Mensah *et al*., 2021; Makheti Mutebi, 2022; Munanura and Kline, 2022; Igiebor *et al*., 2023):

-Livelihoods: Forests provide livelihoods and employment for millions of people, including forestry workers, timber producers, and tourism operators.

-Economic growth: The forestry sector contributes to economic growth through the production of forest products, such as timber and non-timber forest products, and the provision of ecosystem services.

-Food security: Forests provide food and resources, such as wild fruits and medicinal plants, to many rural communities and indigenous peoples.

-Health benefits: Forests provide many health benefits, including clean air and water, recreation opportunities, and stress reduction.

-Climate change mitigation: Forests play a crucial role in mitigating the effects of climate change by absorbing carbon dioxide from the atmosphere and storing it in biomass, soil, and wood products.

-Disaster risk reduction: Forests and their ecosystems can help reduce the risk of natural disasters, such as landslides, floods, and droughts, by conserving soil and water, reducing erosion, and stabilizing slopes.

Investigating quantity and quality in forestry is one of the key challenges since they complement one another and ideal objectives cannot be reached by focusing only on one of them (Asgarzadeh *et al*., 2014). Maintaining the quantity of forests is important for preserving biodiversity and habitat for a wide range of plant and animal species (Coates, 2017; Woo *et al*., 2020; Pfeiffer *et al*., 2021). They are important for attracting tourists, providing economic benefits to local communities while promoting conservation and sustainable use of forest resources (Theophilus, 2019; Malindzakova *et al*., 2021; Dutra *et al*., 2022). Forests have cultural, spiritual, and traditional importance to many communities and indigenous peoples around the world. Without taking quality into account, quantitative development will not be efficient in practice without being very expensive. On the one hand, focusing on quality will also take more time and result in less planted forest area (Asgarzadeh *et al.*, 2014; Storch *et al*., 2018; Kalinin, 2022). As a result, they must to be taken into account together in forestry-related planning and policy.

Norway spruce (*Picea abies*) is a species of evergreen coniferous tree that is native to Europe, particularly in the Nordic and Baltic regions. It is a tall, pyramidal tree that can grow up to 30 m in height, with a trunk up to 1.2 meters in diameter. The tree is characterized by its dark green needles, which are 2.5-7.5 cm long, and its cones, which are 7.5-15 cm in length (Zarei *et al*., 2017; Dincă *et al*., 2019). *Picea abies* is one of the most important tree species in Europe, both economically and ecologically. It is widely grown for its wood, which is used for construction, paper production, and other industrial purposes. In the wild, *Picea abies* is a dominant tree species in many of the forests of central and northern Europe, and it plays an important role in supporting biodiversity and regulating the local climate (Zarei *et al*., 2017). However, the species is also considered invasive in some areas, where it can displace native plant species and alter the ecological balance of ecosystems (Halmemies *et al*., 2022). Their seeds, also known as spruce tips, are small, tender, bright green buds that emerge from the branches in the spring. They are a traditional food source in Scandinavian countries, where they are used to make teas, syrups, and even beer (Cankar *et al*., 2005). Spruce tips have a citrusy, resinous flavor and are a rich source of vitamin C. They also contain antioxidants and other beneficial plant compounds. In recent years, spruce tips have gained popularity in the culinary world as a unique and flavorful ingredient in dishes such as salads, marinades, and sauces (Lučinskaitė *et al*., 2021).

Austrian pine (*Pinus nigra*) is a species of coniferous tree that is native to Europe and is widely cultivated in many other parts of the world. It is a large, long-lived tree that can grow up to 50 m in height, with a trunk up to 1.2 m in diameter. The tree is characterized by its long, blue-green needles, which are 7.5-12.5 cm long, and its cones, which are 5-10 cm in length (Dhaundiyal *et al*., 2021). *Pinus nigra* is an important tree species for many reasons. It is widely grown for its wood, which is used for construction, furniture, and paper production. In the wild, *Pinus nigra* is found in many of the forests of Europe, from the Mediterranean to the Baltic region. The tree is well-adapted to growing in a range of soil types and conditions and is also tolerant of fire and insect damage, making it an important species for reforestation and forest restoration efforts. Additionally, *Pinus nigra* is an important habitat for many wildlife species, providing food and shelter for birds and small mammals (Kolevska *et al*., 2020). Their seeds, also known as pine nuts, are small, elongated seeds that are enclosed in a hard shell. They have a sweet, nutty flavor and a creamy texture, and they are a popular ingredient in many cuisines around the world (Xi *et al*., 2019). Pine nuts are a good source of healthy fats, protein, and a variety of vitamins and minerals, including vitamin E, magnesium, and zinc. They are commonly used in dishes such as pesto, salads, and baked goods, and they are also a key ingredient in traditional dishes such as Italian pesto and Middle Eastern tabbouleh (Faiku *et al*., 2015).

In the central part of Latvia, Krisans *et al*. (2020) investigated the survival rate of *Picea abies* species in various plant groups. They discovered that *Picea abies* planted on the northern slope with a 15% slope had an average diameter and height of 0.5 cm and 0.4 m, respectively, at 25 years old, and were relatively comparable to the best *Picea abies* trees in Europe. Additionally, Muhamed *et al*. (2019) looked at the needle compatibility of exotic Kurdistan plants. They concluded that the *Pinus nigra* species had formed an excellent adaptability to the conditions of the region and had an average diameter and height in this area during the past 30 years of 0.32 cm and 0.11 m, respectively. In the experimental forest ‘Zwierzyniec’ near Ko´rnik, Hazubska-Przyby\l *et al*. (2016) conducted a quantitative and qualitative study on *Picea abies* forestry. They calculated the *Picea abies* trees' average diameter and height growth at 35 years of age to be 0.5 cm and 0.4 m, respectively. Additionally, this study's evaluation of the trees' quality revealed that the trees in this area are in good shape. Ruiz-Peinado *et al*. (2021) conducted a study in Slovakia, Poland, Latvia, Norway, Estonia, Lithuania, Germany, Denmark, and Sweden on the height growth rates of *Pinus nigra* (over 40 years) and *Picea abies* (over 30 years). They reported that *Pinus nigra* and *Picea abies* had average growth heights of 0.46 cm and 0.55 m, respectively. Additionally, they deduced that *Pinus nigra*, at 10 years old, and *Picea abies*, at 20 years old, both exhibit the highest annual height increase.

In this study, the planting of *Picea abies* and *Pinus nigra* saplings in Hawraman, also known as Avroman, which is located in the Kurdish region of eastern Iraq, was examined quantitatively and qualitatively.

Material and Methods

Hawraman, also known as Avroman, is a region located in the Kurdish part of eastern Iraq (Fig. 1). It is known for its unique cultural heritage and traditional way of life. The Hawraman region is located in the Zagros Mountains and is inhabited by Kurdish people who have their own distinct language, customs, and traditions (Biglari and Shidrang, 2019). The Hawraman region is known for its beautiful landscapes, including scenic valleys, rugged mountains, and pristine rivers. The area is also rich in cultural heritage, with many ancient ruins and monuments, such as the Hawraman Rock Castles, which are considered to be some of the most significant examples of rock-hewn architecture in the world.

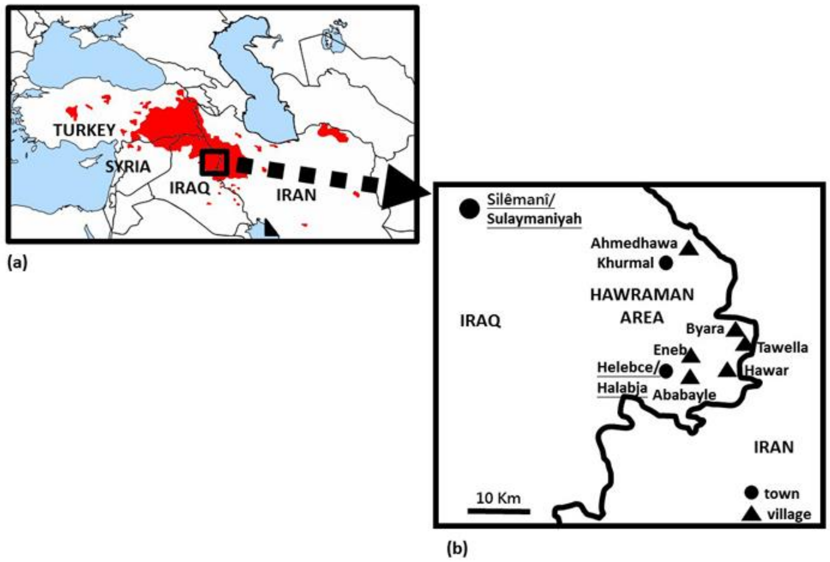

Fig. 1. Map of Hawraman region of Iraqi Kurdistan.

Hawraman Forest Reserve is located 25 kilometers northeast of Balkha along the Zagros Mountain range. This reservoir is located between latitude 35°12'12.5"- 35°12'45.3"N and longitude 46°08'56.3"- 46°09'53.7"E. The closest meteorological station to the research region, has compiled records for 20 years showing that the average annual rainfall is 391.6 mm, with minimum and maximum values ranging from 332.7 mm to 534 mm. According to this station, the average relative humidity is 63.4%. Average daily temperatures are 2.9^{o}C, average maximum temperatures are 12.7^{o}C, and average annual temperatures are 7.6^{o}C. With semi-deep to deep soil cover and a thick texture, this region contains high mountains with a flat top made of pyrrhotite and pyroxene andesite rocks. It is frequently linked to profile evolution and has forest and grazing cover. Table 1 provides information on the region's soil quality.

This reserve has a total size of 5364 ha, of which 225 ha are covered with chestnut forests, and *Picea abies* and *Pinus nigra* saplings that were planted in seven plots. Table 2 depicts where each component is located.

Table 1. A description of the soil type in the area under study.

Sample #	Depth (cm)	Saturation, %	Estimated Soluble Salts	Acidity (pH)	Organic carbon, %	Total Nitrogen, %	Absorbable phosphorus (ppm)	Absorbable potassium (ppm)	Soil texture
1	0-100	0.17	0.29	6.48	0.06	0.27	1.62	156.60	
2	0-100	46.59	0.40	0.77	0.05	0.31	0.23	275.40	
3	0-100	0.87	0.02	0.10	0.18	0.33	11.34	271.08	Silty loam
4	0-100	4.43	0.42	0.12	0.06	0.36	0.38	265.68	
5	0-100	21.22	0.02	0.90	0.05	0.35	3.60	274.32	

Table 2. Characteristics of forested areas in the study.

Plot number	Species	Area (ha)	Planting year	Hight above mean sea level (m)	Slope
1	Chestnut, *Pinus nigra*	49	2014	1530-1550	12
2	Chestnut	11	2014	1490-1500	7
3	*Pinus nigra*	35	2006	1550-1580	12-38
4	Chestnut, *Pinus nigra*	42	2010	1540-1550	23
5	Chestnut, *Pinus nigra*, *Picea abies*	70	2011	1540-1580	23
6	chestnut	4	2010	1530-1550	1
7	chestnut	14	2008	1530-1560	12

The current study was carried out in the Hawraman region of the Kurdish part of eastern Iraq in 2021. The seedlings were six years old when they were measured. It is important to note that *Pinus nigra* and *Picea abies* seedlings were planted at a distance of 3×3 m. In this study, a quantitative and qualitative comparison was made between two species of *Picea abies* and *Pinus nigra* in the same direction and slope (southern range, 23%) (Plot number 5). Hence, a network of 150×200 m that contained 20 sample plots was created and setup in a random, methodical manner. In the set of 20 samples, half were associated with *Pinus nigra*, while the other half were associated with *Picea abies*. The indices of seedling survival, total height, diameter of the collar, and freshness were examined and measured in each of these sample plots (12×12 m). When determining how fresh the needle seedlings were, the color of the needles was taken into account. Therefore, the following division was developed:

-Freshness grade 1: the color of the needles is deep green.

-Freshness grade 3: the color of the needles is pale green and inclined to yellow.

-Freshness grade 2: It is the middle of grades 1 and 3.

A t-test method was used to analyze quantitative data, such as the annual growth average diameter and height and survival percentage, while chi-squared test was used to analyze qualitative data, such as the vigor of the seedlings.

Results

Levene's test was used to confirm homogeneity of variances prior to comparing collar diameter growth, height growth, and survival rates between the two species. The t-test was then used to compare the two species quantitatively. The test's findings demonstrated a statistically significant difference between two species of *Picea abies*, with an average yearly diameter growth of the collar of 1.34±0.15 cm, and *Pinus nigra*, with an average annual diameter growth of 0.71±0.11 cm, at the 95% confidence level ($p<0.05$). The test's findings demonstrated a significant difference between the two species of *Picea abies*, with an average annual growth height of 0.32±0.001 m and *Pinus nigra*, with an average annual growth height of 0.21±0.008 m, at the 99% confidence level ($p<0.01$). The test's findings revealed that, at a 95% level of confidence, there is no statistically significant difference between the average of the *Picea abies* species (91.7±10.2%) and the average of the *Pinus nigra* species (57.4±15.3%) ($p>0.05$). At a confidence level of 99%, the findings of the chi-square test revealed a significant difference between the freshness of the two species of *Pinus nigra* and *Picea abies*. It is worth noting that the quality of saplings is closely related to the quality of the seeds used for propagation. The minerals present in the seeds of *Picea abies* and *Pinus nigra* may have contributed to the observed differences in the growth and freshness of the saplings. For example, seeds of *Picea abies* are known to contain essential minerals such as magnesium, calcium, potassium, and phosphorus, which are essential for plant growth and development. Similarly, seeds of *Pinus nigra* contain minerals such as manganese, copper, zinc, and iron, which may affect the growth and vitality of the saplings. Therefore, a more detailed analysis of the seed mineral content could provide further insight into the observed differences between the two tree species in this study.

Picea abies and *Pinus nigra* are two of the most important commercial tree species in Europe. They are widely used in forestry and as ornamental trees in parks and gardens. An agronomical analysis of these two species can provide valuable information about their growth and yield potential, as well as their ecological requirements.

Growth Habit and Morphology

Picea abies is a large coniferous tree that can grow up to 40 m tall. It has a pyramid-shaped crown with dense foliage and a straight trunk. The branches are slightly drooping and the bark is thin and scaly. *Pinus nigra* is a medium-sized tree that can grow up to 25 m tall. It has an irregular, rounded crown with sparse foliage and a crooked trunk. The branches are more or less horizontal and the bark is thick and dark brown.

Soil and Climate Requirements

Both *Picea abies* and *Pinus nigra* are relatively demanding in terms of soil and climate requirements. They grow best on deep, well-drained soils that are rich in nutrients and have a pH between 5.0 and 6.5. They prefer cool, humid climates with a mean annual temperature between 5 and 12°C and a mean annual precipitation between 600 and 1,500 mm.

Growth and Yield

Picea abies is a fast-growing species that can reach maturity in 80-120 years. It has a high potential for wood production, with a mean annual increment (MAI) of up to 20 m^3 ha^{-1}. It is also a good species for pulpwood production due to its long fibers and high cellulose content. *Pinus nigra* is a slower-growing species that takes 120-180 years to reach maturity. Its wood is of high quality and is used in construction, furniture, and joinery. Its MAI is between 10 and 15 m^3 ha^{-1}.

Pests and Diseases

Both *Picea abies* and *Pinus nigra* are susceptible to a range of pests and diseases. Some of the most common pests include bark beetles, needle cast fungi, and root rot pathogens. To minimize the impact of these pests and diseases, it is important to maintain healthy trees through proper management practices such as thinning and pruning.

In conclusion, an agronomical analysis of *Picea abies* and *Pinus nigra* reveals that these two species have similar soil and climate requirements, but differ in their growth habit, yield potential, and susceptibility to pests and diseases. Understanding these factors is important for selecting the appropriate species for a given site and for managing them effectively to maximize their growth and productivity.

Discussion

The comparison of these results with the results obtained by Muhamed *et al*. (2019), showed that the *Picea abies* species in this region in its early years, both in terms of diameter and height growth and in terms of survival percentage, has a good condition and was able to obtain initial compatibility. *Pinus nigra* can resist harsh, frigid winters and dry, rain-free summers, yet it also thrives in temperate climates. The *Pinus nigra* was superior in terms of growth rate and height when compared to the results of Ruiz-Peinado *et al*. (2021), but it did not have a satisfactory condition in terms of survival rate. There was no discernible difference between the two species in the percentage of survival. A comparison of two species' levels of freshness revealed that *Picea abies* is fresher than *Pinus nigra*. Overall, it can be said that *Picea abies* species have outperformed *Pinus nigra* in this region in terms of quantity and quality, and have established initial compatibility with the local circumstances. As previously noted, despite the fact that these two species were able to develop an initial compatibility with the local environment, the final decision in this case needs to be made after some time has passed.

Conclusions

Forestry in Iraq has a long history and has traditionally played an important role in the country's economy and environment. However, in recent decades, the forestry sector in Iraq has faced significant challenges, including deforestation, overgrazing, and the impacts of war and conflict. Despite these challenges, there have been efforts in recent years to revitalize the forestry sector in Iraq and to promote sustainable forestry practices. This has included the planting of new forests, the management of existing forests, and the development of policies and regulations to support the sustainable use of forest resources. *Picea abies* and *Pinus nigra* are two tree species commonly used in forestry. Both species are valued for their fast growth, durability, and versatility, and are used for a variety of purposes, including timber production, erosion control, and landscaping. The following recommendations are offered:

-It is preferable to make the final decision at a later age (for example, 30 years old) in order to assure the success rate of the adaptation of non-native plants planted in this region, so that in the event of success, forestry can be done on a larger scale.

-Performing corrective actions for forested regions, especially in the initial several years after planting, like clearing and mowing.

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Conflict of interests

The authors declare no conflicts of interest related to this manuscript.

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