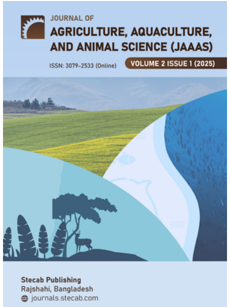

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Research Article

Assessing the Impact of Biotic and Abiotic Factors on Seedling Survival of *Pinus brutia* Ten. in a Semi-Arid Zone (Dohuk Region)

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About Article

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ABSTRACT

The process of natural regeneration in forests is crucial for the sustainability, growth, and stability of biodiversity. It is, therefore, a fundamental concern in forestry development. Natural regeneration is influenced by various biotic and abiotic factors. This study aimed to evaluate the survival and growth of *Pinus brutia* Ten. seedlings resulting from natural regeneration in uneven-aged mixed forests in Dohuk Governorate, located in northern Iraq. Field data were collected from 28 random samples during two inventory periods: the first in October 2022 and the second in October 2023. Data on tree and seedling species distribution within these samples were gathered and analyzed statistically to examine the relationships between the factors influencing the survival rate of *Pinus brutia* ten seedlings. The results indicated that the strongest biotic factors affecting seedling survival included the mean height of *Pinus brutia* trees, spacing between tree species, the number of all tree species, and the number of *Pinus brutia* mother trees. The corresponding correlation values were (-0.59), (-0.48), (0.3), and (-0.27), respectively. Among the abiotic factors, soil nitrogen content also had a notable influence, with a correlation value of (-0.33).

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1. INTRODUCTION

Pinus brutia Ten. is a naturally widespread tree species in northern Iraq. It is a slow-growing, heliophilous species that thrives in a wide range of soils and possesses the ability to withstand both relatively low and high temperatures, as well as resist drought to some extent (Abdullah & Mohammad, 2018). Forests cover approximately 31% of the land area and provide numerous environmental, economic, social, and aesthetic services. These include soil erosion prevention, watershed preservation, and mitigation of the effects of climate change (Alday & Martínez-Ruiz, 2022). Forests also serve as habitats for various species. Natural regeneration is crucial for preserving biodiversity, making it essential to increase awareness and efforts to protect, restore, and manage forests, especially in light of the global climate changes.

2. LITERATURE REVIEW

The process of natural regeneration is one of the key mechanisms for sustaining forests, promoting their growth, and enhancing the stability of biodiversity within the forest ecosystem, while also aiding in adaptation to climate change (Hammond *et al.*, 2020). Simultaneously, global forest restoration activities are on the rise, with afforestation being a central component of these projects. However, challenges arise due to continuous climate changes, the spread of invasive species, and human land-use practices. These factors contribute to uneven distribution patterns, which complicate the natural regeneration process. Climate is regarded as the most influential factor in determining species distribution. In unfavorable conditions, forests exhibit low efficiency in natural regeneration due to limited adaptability to obstacles, resulting in decreased forest productivity. To address these challenges, effective management strategies are required throughout all critical stages of the natural regeneration process. Such strategies will help develop sustainable forests that can provide essential environmental services and produce marketable products (Dey *et al.*, 2018). Ensuring a successful natural regeneration process is vital for forest sustainability, maintaining the dominance of desired species, and achieving other forestry goals. Natural forest regeneration has become a significant concern in recent decades (Clark *et al.*, 1999). Natural regeneration is influenced by various biotic factors, such as stand composition and structure, as well as abiotic factors, including environmental elements like climate and soil. These factors can either positively or negatively impact the stages of regeneration (Piffer *et al.*, 2022). Understanding the dynamics of the natural regeneration process is crucial for developing effective forest management plans (Saeed & Jassim, 2014; Al-Alaf *et al.*, 2009). This study, therefore, aims to investigate the effects of biotic and abiotic factors on the success of the natural regeneration process in uneven-aged, mixed natural forests in Dohuk Governorate, with a specific focus on *Pinus brutia* trees.

3. METHODOLOGY

The study was conducted in Dohuk Governorate, located in the northern part of Iraq. It is bounded by two latitudes (36° 18′ 12.64′′ - 37° 20′ 33.55′′) and two longitudes (42° 20′ 25.36′′ - 44° 17′ 40.50′′), with an elevation ranging from 430 to 2500 meters above sea level. The total vegetation area of Dohuk Governorate spans 3052 km², which constitutes 27.58% of the total area of the governorate (Applied Remote Sensing & GIS Center, 2015). The region is characterized by its mountainous terrain and relatively moderate climate. The soil composition is diverse, ranging from sandy soils in lowland areas to clay soils in valleys and agricultural regions. Based on its chemical composition, the soil is classified as salt-free (Buringh, 1960). The study samples were determined through an initial survey, which involved random selection from all locations. Each sample was square-shaped, with dimensions of 20 x 20 meters. A total of 28 samples were collected. Data was gathered for each of these samples, starting from the first inventory conducted in October 2022. The inventory involved taking measurements of every individual within the sample, including trees, shrubs, and seedlings, as well as all species present. The second inventory, conducted one year after the first, focused on measuring *Pinus brutia* seedlings. Field measurements classified *Pinus brutia* seedlings into three categories based on diameter and height: seedlings (less than 1.3 meters in height), juveniles (more than 1.3 meters in height and less than 12 cm in diameter at breast height), and trees (more than 1.3 meters in height and greater than 12 cm in diameter at breast height) (Oliver *et al.*, 1996). The variables measured in this study included the number of species identified in each sample. The species composition varied from one sample to another. In general, the species identified included *Pinus brutia, Quercus aegilops, Quercus infectoria, Prunus microcarpa, Juniperus oxycedrus, Crataegus azarolus, Paliurus spina-christi, Salix acmophylla, Populus euphratica*, and *Tamarix arceuthoides.* Additionally, the number of mother trees of *Pinus brutia* that produced cones and seeds within each sample was recorded. The average height of the trees was calculated by determining the arithmetic mean of all the heights within each sample, for each species separately. The following equation was used for the calculation:

$$\bar{h} = (\Sigma^{n}_{i=1} h_i)/n$$

Where:

$\bar{h}$ = height mean of trees for the sample (m),

h_i = height of trees (m),

n = number of trees in the sample, and the distances between trees and all tree categories and for all species for each sample were estimated from the following relationship:

$$S_p = \sqrt{(10000/N)}$$

Where:

S_p = distance between tree (m),

N = the total number of all individuals within a unit area of a hectare.

The nitrogen content of the soil was also determined using the Kjeldahl method at the central laboratory of the College of Agriculture and Forestry, University of Mosul. Additionally, calculations were performed for the *Pinus brutia* seedlings. This included counting the number of seedlings with a height of less than 1.3 meters recorded in the first inventory for each sample. These seedlings were marked during the initial inventory process. For the second inventory, the number of seedlings for each sample was calculated by revisiting the same samples and counting all seedlings that were marked during the initial inventory. Furthermore, the number of new seedlings resulting from seed germination (i.e., naturally regenerated seedlings) was recorded. The number of entering seedlings, or those that were not included in the first inventory but appeared in the second inventory, was estimated by subtracting the number of naturally regenerated seedlings from the total number of seedlings recorded in the second inventory. The number of seedlings lost between the first and second inventory was calculated using the following relationship:

$M = (N_1 + N_I) - N_2$

Where: M = the number of mortality seedling, N_1 = the number of seedlings in the first inventory, N_I = the number of ingrowth seedlings that entered the second inventory as a result of germination and were not included in the first inventory, N_2 = the number of seedlings in the second inventory that were marked in the initial inventory and return process. To it and account for it in the second inventory. The number of surviving seedlings between the first and second inventories was also calculated through the following relationship:

$S = N_1 - M$

Where:

S = the number of surviving seedlings during the first and second inventory,

N_1 = the number of seedlings in the first inventory (first year),

M = the number of mortality seedling.

3.1. Statistical Analysis

Several statistical methods were employed to analyze the data, interpret the results, and present them in a manner that aligns with the objectives of this study. Appropriate statistical techniques were chosen to explore and understand the nature of the relationships between the variables under investigation. Among these methods were those related to correlation and regression analysis.

Correlation is a statistical technique used to determine the strength and direction of the relationship between two independent variables. The relationship between any two variables can be analyzed by estimating a statistical measure called the Pearson correlation coefficient, denoted by (r). This measure is considered an unbiased estimator of the population correlation coefficient. Regression analysis is a widely used statistical method for determining the true relationship between two or more variables, as well as the direction of this relationship. In regression analysis, one variable is treated as the dependent variable, while the others are considered independent variables. The relationship between the variables is expressed in the form of a mathematical model, known as the regression equation, which can be used to estimate or predict the value of the dependent variable. The following statistical measures were used in this study: the coefficient of determination (R^2), standard error (S.E.), standardized residual (e_S), and the p-value, which measures the level of significance

4. RESULTS AND DISCUSSION

The process of natural regeneration is considered slow and complex due to the interaction between seedling establishment and survival success and the various site-specific factors. Seedling activity and growth are influenced by numerous biotic and abiotic factors, the most important of which are competition between the upper and lower crown canopies for natural resources, as well as climate and soil characteristics. These resources vary both spatially and temporally, and the species differ in their ability to efficiently use these resources and tolerate shortages (Pardos *et al.*, 2005). The variation in seedling growth, activity, and survival on a site is driven by the gradient in available natural resources, which results in patterns of seedling density and, subsequently, forest community composition alongside mature trees (Latham, 1992). The number of seedlings on the forest floor is often insignificant unless these seedlings reach an appropriate size and survive under the site's available natural resource conditions (Collet *et al.*, 2001). The stand composition, including species and structure, affects the local climate of the stand and governs the competition process for natural resources among individuals. These resources are also influenced by plant diversity within the stand and the ability of species to respond to resource availability, which, in turn, affects stand characteristics. Natural resources are crucial to the success and survival of seedlings, directly influencing the richness of the natural regeneration process (Smith-Martin *et al.*, 2017). The presence of large mother trees, the increased mean height of *Pinus brutia* trees, and the natural regeneration of *Pinus brutia* seedlings all impact seedling growth through competition for resources such as light, water, and nutrients. These large trees can stress young seedlings by obstructing light required for photosynthesis and limiting moisture and nutrients, ultimately hindering seedling growth and survival under these conditions (Pretzsch, 2014). While increasing spacing between tree species may reduce the number of surviving seedlings, this spacing can improve the environment and local climate for the trees and provide mutual protection for seedlings from harsh conditions such as high temperatures, extreme cold, or strong winds. These factors, including drought or frost stress, can reduce seedling survival chances. Moreover, tree species work together to conserve moisture by reducing evaporation when distances between them are kept sufficiently close, providing adequate moisture for better seedling growth (Canham & Uriarte, 2006). The nitrogen content in the soil also affects seedling survival. High concentrations of nitrogen can disrupt the balance of other nutrients, increase soil acidity, and promote the growth of herbs and bushes, which in turn increases competition with seedlings for natural resources. Additionally, excess nitrogen can disturb seedling growth by encouraging more vegetative growth at the expense of root development, making seedlings less resilient to environmental stresses such as drought and extreme cold, thereby reducing their survival rate (Aber, 2004). Given the importance of understanding forest tree dynamics and managing them effectively to enhance their vitality and sustainability, we analyzed data from 28 samples of *Pinus brutia* trees in an uneven-aged, mixed stand naturally growing in the Dohuk forests. Statistical analysis was performed using Statgraphics Centurion 18 to assess the correlations between biotic and abiotic factors affecting seedling survival. The strongest correlations, whether positive or negative, were identified from the correlation matrix, and these correlations are presented in Figure 1.

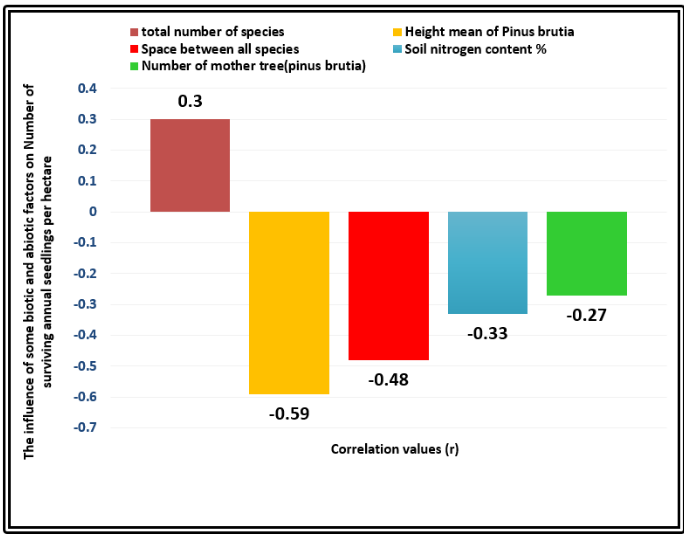

Figure 1. The correlation between the number of surviving seedlings of *Pinus brutia* Ten. And some biotic and abiotic factors

As shown in Figure 1, the most influential factors affecting the number of surviving *Pinus brutia* seedlings in uneven-aged mixed stands naturally growing in the Dohuk forests were biological factors, including the number of species in the sample, the mean height of the *Pinus brutia* trees, the spacing between trees of all species in the sample, and the number of mother trees of *Pinus brutia.* Among the abiotic factors, the most influential was the soil nitrogen content. Figure 1 illustrates that the number of species in the sample had a direct correlation with the number of surviving *Pinus brutia* seedlings, with a correlation value of 0.3. Additionally, an inverse correlation was found between tree spacing and the number of surviving seedlings, with a correlation value of -0.48. This suggests that as the distance between trees of all species per unit area increases, the survival rate of pine seedlings decreases. Both the number of species in the sample and the spacing between trees reflect the plant diversity within the stand. Species differ in their ability to grow and develop, particularly in the lower layers of the forest floor, due to biological interactions among species and their influence on the environment. These interactions affect seedling movement and ultimately contribute to stand formation (Flinn & Vellend, 2005). Competition for natural resources between seedlings and other species is reduced when the resource requirements of these species differ in terms of their utilization mechanisms and timing. The presence of biodiversity and moderate spacing improves soil properties and increases fertility through nutrient recycling, making the soil environment more suitable for seedling growth and development. Furthermore, these species are better adapted to climate change, offering mutual protection from extreme environmental factors such as high temperatures, extreme cold, or strong winds. This helps reduce evaporation and conserve moisture, thus enhancing seedling growth and survival (Wedin *et al.*, 1997). Figure 1 also shows an inverse correlation between the number of mother trees and the mean height of *Pinus brutia* trees and the number of surviving *Pinus brutia* seedlings, with correlation values of -0.27 and -0.59, respectively. This is because *Pinus brutia* seedlings are often clustered close to one another and near the mother trees, as seeds fall directly beneath these trees and germinate. Due to the high density of these seedlings, there is intense competition for natural resources, especially with the mother trees, which have larger crowns and root systems. As a result, the survival chances of these seedlings are reduced. Grubb *et al.* (1996) noted that the increased height and size of mother trees enable them to consume a significant portion of available natural resources, preventing sufficient light from reaching the seedlings. This inhibits seedling growth and decreases their survival and development. Additionally, Figure 1 reveals an inverse correlation between soil nitrogen content and the number of surviving *Pinus brutia* seedlings, with a correlation value of -0.33. This inverse relationship is explained by the fact that increased nitrogen concentrations have both direct and indirect effects on seedling growth and survival. Elevated nitrogen levels promote the growth of grasses and shrubs, which become stronger competitors for natural resources, particularly with naturally regenerated seedlings. Excess nitrogen can also alter soil properties, disrupt the balance of other nutrients, increase soil acidity, and interfere with the physiological processes of seedlings. Additionally, increased nitrogen levels can lead to a rise in pathogens and a decrease in microbial activity in the soil. These factors disrupt seedling growth by promoting excessive vegetative growth at the expense of root development, making seedlings more susceptible to environmental stresses and reducing their chances of survival (Bobbink, 2010). To better understand the relative effects of the biotic and abiotic factors associated with the number of surviving seedlings of *Pinus brutia* in uneven-aged mixed stands growing naturally in the Dohuk forests, we calculated the relative effects of these factors, as shown in Figure 2.

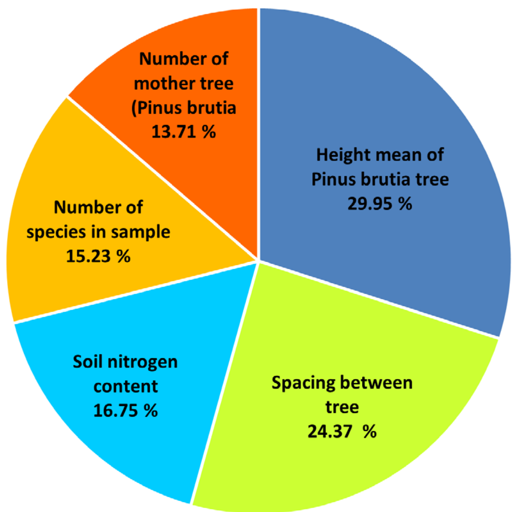

Figure 2. The relative effect of some biotic and abiotic factors on the number of surviving seedlings of Pinus brutia Ten.

Figure 2 shows a variation in the relative influence of several biotic and abiotic factors on the number of surviving *Pinus brutia* seedlings. Both the number of mother trees and the mean height of *Pinus brutia* trees had a significant impact on the number of surviving seedlings, with relative influence values of 13.71% and 29.95%, respectively. These factors reflect the extent of competition between *Pinus brutia* seedlings and mature trees. The seedlings tend to gather under the crown canopy of the mother trees and are located close to other *Pinus brutia* trees, which have larger diameters and heights. As a result, these trees hinder the seedlings' access to light necessary for photosynthesis. Furthermore, the development of the vegetative and root systems of the mature trees reduces the availability of moisture and nutrients in the soil, which affects seedling growth and makes them more vulnerable to mortality. This phenomenon is referred to as "self-thinning" within the stand (Burkhardt & Tome, 2012). Figure 2 also illustrates that both the number of species in the sample and the spacing between trees influenced the number of surviving seedlings, with relative effect values of 15.23% and 24.37%, respectively. These two factors impact the local environment and climate through biological interactions among species. They improve soil properties, facilitate nutrient recycling, reduce evaporation, and increase soil humidity, which, in turn, enhances soil fertility. Additionally, these factors help moderate temperature extremes (high heat and cold), providing protection for the seedlings of *Pinus brutia* and improving their growth and survival (Smith-Martin *et al.*, 2017). It is also evident from Figure 2 that soil nitrogen content affected seedling survival, with a relative influence value of 16.75%. This is because nitrogen levels, whether increased or decreased, influence various soil properties, including nutrient availability, acidity, and the activity of microorganisms and pathogens. Appropriate nitrogen concentrations can support seedling growth and development, while imbalances—either too high or too low—negatively affect seedling growth and, consequently, reduce their survival rate (Aber *et al.*, 1998).

4.1. Modeling the Number of Surviving Seedlings of *Pinus brutia* Trees

Modeling the survival of seedlings during the natural regeneration process in forest trees is a vital tool for sustainable forest management. These models provide valuable insights into the estimated number of seedlings that will survive and eventually mature into full-grown trees, thereby ensuring the continuity of forest cover. Such models are also crucial for forest managers and development officers, aiding in the decision-making process for managing natural resources and implementing developmental actions to support natural regeneration. For example, they can guide afforestation or thinning operations designed to reduce competition or help with voluntary cutting decisions that will facilitate seedling growth and survival. Additionally, these models play an essential role in evaluating biotic and abiotic factors that influence seedling development, which helps in identifying the optimal conditions for their growth. This understanding is crucial for preserving biodiversity by ensuring that species can regenerate, grow, and develop, thus enhancing ecosystem resilience to future climate change (Rank *et al.*, 2022). In this study, we modeled the number of surviving *Pinus brutia* seedlings in mixed-aged forests growing naturally in Dohuk forests. The analysis was conducted using data from 28 samples and the statistical program Statgraphics Centurion 18. The resulting equation for estimating the number of surviving seedlings, as the dependent variable, was based on two independent variables: the mean height of *Pinus brutia* trees and the spacing between all trees per unit area. The equation derived is as follows:

No. survival seedling (*Pinus brutia*) = 3761.66 - 414.33 * (Pinus height mean) - 1192.18 * (Space between all species)

Table 1. Variables of the equation for estimating the number of surviving seedlings of *Pinus brutia* with their statistical parameters.

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	3761.66	241.993	15.5445	0.0000
Pinus height mean	-414.33	65.604	-6.31562	0.0000
Space between all species	-1192.18	189.743	-6.28311	0.0000
R^2 = 0.80			S.E. = 336.883	

Upon reviewing the statistical measures in Table (1) for the equation, we observe that the independent variables—spacing between all trees per unit area and the mean height of all *Pinus brutia* trees (including seedlings, juveniles, and adult trees)—are integral to the model. These trees, being young and of uneven age, exhibit a dynamic, stable, and balanced structure. The number of seedlings is greater than that of juveniles, while juveniles are fewer than mature trees. This distribution reflects a continuous, balanced state of regeneration. The two independent variables, spacing and mean height, significantly influenced the estimation of surviving *Pinus brutia* seedlings. The coefficient of determination (R^2) reached 0.80, indicating a strong correlation and high explanatory power of the

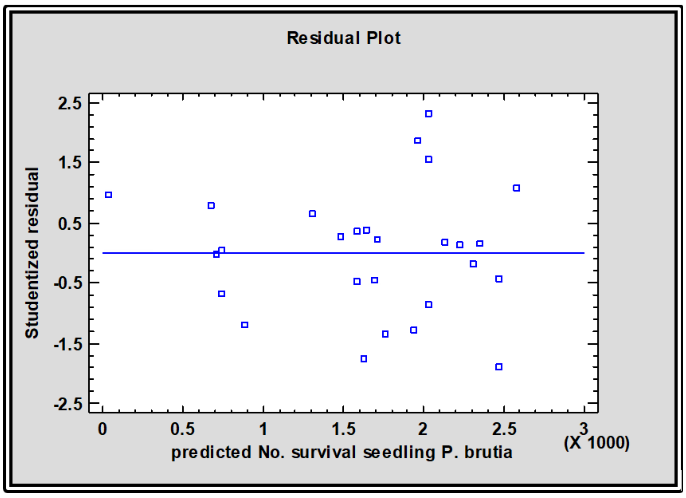

Figure 3. Distribution of random deviations between the real and estimated values of the numbers of surviving seedlings of Pinus brutia and the standard deviation.

independent variables. Additionally, the P-value was found to be less than 0.05, which confirms a highly significant relationship between the independent variables, with a confidence level exceeding 95%. To further ensure the validity of the model and check for potential autocorrelation in the residuals of the independent variables, a residual analysis was conducted, as shown in Figure 3.

From Figure 3, we observe that the data points are randomly distributed along the line representing the zero point. This indicates that there is no autocorrelation between the observations for the various variables in the equation. Consequently, the equation can be reliably used to estimate the number of surviving *Pinus brutia* seedlings per unit area in uneven-age mixed stands growing naturally in the forests of Dohuk.

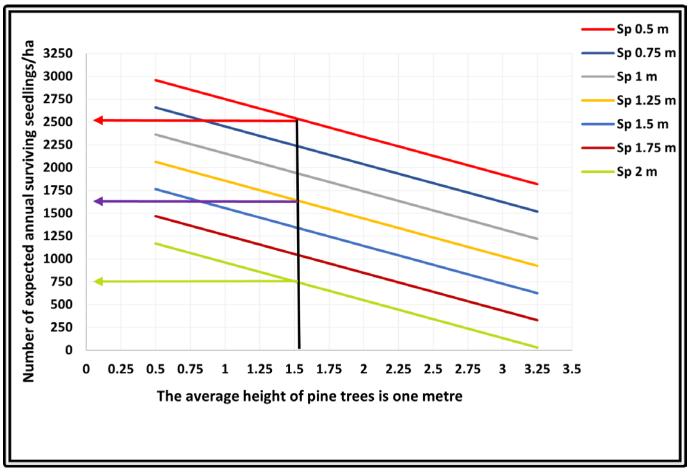

Figure 4. Expected number of surviving seedlings of Pinus brutia Ten./ha

The data used to establish the relationship between the independent variables and the dependent variable in the model is shown in Figure 4.

Figure 4 illustrates that an increase in the height mean of *Pinus brutia* trees and the spacing between trees for all species per unit area results in a decrease in the number of surviving *Pinus brutia* seedlings. For instance, when the average height of *Pinus brutia* trees is 1.5 meters and the spacing between trees per unit area is 2 meters, the number of surviving seedlings is estimated to be 750 seedlings per year per hectare. However, when the spacing between trees is reduced to 1.25 meters with the same tree height, the number of surviving seedlings increases to 1,625 seedlings per year per hectare. Further, when the spacing between trees is reduced to 0.5 meters, the number of surviving seedlings increases to 2,500 seedlings per year per hectare at the same tree height. This shows that as the average height of *Pinus brutia* trees increases, competition for natural resources intensifies, which in turn hinders seedling growth, making them more susceptible to death and failure (Burkhardt and Toome 2012). Conversely, reducing the spacing between trees per unit area helps to modify the ecosystem within the stand by improving soil properties, reducing evaporation, and increasing humidity due to the biological interactions among species. These processes protect the seedlings from environmental stresses, thereby creating more favorable conditions for the growth and survival of *Pinus brutia* seedlings (Smith-Martin *et al.* 2017).

5. CONCLUSIONS

This study highlights the influence of various biotic and abiotic factors on the survival of *Pinus brutia* seedlings. Among the key factors found to affect seedling survival were the mean height of *Pinus brutia* trees, tree spacing, the number of species present, and the number of mother trees. To enhance the survival rate of *Pinus brutia* seedlings, certain developmental practices, such as thinning or pruning *Pinus brutia* trees, can be implemented. These practices would reduce competition for natural resources between trees and seedlings, ultimately benefiting seedling growth. Additionally, introducing other tree species that can improve soil and environmental conditions will promote the survival and development of *Pinus brutia* seedlings by increasing biodiversity in the forest stand.

REFERENCES

Abdullah, M. O., & Mohammad, M. Y. (2018). Effect of Organic Fertilizer Pow Humus and Two Seaweed Extracts Hypra Tonic and Alga 300 on Growth of *Pinus brutia* Ten. and Pinus pinea L. Seedlings. *Mesopotamia Journal of Agriculture, 64*(2), 181. https://doi.org/10.33899/magrj.2018.161456

Aber, J., McDowell, W., Nadelhoffer, K., Magill, A., Berntson, G., Kamakea, M., McNulty, S., Currie, W., Rustad, L., & Fernandez, I. (1998). Nitrogen saturation in temperate forest ecosystems: Hypotheses revisited. *BioScience, 48*(11), 921–934. https://doi.org/10.2307/1313296

Aber, J. D., & Magill, A. H. (2004). Chronic nitrogen additions at the Harvard Forest (USA): The first 15 years of a nitrogen saturation experiment. *Forest Ecology and Management, 196*(1), 1-5. https://doi.org/10.1016/j.foreco.2004.03.009

Al-Allaf, M. Y. S., Younis, M. S., & Mahmood, M. A. (2009). Yield Prediction Equation for *Pinus brutia* Ten. Plantation in Sinjar Region. *Journal of Mesopotamia Agriculture, 37*(2). https://doi.org/10.33899/magrj.2009.27417

Alday, J. G., & Martínez-Ruiz, C. (2022). Expansion of naturally regenerated forest. *Forests, 13*(3), 456. https://doi.org/10.3390/f13030456

Applied Remote Sensing & GIS Center. (2015). *Mapping and estimating vegetation coverage in Iraqi Kurdistan region using remote sensing and GIS.* University of Zakho.

Bobbink, R., Hicks, K., Galloway, J., Spranger, T., Alkemade, R., Ashmore, M., Bustamante, M., Cinderby, S., Davidson, E., Dentener, F., Emmett, B., Erisman, J. W., Fenn, M., Gilliam, F., Nordin, A., Pardo, L., & de Vries, W. (2010). Global assessment of nitrogen deposition effects on terrestrial plant diversity: A synthesis. *Ecological Applications, 20*(1), 30–59. https://doi.org/10.1890/08-1140.1

Buringh, P. (1960). *Soils and soil conditions in Iraq.* Ministry of Agriculture.

Burkhart, H. E., & Tomé, M. (2012). Quantifying stand density. *Modeling Forest Trees and Stands*, (pp. 175-200).

Canham, C. D., & Uriarte, M. (2006). Analysis of neighborhood dynamics of forest ecosystems using likelihood methods and modeling. *Ecological Applications, 16*(1), 62–73. https://doi.org/10.1890/04-1481

Clark, J. S., Beckage, B., Camill, P., Cleveland, B., HilleRisLambers, J., Lichter, J., ... & Wyckoff, P. (1999). Interpreting recruitment limitation in forests. *American Journal of Botany, 86*(1), 1-16. https://doi.org/10.2307/2656950

Collet, C., Lanter, O., & Pardos, M. (2001). Effects of canopy opening on height and diameter growth in naturally regenerated beech seedlings. *Annals of Forest Science, 58*(2), 127-134. https://doi.org/10.1051/forest:2001112

Dey, D. C., Knapp, B. O., Battaglia, M. A., Deal, R. L., Hart, J. L., O'Hara, K. L., Schweitzer, C. J., & Schuler, T. M. (2018). Barriers to natural regeneration in temperate forests across the USA. *New Forests, 50*(6), 11–40. https://doi.org/10.1007/s11056-018-09694-6

Flinn, K. M., & Vellend, M. (2005). Recovery of forest plant communities in post-agricultural landscapes. *Frontiers in Ecology and the Environment, 3*(5), 243-250. https://doi.org/10.1890/1540-9295(2005)003[0243:ROFPCI]2.0.CO;2

Grubb, P. J., Lee, W. G., Kollmann, J., & Wilson, J. B. (1996). Interaction of irradiance and soil nutrient supply on growth of seedlings of ten European tall-shrub species and Fagus sylvatica. *Journal of Ecology, 84*(6), 827-840. https://doi.org/10.2307/2960555

Hammond, M. E., Pokorný, R., Okae-Anti, D., Gyedu, A., & Obeng, I. O. (2021). The composition and diversity of natural regeneration of tree species in gaps under different intensities of forest disturbance. *Journal of Forestry Research, 32*(1), 1-7. https://doi.org/10.1007/s11676-020-01269-6.

Latham, R. E. (1992). Co-occurring tree species change rank in seedling performance with resources varied experimentally. *Ecology, 73*(6), 2129–2144. https://doi.org/10.2307/1941461

Oliver, C. D., Larson, B. C., & Oliver, C. D. (1996). *Forest stand dynamics* (Vol. 520). New York: Wiley.

Pardos, M., Del Castillo, J. R., Cañellas, I., & Montero, G. (2005). Ecophysiology of natural regeneration of forest stands in Spain. *Forest Systems, 14*(3), 434-445. https://doi.org/10.5424/srf/2005143-00939

Piffer, P. R., Rosa, M. R., Tambosi, L. R., Metzger, J. P., & Uriarte, M. (2022). Turnover rates of regenerated forests challenge restoration efforts in the Brazilian Atlantic forest. *Environmental Research Letters, 17*(4), 045009. https://doi.org/10.1088/1748-9326/ac5ae1

Pretzsch, H., Biber, P., Schütze, G., Uhl, E., & Rötzer, T. (2014). Forest stand growth dynamics in Central Europe have accelerated since 1870. *Nature Communications, 5*, 4967. https://doi.org/10.1038/ncomms5967

Rank, R., Maneta, M., Higuera, P., Holden, Z., & Dobrowski, S. (2022). Conifer Seedling Survival in Response to High Surface Temperature Events of Varying Intensity and Duration. *Frontiers in Forests and Global Change, 4*, 731267. https://doi.org/10.3389/ffgc.2021.731267

Saeed, M., & Jasim, A. (2014). Distance-Dependent Competition Indices for Predicting Growth of *Pinus brutia* Ten. Trees in Zaweeta Region. *Mesopotamia Journal of Agriculture, 42*(1). https://doi.org/10.33899/magrj.2014.88449.

Smith-Martin, C. M., Gei, M. G., Bergstrom, E., Becklund, K. K., Becknell, J. M., Waring, B. G., Werden, L. K., & Powers, J. S. (2017). Effects of soil type and light on height growth, biomass partitioning, and nitrogen dynamics on 22 species of tropical dry forest tree seedlings: Comparisons between legumes and nonlegumes. *American Journal of Botany, 104*(3), 399–410. https://doi.org/10.3732/ajb.1600276

Wedin, D. A., Reich, P. B., Ritchie, M. E., Siemann, E., Tilman, D., & Knops, J. M. H. (1997). The influence of functional diversity and composition on ecosystem processes. *Science, 277*(5330), 1300–1302. https://doi.org/10.1126/science.277.5330.1300