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The effect of some competition indices depends on distance in diameter growth for *Pinus brutia* Ten. in Dohuk governorate.

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ABSTRACT

The effectiveness of competition in predicting the increase in diameter (DI) for Brutian pine trees (Pinus brutia Ten.) in Duhok Governorate, northern Iraq latitude *(37° 20′ 33.55″ - 36° 18′ 12.64″)*, longitude *40.50″ - 42° 20′ 25.36″) (44° 17′*was evaluated. The results indicated that competition is a significant factor in determining growth in these forests. That competition varies locally, with variable tree densities and relatively complex tree structures, creating heterogeneous conditions. This study was conducted at different and varied sites regarding climate and topography by selecting three distinct density levels, from each of which (10) circular samples with a radius of (11 m) were chosen. From these, various data and geographical coordinates were collected including (D, height, CH, crown radius, BA, number of trees per unit area, distance between competing trees) and the target tree, and then developing several equations representing the relationship between competition indices based on distance as an independent variable and diameter growth as a dependent variable. The R^2 values for the low-density level were (CI6 = 0.21, CI7 = 0.42, CI8 = 0.21, CI9 = 0.42). For the medium-density level, they were (CI6 = 0.45, CI7 = 0.43, CI8 = 0.83, CI9 = 0.43). For the high-density level, they were (CI6 = 0.24, CI7 = 0.69, CI8 = 0.70, CI9 = 0.83).

***Keywords*: ** Pinus brutia، competition index ، diameter growth، densities، Atrush forest**.**

INTRODUCTION

Forests constitute critical ecosystems of paramount significance to humanity, serving as the primary source of oxygen production and air purification by mitigating toxic gases and pollutants, notably carbon dioxide. Beyond their ecological role, forests are vital for supplying timber and derivative products, such as cellulose pulp, among others. They also provide protective functions, including soil conservation against erosion and degradation, alongside contributing to tourism-related benefits. Furthermore, forests represent a key livelihood resource for adjacent communities, with many relying on them for sustenance, nutrition, and natural grazing for livestock [1]

The native range of the Brutia pine (*Pinus brutia* Ten.) encompasses the Mediterranean Basin, with its distribution spanning Turkey, Iran, Georgia, Uzbekistan, northern Iraq, western Syria, Lebanon, Cyprus, and Palestine. This species thrives in nutrient-poor soils, rendering it one of the most dominant timber-producing species in the Mediterranean region, where it attains considerable heights. Its adaptability to diverse environmental conditions enables it to flourish in challenging habitats. The fire-resistant properties of its cones further enhance its suitability for cultivation in fire-prone regions [2] Pinus brutia serves as a primary source of timber, integral to various wood-based industries, including the production of cellulose pulp [3]

This study identified four distinct relationships examining the influence of the independent variable, defined as the distance-dependent competition coefficient, on the dependent variable, represented by diameter growth, which was the primary focus of the research. The equations delineating the competition indices are presented below:

1- $CI_6 = \sum_{i=1}^{n} \mathrm{hi}/(\mathrm{h} * \mathrm{disti})$ [4]
2- $CI_7 = \sum_{i=1}^{n} \arctan(\frac{\mathrm{di}}{\mathrm{disti}})$ [5]
3- $CI_8 = \sum_{i=1}^{n} \left(\frac{di}{d}\right) * \arctan(\frac{di}{disti})$ [5]
4- $CI_9 = \sum_{i=1}^{n} \arctan(\mathrm{hi} * \mathrm{disti})$ [5]

From the competition indices mentioned above, it is observed that they varied in terms of the independent variables used in their formulation. In the first and fourth indices, tree height was utilized, whereas the diameter at breast height was employed in the second and third competition indices

Materials and Methods

Study Area

The study was conducted in Duhok Governorate, located in the northern part of Iraq, situated between latitudes 36°18′12.64″ and 37°20′33.55″ N and longitudes 42°20′25.36″ and 44°17′40.50″ E, at an elevation ranging from 430 to 2,500 meters above sea level. The vegetative cover of Duhok Governorate spans 3,052 km², representing 27.58% of the governorate's total area [6] Duhok is characterized by its mountainous terrain and relatively moderate climate. Its climate resembles that of the Mediterranean Basin, with low temperatures and relatively high humidity during winter, accompanied by moderate annual rainfall ranging from 600 to 800 mm. Summers, however, are hot and dry with elevated temperatures [7].

Sample selection and Data collection

Study samples were collected from several sites in Zawita Atrush , and Siyara Tika and Ashawa, affiliated with the Sarsank. These sites were selected following preliminary surveys of Duhok Governorate, chosen for their natural forests with diverse vegetative cover and evidence of natural regeneration processes. Additionally, these sites were distinguished by their varied climatic and topographical characteristics.

Field work

The study samples were determined through a preliminary survey across all sites. Each sample plot was circular in shape with a radius of 17.90 meters. Within each plot, three representative trees were selected within a radius of 11 meters. Field measurements for each sample plot included data on the representative tree (coordinates, diameter, height, crown width, and distances between the representative tree and neighboring trees within the 11-meter radius). These measurements were applied to the three representative trees within each sample plot. Additionally, measurements were taken for all trees present within the sample plot, and these trees were marked using paint for identification.

Tree Height (H)

It is the vertical distance between the base of the tree at ground level and the highest point at the top of the tree, measured in meters. Tree heights were measured using the Haga device, and the following relationship was used to determine the height [8].

$$\boldsymbol{H = p\left|\frac{\alpha_T \mp \alpha_B}{\alpha_\rho \mp \alpha_B}\right|}$$

Tree diameter (D)

The diameter is the straight line connecting the two edges of the tree trunk's circumference, passing through its center. Tree diameters were measured using a measuring tape. For trees taller than 2 m, the diameter was measured at a height of 1.3 m above ground level, a measurement referred to as the Diameter at Breast Height (DBH). When using the measuring tape, the circumference of the tree trunk is obtained, and to calculate the diameter, the following equation is applied [10].

$$\boldsymbol{D = \frac{C}{\pi}}$$

Estimation of Diameter Growth Over the Past Five Years

The diameter is a critical variable in assessing tree growth and varies with stand density. In high-density stands, longitudinal growth tends to predominate at the expense of diameter growth, whereas in low-density stands, noticeable diameter growth occurs at the expense of longitudinal growth [11] The diameter growth over a five-year period was calculated using the following equation [12].

$G5y = -2.40649-0.0566836*D+1.66948*Ln(D)+0.000164516*D^2$

Low density

$R^2 = 0.15$ $\qquad$ $CAI\ d = 0.239 + 0.016\ CI5$

$CAI\ d = 0.181 + 0.022\ CI7$ $\qquad$ $R^2 = 0.42$

Middle density

$CAI\ d = 0.262 + 0.041\ CI2$ $\qquad$ $R^2 = 0.14$

$CAI\ d = 0.053 + 0.028\ CI8$ $\qquad$ $R^2 = 0.83$

Height density

$CAI\ d = 0.218 + 0.031\ CI6$ $\qquad$ R2= 0.24

$AI\ d = 0.042 + 0.0152\ CI9$ $\qquad$ R2= 0.83

Results and discussion

Impact of Competition Indices on Diameter Growth Across Three Stand Densities

Diameter growth of individual trees is influenced by a variety of factors, including genetic traits, diameter at breast height (D.B.H.), total height, age, crown size, competition indices, site factors, stand density, stand age, and the number of stems per sample plot [12].

Stand density, defined as the number of trees per unit area, significantly affects tree characteristics such as diameter, height, basal area, and volume. In this study, data were collected from three stand density levels low, medium, and high with thirty sample plots for each density category. Statistical software, including Excel, SPSS V27, and R-Studio, was used to analyze the data and derive the equations.

The effects of competition indices on diameter growth across the three density levels were investigated to determine which index had the most significant impact on the dependent variable (diameter growth). The results are presented below:

1. Competition Index CI6: The strongest relationship between the competition index (CI) and diameter growth was observed at medium density, with a coefficient of determination (R^2) of 0.45. In contrast, the R^2 values were 0.21 for low density and 0.24 for high density. (Table1) illustrates the analysis of the independent variables (CI6) in relation to the dependent variable (Current Annual Increment in Diameter, CAI_d).

(Table1): Analysis Values of the Independent Variables (CI6) in Relation to the Dependent Variable (CAI_d)

Influencing Variable	Path Direction	Dependent Variable	Estimate	Standard Error (SE)	t-value (Calculated)	t-value (Statistics)
$\hat{\beta}_0$	→	CAI d	0.214	0.020	10.543	2.04
CI6	→		0.101	0.037	2.758	

2. The Competition Index CI7 exhibited the greatest influence on diameter growth in high-density stands, with a coefficient of determination (R^2) of 0.69. In contrast, the R^2 values were 0.42 for low-density stands and 0.43 for medium-density stands.

(Table2) presents the analysis values of the independent variables (CI7) in relation to the dependent variable (Current Annual Increment in Diameter, CAI_d).

Influencing Variable	Path Direction	Dependent Variable	Estimate	Standard Error (SE)	t-value (Calculated)	t-value (Statistics)
$\hat{\beta}_0$	→	CAI d	0.181	0.020	8.878	2.04
CI6	→		0.022	0.005	4.586	

3. Competition Index CI8 the strongest relationship between the Competition Index (CI) and diameter growth was observed at medium density, with a coefficient of determination (R^2) of 0.83. In comparison, the R^2 values were 0.21 for low-density stands and 0.70 for high-density stands. (Table3) presents the analysis values of the independent variables (CI8) in relation to the dependent variable (Current Annual Increment in Diameter, CAI_d).

(Table3): Analysis Values of the Independent Variables (CI8) in Relation to the Dependent Variable (CAI_d) to the Dependent Variable (CAI_d)

Influencing Variable	Path Direction	Dependent Variable	Estimate	Standard Error (SE)	t-value (Calculated)	t-value (Statistics)
$\hat{\beta}_0$	→	CAI d	0.236	0.015	15.371	2.04
CI6	→		0.009	0.003	2.708	

4. Competition Index CI9 the strongest relationship between the Competition Index (CI) and diameter growth was observed at high density, with a coefficient of determination (R^2) of 0.83. In comparison, the R^2 values were 0.42 for low-density stands and 0.43 for medium-density stands. (Table 4) presents the analysis values of the independent variables (CI9) in relation to the dependent variable (Current Annual Increment in Diameter, CAI_d).

(Table 4): Analysis Values of the Independent Variables (CI9) in Relation to the Dependent Variable (CAI_d)

Influencing Variable	Path Direction	Dependent Variable	Estimate	Standard Error (SE)	t-value (Calculated)	t-value (Statistics)
$\hat{\beta}_0$	→	CAI d	0.171	0.022	7.628	2.04
CI6	→		0.021	0.005	4.555	

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تأثير بعض دلائل التنافس المعتمدة على المسافة في النمو القطري لأشجار الصنوبر البروتي في محافظة دهوك.

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الخلاصة

تم تقييم فعالية المنافسة للتنبؤ بالزيادة في القطر (***DI***) لاشجار الصنوبر البروتي ***Pinus brutia Ten.*** في محافظة دهوك شمال العراق. أشارت النتائج إلى أن التنافس عامل مهم لنمو وتطور الأشجار في الغابات وأن التنافس يختلف محليًامع وجود الكثافات المختلفة إضافة الى تركيبة المشاجر المعقدة نسبيا اذ يخلق ذلك تركيبا غير متجانسا. أجريت هذه الدراسة في مواقع مختلفة ومتباينة من حيث المناخ والطبوغرافية عن طريق اختيار ثلاث كثافات متباينة من كل كثافة ثم اختيار (10) عينات دائرية الشكل نصف قطرها (11م) ومنها تم اخذ البيانات المختلفة والاحداثيات الجغرافية وقد تضمنت البيانات المقاسة القطر والارتفاع وارتفاع مركز التاج ونصف قطر التاج والمساحة القاعدية وعدد الأشجار في وحدة المساحة والمسافة بين الأشجار المنافسة والشجرة الدالة وثم إيجاد عدة معادلات تمثل العلاقة بين دلائل التنافس المعتمدة على المسافة كمتغير مستقل والنمو في القطر كمتغير معتمد . وكانت قيم R^2 للخفيفة الكثافة هي (***CI6*** =***0.21*** ، ***CI7*** =***0.42*** ، ***CI8*** =***0.21*** ، ***CI9*** =***0.42***). اما للمتوسطة الكثافة هي (***CI6*** =0.45 ، ***CI7*** =0.43 ، ***CI8*** =0.83 ، ***CI9*** =***0.43***).اما للعالية الكثافة هي (***CI6*** =0.24 ، ***CI7*** =0.69، ***CI8*** =0.70 ، ***CI9*** =0.83).

الكلمات المفتاحية: الصنوبر البروتي، دلائل التنافس، النمو القطري، الكثافات، غابة اتروش.