Seed Production Variability of Aleppo Pine (*Pinus Halepensis* Mill.) within Korbus Arboretum (North East of Tunisia)

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Abstract: About 50 years ago (in the 1960's), 30 Tunisian Aleppo pine provenances were planted in Korbus arboretum (NE of Tunisia). For this study, only twelve provenances were selected and assessed. The selected provenances were evaluated for seed production, tree height and diameter. Results showed high inter-provenance variability for all the traits considered. However, within this site, the produced overall Aleppo pine cones per tree was less than the half in comparison to the interior forest of the country. Similarly, the average produced cone was lighter with less seeds content compared to non maritime coastal forests. The developed mature cones per tree in terms of number and weight were the major factors influencing seed yield within the site.

Keywords: Aleppo pine, provenances, cone production, seed yields, korbus arboretum, tunisia.

1. INTRODUCTION

In Tunisia, the Aleppo pine forests extend across the entire dorsal from the east of Zaghouan district to Jebel Chambi and Semmema in the west of Kasserine district [1]. According to previous research and reports, the forest area of the species ranges from humid to the upper arid zone. Aleppo pine forests occupy the highest surface area in the Mediterranean region with 2.5 million hectares [2] ranging from Portugal in the west to minor countries of Asia in the East and from the south of France in the North to South coast of the Mediterranean Sea. Moreover, in the last century, the species plantations were detected in the USA and others countries worldwide [3]. In Tunisia, this species is used for multiple purposes such as reforestation, anti-erosion, seed production and wood production. Due to its poor wood quality, the significant uses of the species production have been decoration, papermaking (some industry) and previously tannin (skins industry) and resin productions. However, wood products of the Aleppo pine are insignificant in comparison to non-wood products [4]. Pine cone is one of the most important productions of Aleppo pine and research findings have shown that Aleppo seed cone productions are influenced by multiple factors [5].

In this study, the aim is to study the genetic variability and the environmental factors influencing cone and seed characteristics produced by the average Aleppo pine tree of 12 Tunisian provenances in Korbus Arboretum (NE of Tunisia).

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2. MATERIAL AND METHODS

2.1. Study Site and its Ecological Features

Korbus arboretum is located in the eastern seaboard of Nabeul district. This site occupied a sub-humid zone with an elevation of 180meter above sea level [36°50'N-8°48'E]. Within this region, the average annual rainfall and temperature are about 540mm/year and 18°C, respectively. Soil is calcareous bedrock with superficial sandy loam substrate. The studied arboretum consists of many planted stands. Each stand was planted with several provenances of Aleppo pine forest species. Original seeds of forest species provenances were obtained from Tunisia and other foreign native forests. The arboretum breeding program is developed to discover suitable provenances of forest species which will be more productive in terms of biomass [6]. In this study, a total of 12 of 30 Aleppo pine Tunisian provenances were selected to evaluate their seed and cone production.

2.2. Field and Laboratory Measurements

Overall, a total of 327 Aleppo pine trees were selected and measured for their diameter at breast height (DBH) and total height (H_o). Three to four average trees per provenance without any evident damage were selected to harvest their mature cones. A total of 490 cones were harvested from the selected trees. In the laboratory, total cone mass per tree was measured for each harvested provenance and then the seeds were extracted, counted and weighed [7].

2.3. Statistical Analysis

Descriptive statistics and simple regression analyses were used to study the possible relationships

between seed cone production variables and its influencing factors. One-way ANOVA and Tukey's Studentized Range test were used to assess differences between selected provenances for the measured parameters. During simple regression analysis, only correlation coefficients with r>0.300 were retained if their p-value>0.05.

3. RESULTS

3.1. Tree, Cone and Seed Characteristics

Results showed that average Aleppo pine tree measured 35cm and 12mm in DBH and H_o attaining, respectively. An affine positive trend relationship was found between both epidometric variables (r = 0.698; p<0.001) (Figure **1**). The overall average tree produced a mean cone number of 51 ± (7) per tree weighing a total of 921.6 ± (151.2) g/tree. The mean number of produced cone by provenance (C#/T) ranges from 8 ± (5) cone/tree to 97 ± (42) cones/tree weighing (CM/T) 137.70 ± (79.50) g/tree to 2018.6 g/tree (Table **1**). Large variability's between provenances was observed for cone weight with an average mass (ACM) of about 17.2 ± (0.8). But the difference between provenances was limited significantly by minimum and maximum mean values: 11.0 ± (3.0) g/cone and 20.6 ± (1.6) g/cone registered in provenance O (Oued Elbir) and provenance Z (Jbel Koumine), respectively. Likewise, seeds number produced per average tree was about 2713 ± (370) seeds/tree weighing 11,06 ± (0,46) g/tree. Consequently, higher seed number (S#/T) and heavier seed mass (SM/T) produced per average tree was observed in the provenance X (Takrouna II) with an average mean values of about 4808 ± (791) seeds/tree weighing 82,94 ± (21,07) g/tree. On the contrary the lower seed number (S#/T) and lighter seed mass (SM/T) produced per average tree was observed in W (Sodga) provenance with an average mean values of about 698 ± (403) seeds/tree weighing about 7.28 ± (4.20)g/tree.

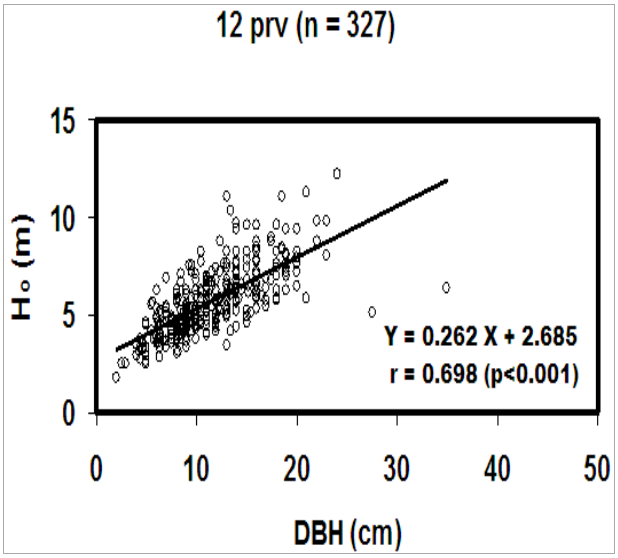

Figure 1: Relationship between total height (H_o) and diameter at breast height (DBH) of 12 assessed Tunisian Aleppo pine provenances within Korbus arboretum (NE of Tunisia).

Table 1: Mean Number and Weight of the Produced Cone per Individual Average Aleppo Pine Tree Observed in the Arboretum of Korbus (North-East of Tunisia)

*Prv. and Its Origin	C#/T (n)	CM/T (g)	*ACM* (g)	*S#/T* (n)	*SM/T* (g)
H (Sakiet)	17 ± (2) bc	277.6 ± (44.7) c	16.6 ± (0.9) bc	1074 ± (132) bc	9.90 ± (1.76) cd
J (Korbus)	22 ± (5) bc	401.4 ± (138.0) c	16.9 ± (3.8) bc	1180 ± (556) bc	12.82 ± (6.08) cd
O (Oued El Bir)	23 ± (5) bc	198.5 ± (12.9) d	11.0 ± (3.0) d	1047 ± (221) bc	9.96 ± (2.10) cd
R (Berino)	34 ± (8) bc	695.45 ± (180.1) b	20.5 ± (2.1) ab	1090 ± (232) bc	13.65 ± (3.18) cd
U (Jebel chehid)	67 ± (17) ab	976.0 ± (235.1) ab	15.0 ± (2.2) bc	3225 ± (1021) ab	33.60 ± (9.69) bc
V (Dernaïna)	77 ± (10) ab	1258.6 ± (348.3) ab	16.1 ± (3.3) abc	3516 ± (670) ab	43.60 ± (9.08) b
W (Sodga)	8 ± (5) c	137.7 ± (79.5) de	15.2 ± (3.0) bc	698 ± (403) c	7.28 ± (4.20) d
X (Takrouna II)	89 ± (21) ab	1807.6 ± (531.3) ab	19.6 ± (1.3) ab	4808 ± (791) a	82.94 ± (21.07) a
Z (Jebel koumine)	58 ± (18) abc	1291.0 ± (466.1) ab	20.6 ± (1.6) ab	4181 ± (1582) ab	50.08 ± (20.14) ab
AB (Wesletia sud)	32 ± (13) bc	456.0 ± (183.5) c	16.8 ± (5.0) abc	2127 ± (942) bc	18.66 ± (9.41) cd
AG (Selloum)	59 ± (20) ab	1167.4 ± (534.6) ab	18.2 ± (1.5) bc	3757 ± (1633) ab	50.86 ± (29.78) ab
AH (M'Guila)	97 ± (42) a	2018.6 ± (968.2) a	19.7 ± (2.9) abc	4686 ± (1848) ab	52.68 ± (21.94) ab
Overall mean	51 ± (7)	921.6 ± (151.2)	17.2 ± (0.8)	2713 ± (370)	33.11 ± (5.44)

*Prv: Provenance, C#/T: mean cone number produced by average tree, CM/T (g): Mean cone weight per tree, ACM: average cone mass, S#/T: mean seed number produced by average tree, SM/T (g): mean seed weight per tree. For each variable, different column letters indicate significant differences among Aleppo pine provenances (p< 0.05).

Table 2: Pearson Correlations Matrix Obtained between Epidometric Variables, Cone Weight, in Addition to the Produced Seed and Cone per Average Tree within Korbus Arboretum (NE of Tunisia)

	H_o	DHP	C#/T	ACM	CM/T	S#/T	SM/T
H_o	1						
DHP	0.370*	1					
C#/T	-0.029	0.061	1				
ACM	0.042	0.290	0.278	1			
CM/T	0.011	0.129	0.964***	0.468**	1		
S#/T	0.037	0.167	0.932***	0.354*	0.922***	1	
SM/T	0.070	0.207	0.879***	0.445**	0.907***	0.949***	1

*p<0.05; **p<0.01; ***p<0.001.

3.2. Factors Influencing Seed and Cone Production

Within this arboretum, H_o and DBH were not statistically significant variables when calculating the number and weight of cones and seeds produced by average tree. Nevertheless, C#/T showed very high significant level (p<0.001) with CM/T, S#/T and SM/T, having where correlations coefficients of r = 0.964, r = 0.932 and r = 0.879, respectively. Furthermore, ACM showed high significant influence (p<0.01) on the produced seed (SM/T) and cone (CM/T) mass per tree with respective correlations coefficients of, r = 0.445 and r = 0.468. Moreover, ACM showed significant effect on S#/T with regression value of r = 0.354 (p<0.05). Additionally, very high significant influences (p<0.001) were recorded between CM/T and S#/T (r = 0.922) and between CM/T and SM/T (r = 0.907). This means that a decrease in cone mass produced per tree would result in a lower seed number and mass. Concerning S#/T, high correlation was recorded with SM/T (r = 0.949; p<0.001). (Table **2**)

4. DISCUSSION

From the 12 assessed provenances, taller and larger trees are forthcoming from AG (Salloum) provenances in comparison to the remaining used and selected provenances. Earlier it was shown that pine tree planted in dense forest stands often compete for light which stimulates their growth in height [8]. This competition on water and nutrients allocate growth, rooting and branching simulation where simulations activate the cationic exchange and root absorption, which requires an immediate development of wood (Xylem and Phloem) to convey the absorbed solutes laterally and vertically [9]. However, trees growing in open areas and low density are often subjected to well-developed crowns. In fact, isolated trees receive more light and nutrients resources in addition competition level will be less heightened [10]. In this study, no significant regression between epidometric variables and seed cone productions parameters was registered. Conversely, within this arboretum, average Aleppo pine tree planted produce less than the half of cone and seed in comparison to Tunisia interior wide-forest. Even so, a variability is detected between provenances where trees from AH (M'Guilla) products significantly more cones and weights more than other provenances. Similarly, lighter mature cones are produced by provenances W (Sodga) and O (Oued El-Bir). Produced seeds from provenance W (Sodga) were significantly important in terms of number and weight per tree. Therefore, this variability can be explained by high inter-competition degree for light sources and nutrient availability. The weak cone production level and the small developed cones size observed in the other provenances is explained by leaves photosynthetic activity reduction added to an increased stand density. Similarly, maritime effect can also be used to explain the observed low production rate of seed and cone within the arboretum.

CONCLUSION

From this research, an intra-specific variability was detected for cone seed production between the selected provenances. This variability can be explained by the adaptation level of the trees within the new plantation site, in addition to the developed competition between provenances for light, water and nutrients resources. Overall provenances, a stand planted in coastal maritime zone have smaller and lighter mature cones with lower seeds contents in comparison to the interior Aleppo pine forests of Tunisia.

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