Aleppo Pine Seed Production of Several Tunisian Ecotypes Planted in a Coastal Forest Stand

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Abstract: The demand of Aleppo pine seeds has risen largely to reach the Mediterranean countries necessities in the last decades. To study seed cone production of the species, 33 blocs (12x10m; 120m²) were planted with a limited number of Tunisian Aleppo pine ecotypes where only twelve are selected here to be surveyed. During plantations all ecotypes are spaced two meter each other. Selected ecotypes are evaluated for their survival rates, measured for their epidometric variables (total height (H_o) and their diameter at breast height (DBH)). Therefore, the average tree characteristic for each ecotype is defined as a representing tree and then an overall of 40 trees were used for cones harvesting. Consequently, seed and cone production variability between Aleppo pine ecotypes is detected using simple regression analysis. Results showed an overall survival rate of 82.9% within the site since 1963. High significant ($p<0.01$) linear positive relationship (H_o-DBH was recorded across ecotypes. Ecotypes variability is noticed for all the measured parameters including seed cone production parameters. However, coastal forest Aleppo pine stand showed an overall produced seed cone number less than the half (50 Cones/tree) in comparison to non-coastal forest within Tunisia. Similarly, in the coastal forest, the produced cones size and weight are often smaller and have less seeds contents than those produced within non-coastal forests. Likewise, we thought that cone traits are a major factor influencing seed yield in coastal forest stands. Finally, obtained results can be used as a scientific support to reach futures investigations research work in others Aleppo pine planted zones in Tunisia.

Keywords: Aleppo pine ecotypes, survival rate, cone traits, cone number, seed yields, Tunisia.

1. INTRODUCTION

In Tunisia, the Aleppo pine is the main forest tree species that extends from its sub-humid zone in the north to the arid zone in the south. The climatic region for this species conformity is the semi arid zone [1]. The forests species cover more than 50% of the forest area within this country [2, 3]. The density of the forest species varied from 250 trees/ha to more than 2200 trees/ha [4]. Low forest densities of this species are often clear, degraded and mixed by various species [5, 6]. Actually, these forests extend along the entire dorsal from the east of the country to Jebel Chambi, Jbel Semmema and Jebel Salloum in the west [7]. By Government, the Aleppo pine forests are distributed mainly among six Tunisian districts with a limited zone of 93.7% of the forested area [5, 8]. According to previous research and reports, the forest area of the species ranges from humid bioclimatic zone to upper arid bioclimatic zone within the Tunisian state. Specialists' efforts have shown that the forest area of this species is composed by an approximate of thirteen groups using the most important accompanying species within each region. However, groups varied according to species stratum, nature and quality of accompanied species [5, 6]. World widespread, Aleppo pine forests occupy more than 3.5 million hectares where 2.5 million hectares are found in the Mediterranean region [9, 10]. Its range is quite extensive from Portugal in the west to Minor countries of Asia in the East and from southern France in the North to South coast of the Mediterranean Sea (Maghreb countries) [11-13]. Actually, the Aleppo pine forests area within the southern Mediterranean coast in Maghreb grouped countries (Algeria, Morocco and Tunisia) exceeds an over of 1.2 million hectares [13, 14]. In Europe, the northern coast of the Mediterranean Sea, this species is restricted especially in Spain with more than one million hectares [15]. In Greece, this species occupies about 330,000 ha, 236,000 ha in France and 20,000 ha in Italy [16, 17]. In the last century, Aleppo pine plantations were detected in the United States of America, Venezuela, Argentina, Australia and South Africa [18-21].

Within Tunisia, the species trees are characterized by its abundant seed production. Similarly, this species can be used for multiple purposes such as; reforestation of degraded areas programs, an anti-erosion species, production of edible seeds in addition to its wood production [1]. Due to its poor wood quality, the species production significant uses are moved to decoration and resin productions [22]. Similarly, Aleppo pine is also used in papermaking and its bark is rich in tannin mainly for older trees where it is used in the preparation of skins [23, 24]. Similarly, [8] shown that

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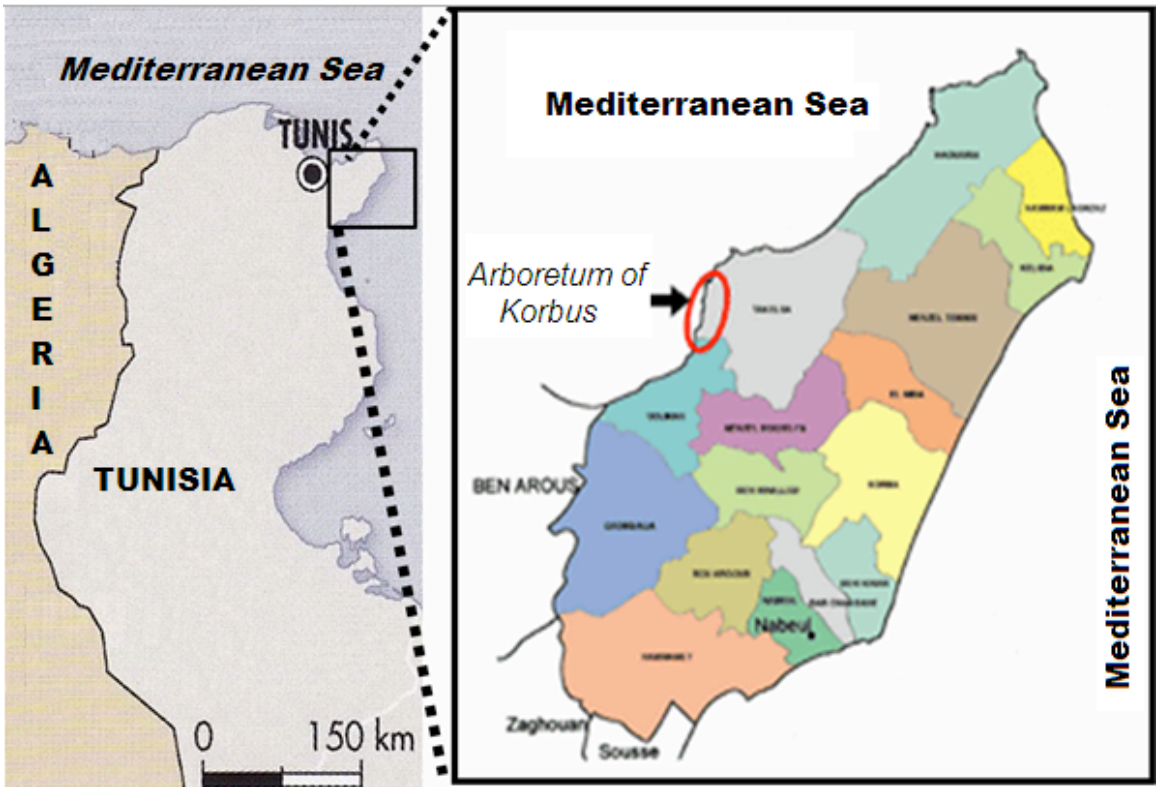

Figure 1: Map showing the Tunisian arboretum of Korbus locality.

wood products income and benefits of the Aleppo pine are insignificant in comparison to its non-wood products. Prior research have shown that Aleppo seed and cone productions are influenced by Multiple factors relating Bioclimatic zone characteristics to trees morphology and forest site properties [25-27].

In this study, the aims was inspired from an earlier author's published work to evaluate seed cone characteristics produced by the average Aleppo pine tree for 12 Tunisian ecotypes planted in Korbus Arboretum (North East of Tunisia) under similar environmental factor effect.

2. MATERIAL AND METHODS

2.1. Study Site

During 1963, Franclet and Shonenberger created an arboretum network spreading the country from east to west and from north to south with more than 30 experimental forest arboreta. The arboretum of Korbus is one of them, its surrounding the eastern seaboard of Nabeul district (Figure **1**). Actually, this site consists of many planted stands where each stand was planted with many ecotypes of an only forest species. During this period the forest or semi forest selected species are; *Acacia tortilis* Savi, *Argania spinosa* (L), *Cypressus lusitanica* Carr., *Eucalyptus sp*, *Pinus halepensis* Mill., *P. radiata* (L), *P. canariensis* Smith, *P. laricio* Poir, *P. pinaster* Soland, *P. pinea* (L), *Pistacia atlantica* Desf, *Tetraclinis articulata* Mast, *Thuya orientalis* (L), *Quercus* sp. However, forest species ecotypes have been gotten from Tunisian native forests or imported from foreign countries such as Algeria, Australia, Brazil, France, Italy, Kuwait, Morocco, Pakistan, Portugal, Turkey, Spain, Sudan and USA.

The leading aim of the arboretum is an appropriate breeding program to discover the main suitable forest species under similar environmental factor effect [28]. Similarly, the arboretum is created to select the most productive species especially in terms of biomass [29, 30]. During this study, a total of 12 Aleppo pine Tunisian ecotypes are selected to assess their survival rate and to evaluate their seed and cone production within the new bioclimatic habitat which have the same traits such as; soil, site fertility, rainfall, temperature, land aspect etc. The original stand characteristics of each ecotype are cited in Table **1**.

2.2. Ecological Features of the Study Site

Korbus arboretum occupied a sub-humid bioclimatic zone with an elevation of 180 meter above sea level. The geographical coordinates of the study site is 36°50'

Table 1: Original Stand Characteristics of 12 Aleppo Pine Selected Provenances Planted in Korbus Arboretum (North-East of Tunisia)

N°	Prv.	Origine	Lat. (°N)	Long. (°E)	Alt. (m)	P (mm)
1	H	Sakiet	36° 15’	8° 25’	700	700
2	J	Jebel Korbous	36° 48’	10° 35’	200	600
3	O	Oued Elbir	36° 53’	10° 47’	50	550
4	R	Berino	35° 28’	8° 37’	960	650
5	U	Jebel Chèhid	36° 23’	9° 20’	650	550
6	V	Dernaïna	35° 07’	8° 30’	1100	275
7	W	Sodga	36° 02’	9° 35’	730	645
8	X	Takrouna π	36° 22’	8° 5’	700	850
9	Z	Jebel koumine	35° 08’	9° 08’	600	250
10	AB	Ouesselatia Sud	35° 48’	9° 45’	300	400
11	AG	Selloum	35° 05’	8° 40’	900	400
12	AH	M’Guila	35° 20’	9° 12’	800	300

Prv: Provenance,
Lat: Latitude
Long: Longitude
Alt: Altitude
P: Rainfall.

and 8°48' for its latitude and its longitude, respectively. Similarly, climatic database of the National Meteorological Institute of Tunisia for the nearest station to the arboretum was used to obtain the main climatic factors. For the temperature and rainfall, we calculated mean annual (T_a), mean maximum (T_{Max}) and mean minimum (T_{Min}), in addition to the mean annual rainfall (P) values using the last ten years (2004-2014) with available data during the active vegetative growth period [31]. The mean annual rainfall is of about 540mm/year. The average annual temperature is of about 18°C where its range varies from a minimum of 7.9°C and a maximum average of 32.4°C. In general, the soil horizons are calcareous with superficial sandy loam substrate, developed from calcareous bedrock [28]. In addition to Aleppo pine ecotypes plantations, natural vegetation was constituted by *Quercus coccifera* L., *Pistacia lentiscus* L., *Rosmarinus officinalis* L., *Cistus menspeliensis* L., *Cistus villosis* L., *Golobularia alypum* L.

2.3. Field and Laboratory Measurements

The total area of the Aleppo pine planted area in the arboretum is of about 4 ha. The shape of this stand area is divided into 33 rectangular plots designed randomized complete block. In each plot, there were planting 30 Aleppo pine ecotypes where each ecotype is represented by a single tree in each plot blocks and spaced two meter from each other. However, within the 33 plots, only 12 selected Aleppo pine ecotypes where a total of 327 of Aleppo pine trees were sampled. Then, we measured the diameter at breast height (DBH) and the total height (H_o) for all trees per selected ecotype [7]. Later, we define the average size tree representing each ecotype [27]. A number of three to four average trees per ecotype without any evident damage were selected for harvesting their mature cones [32]. The total number of mature cones bearded by those selected is counted. Then, a total of 490 cones were harvested from 40 average trees representing 12 Aleppo pine Tunisian ecotypes (Table **2**). Thereafter, in the laboratory, for each ecotype we calculated its survival rate within the arboretum by multiplying the number of survived trees multiplied by 100 and divided by 33 blocks [33]. Afterwards, all harvested mature cones without any obvious damage were measured for their size and their weight *sensus* [5, 8]. Therefore, to facilitate seeds extractions, all cones were placed in an oven at 50°C and a humidity of 62% [22]. Then the seeds easily released from each cone were counted and weighed by cone and then estimated by medium sized tree from.

2.4. Statistical Analysis

Possible relationships between seed and cones production variables were studied using descriptive

Table 2: Survival Plantation Rates of 12 Aleppo Pine Provenances (Since 1963), Mean Number of Selected Average Trees, Mean Number of Harvested and Produced Cones by Average Trees with in Korbus Arboretum

*Prv. and its Origin	SR (%)	# AT	# HCones	# PCones	H_o (m)	DHP (cm)
H (Sakiet)	75.76	4	27	50	6.1 ± (0.4) ab	11.2 ± (0.2) ab
J (Jebel korbus)	87.88	3	19	-	6.1 ± (0.7) ab	10.7 ± (0.7) ab
O (Oued Elbir)	84.85	3	20	68	6.6 ± (0.2) ab	11.3 ± (0.3) ab
R (Berino)	78.79	3	30	60	6.7 ± (0.5) ab	12.0 ± (1.2) ab
U (Jebel chèhid)	90.91	4	87	267	5.7 ± (0.2) ab	9.5 ± (1.4) b
V (Dernaïna)	87.88	3	46	231	5.2 ± (0.1) b	12.2 ± (0.4) ab
W (Sodga)	78.79	3	33	63	6.7 ± (0.1) ab	11.7 ± (0.2) ab
X (Takrouna II)	90.91	3	20	268	6.2 ± (0.2) ab	11.1 ± (0.1) ab
Z (Jebel koumine)	84.85	3	25	117	5.9 ± (0.2) ab	11.2 ± (0.4) ab
AB (Ouesselatia sud)	72.73	3	32	96	5.3 ± (0.3) b	9.9 ± (2.2) ab
AG (Selloum)	78.79	4	61	236	7.2 ± (0.1) a	14.6 ± (0.8) a
AH (M'Guila)	78.79	4	90	388	5.9 ± (0.4) ab	12.8 ± (0.6) ab
Total or mean	82.85	40	490	1863	6.1 ± (0.1)	11.6 ± (0.3)

*Prv: Provenance,
SR: Survival rate,
AT: mean number of selected average trees,
HCones: mean number of harvested cones,
PCones: mean number of produced cones,
H_o: total height,
DHP: diameter at breast height.

statistics and simple regression analyses. Similarly, Tukey's Studentized Range test and one-way ANOVA were used to assess differences between 12 Aleppo pine ecotypes for its survival rates, epidometric measurements, in addition to seed and cone production features. For that reason, only correlation coefficients relating explanatory variables to dependant seed and cones production parameters with $r>0.300$ were retained if their significant level is of $p>0.05$. Therefore, explanatory variables used here are average tree measurements *sensus* [5], cones traits *sensus* [7], the average production rate of seed and cone *sensus* [4, 7, 8]. The statistical analysis is done using the programme [34].

3. RESULTS

3.1. Survival Rate and Ecotypes Trees Characteristics

The results showed that over the past fifty years, the losses plantation rate within Korbus arboretum vary from 9.1 % to 27.3% with an overall mean value of about 17.4% (Table **2**). Subsequently, the survival plantation rate across the 12 Aleppo pine ecotypes is of about 82.5%. Both ecotypes (U and X) coming from Jebel Chehid (Central of Tunisia) and from Takrouna (North-West of Tunisia) showed the most important survival rate with a respective percentile of 90.9% (Table **2**). Similarly, results showed that within Korbus arboretum, these 12 Aleppo pines selected ecotypes has an average size tree characterized by a diameter at breast height (DBH) of about 11.6 ± (0.3)cm and a total height (Ho) of about 6.1 ± (0.1) m (Table **2**). Furthermore, average trees DHP varied significantly between minimum and maximum mean values of about 9.5 ± (1.4)cm and 14.6 ± (0.8)cm, recorded respectively for ecotype U (Jebel Chehid) and for ecotype AG (Salloum). Similarly, trees total height showed a range of significant variation stating from 5.3 ± (0.3) m to 7.2 ± (0.1) recorded respectively for ecotype AB (Ouesseletia south) and AG (Salloum). Likewise, within this arboretum an overall highly significant correlation ($r = 0.698$) linking total height (H_o) to diameter at breast height (DBH) was recorded (Data not shown). Similarly, if each ecotype was treated separately, high and significant correlations coefficients were also confirmed between both aforementioned variables (Figure **2**). Furthermore, these correlations coefficients range from $r= 0.515$ registered in ecotype V (Dernaïna) and $r= 0.867$ noted in ecotype W (Sodga).

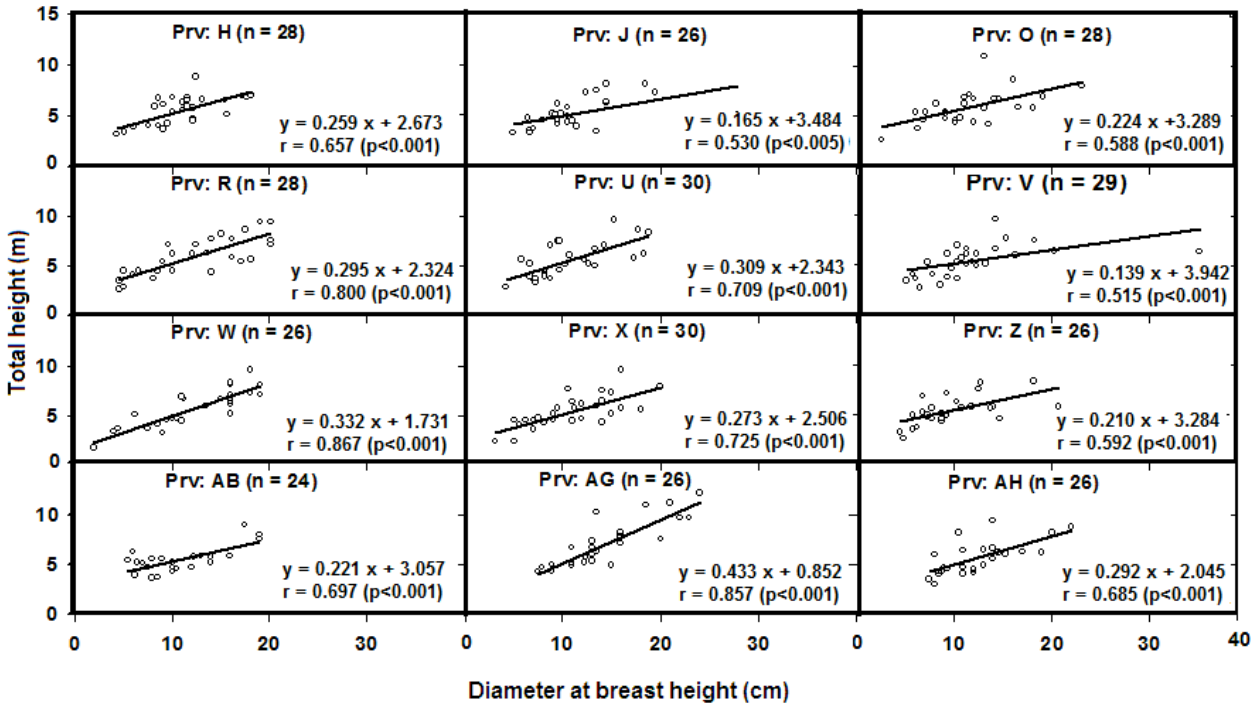

Figure 2: Relationships between total height (Ho) and Diameter at breast height (DBH) of 12 Aleppo pine provenances assessed in 2014 within the Arboretum of Korbus (North-east of Tunisia).

3.2. Cones and Seed Production Characteristics

3.2.1. Cones Production Characteristics

Across the arboretum of Korbus, recorded results showed that the average Aleppo pine ecotype tree produce a mean number of about 51 ± (7) cones/tree weighing of about 921.63 ± (151.22)g/tree (Table **3**). However, if ecotypes are treated separately, the mean number of produced cone (C#/T) ranges from 8 ± (5) cone/tree to 97 ± (42) cones/tree weighing (CM/T)

Table 3: 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)	*ACL* (mm)	*ACWd* (mm)	*ACM* (g)
H (Sakiet)	17 ± (2) bc	277.6 ± (44.7) c	61.5 ± (4.9) b	25.1 ± (1.5) bc	16.6 ± (0.9) bc
J (korbus)	22 ± (5) bc	401.4 ± (138.0) c	56.3 ± (5.0) c	24.5 ± (1.5) bc	16.9 ± (3.8) bc
O (Oued Elbir)	23 ± (5) bc	198.5 ± (12.9) d	53.9 ± (0.5) c	24.9 ± (0.1) bc	11.0 ± (3.0) d
R (Berino)	34 ± (8) bc	695.45 ± (180.1) b	59.2 ± (2.6) bc	26.5 ± (1.2) ab	20.5 ± (2.1) ab
U (Jebel chehid)	67 ± (17) ab	976.0 ± (235.1) ab	54.3 ± (1.9) c	23.5 ± (0.9) c	15.0 ± (2.2) bc
V (Dernaïna)	77 ± (10) ab	1258.6 ± (348.3) ab	56.4 ± (4.9) c	25.2 ± (1.2) bc	16.1 ± (3.3) abc
W (Sodga)	8 ± (5) c	137.7 ± (79.5) de	57.7 ± (4.5) bc	24.4 ± (2.0) bc	15.2 ± (3.0) bc
X (Takrouna II)	89 ± (21) ab	1807.6 ± (531.3) ab	67.7 ± (3.4) a	27.1 ± (0.2) a	19.6 ± (1.3) ab
Z (Jebel koumine)	58 ± (18) abc	1291.0 ± (466.1) ab	58.3 ± (8.2) bc	26.1 ± (1.5) bc	20.6 ± (1.6) ab
AB (Wesletia sud)	32 ± (13) bc	456.0 ± (183.5) c	56.8 ± (5.6) bc	24.1 ± (2.4) bc	16.8 ± (5.0) abc
AG (Selloum)	59 ± (20) ab	1167.4 ± (534.6) ab	59.9 ± (2.6) bc	25.9 ± (1.8) bc	18.2 ± (1.5) bc
AH (M'Guila)	97 ± (42) a	2018.6 ± (968.2) a	60.5 ± (5.6) bc	25.3 ± (0.9) bc	19.7 ± (2.9) abc
Overall mean	51 ± (7)	921.6 ± (151.2)	58.7 ± (1.2)	25.1 ± (0.4)	17.2 ± (0.8)

*Prv: Provenance,

C#/T: Mean cone number produced by average tree provenance,

CM/T (g): Mean cone weight per tree,

ACL: Average cone length,

ACWd: Average cone width,

ACM: Average cone mass.

respectively, 137.70 ± (79.50)g/tree to 2018.6g/tree. Likewise, the maximum significant mean cone number produced per average tree is observed with the ecotype AH (M'Guila) where the minimum one is recorded here with W (Soda) ecotype. Equally, intermediate mean values were recorded between ecotypes for the number and the corresponding weight of the produced cone per average tree. For cone size and its dimensions, results showed a great variability's between the assessed ecotypes (Table **3**). Within the arboretum, the average cone length (ACL) is of about 58.7 ± (1.2)mm where its range vary significantly ($p<0.05$) between a minimum and a maximum mean values of about 53.9 ± (0.5) and 67.7 ± (3.4) registered in both ecotypes O (Oued El Bir) and X (Takrouna), respectively. Furthermore, across assessed Aleppo pine's ecotypes, the mean cone width (ACWd) is averaged 25.1 ± (0.4)mm which ranging between a minimum and maximum significant mean values of about 23.5 ± (0.9)mm and 27.1 ± (0.2)mm recorded in ecotype U (Jebel Chehid) and ecotype X (Takrouna), respectively. Similarly, the average cone mass (ACM) of the selected ecotypes is of about 17.2 ± (0.8) limited significantly by minimum and maximum mean values of 11.0 ± (3.0)g/cone and 20.6 ± (1.6)g/cone registered in ecotype O (Oued Elbir) and ecotype Z (Jbel Koumine).

3.2.2. Seeds Production Characteristics

The results showed that seeds number content (S#/C) within an average sized cone is of about 54 ± (2) seeds/Cone weighing (SM/C) about 0.59 ± (0.04)g/Cone (Table **4**). Therefore, heavier and higher significant ($p<0.05$) mean number of seeds is observed within an average cone produced by the ecotype AB (Ouesletia South) with a mean seeds content number of about 65 ± (2) seeds/Cone weighing of about 0.62 ± (0.16)g/Cone. By contrast, lowest and lighter significant mean seed number is observed in the ecotype R (Bireno) with an average mean seeds number and weight of 37 ± (9) seeds/Cone and 0.40 ± (0.07)g/cone. Similarly to the production of seeds per cone, the results showed that within this arboretum the total number of seeds produced per average tree is of about 2713 ± (370) seeds/tree weighing about 11.06 ± (0.46)g/tree (Table **4**). Therefore, higher seed number (S#/T) and heavier seed mass (SM/T) produced per average tree was observed in the ecotype X (Takrouna II) with an average mean values of about 4808 ± (791) seeds/tree weighing 82.94 ± (21.07)g/tree (Table **4**). By opposite, the lower seed number (S#/T) and lighter seed mass (SM/T) produced per average tree was observed in the ecotype W (Sodga) with an average mean values of about 698 ± (403) seeds/tree weighing about 7.28 ± (4.20)g/tree. Across selected ecotypes, the average individual seed mass recorded within Korbus

Table 4: Mean Seed Number and Seed Weight, in Addition to the Individual Seed Mass Produced Per Individual Aleppo Pine Cone and Tree in the Arboretum of Korbus (North-East of Tunisia)

*Prv. and its Origin	*S#/C* (n)	*SM/C* (g)	*S#/T* (n)	*SM/T* (g)	*ASM* (mg)
H (Sakiet)	65 ± (4) ab	0.59 ± (0.03) b	1074 ± (132) bc	9.90 ± (1.76) cd	10.21 ± (2.42) ab
J (korbus)	64 ± (18) ab	0.50 ± (0.20) bc	1180 ± (556) bc	12.82 ± (6.08) cd	10.74 ± (1.38) ab
O (Oued Elbir)	46 ± (1) bc	0.44 ± (0.01) bc	1047 ± (221) bc	9.96 ± (2.10) cd	12.51 ± (1.16) ab
R (Berino)	37 ± (9) c	0.40 ± (0.07) c	1090 ± (232) bc	13.65 ± (3.18) cd	10.72 ± (1.13) ab
U (Jebel chehid)	50 ± (8) ab	0.51± (0.07) bc	3225 ± (1021) ab	33.60 ± (9.69) bc	10.95 ± (0.97) ab
V (Dernaïna)	45 ± (6) bc	0.56 ± (0.05) b	3516 ± (670) ab	43.60 ± (9.08) b	9.45 ± (2.33) b
W (Sodga)	53 ± (14) abc	0.58 ± (0.15) bc	698 ± (403) c	7.28 ± (4.20) d	11.13 ± (0.88) ab
X (Takrouna II)	56 ± (5) ab	0.92 ± (0.02) a	4808 ± (791) a	82.94 ± (21.07) a	16.70 ± (1.75) a
Z (Jebel koumine)	65 ± (7) ab	0.75 ± (0.11) b	4181 ± (1582) ab	50.08 ± (20.14) ab	11.47 ± (0.50) ab
AB (Wesletia sud)	65 ± (2) ab	0.62 ± (0.16) bc	2127 ± (942) bc	18.66 ± (9.41) cd	10.15 ± (0.68) b
AG (Selloum)	59 ± (6) ab	0.69 ± (0.18) b	3757 ± (1633) ab	50.86 ± (29.78) ab	9.51 ± (0.03) b
AH (M'Guila)	50 ± (6) ab	0.56 ± (0.13) bc	4686 ± (1848) ab	52.68 ± (21.94) ab	10.68 ± (0.22) ab
Overall mean	54 ± (2)	0.59 ± (0.04)	2713 ± (370)	33.11 ± (5.44)	11.06 ± (0.46)

*Prv: Provenance,

S#/C: mean seed number produced by average tree provenance,

SM/C (g): S#/T: mean seed number produced by average tree provenance,

SM/T (g): Mean seed weight per tree.

arboretum is of about 11.06 ± (0.46) mg/seed. Likewise, the heavier seed mass is recorded in the ecotype X (Takrouna II) with a mean weight value of about 16.70 ± (1.75) mg/seed. By contrast, lighter single seed mass is registered in the ecotype V (Dernaia) and the ecotype the ecotype AG (Selloum) with an average mean single seed weight of about 9.45 ± (2.33) mg/seed and 9.51 ± (0.03) mg/seed, respectively (Table **4**).

3.3. Factors Influencing the Seed and Cone Production

The relationships between variables influencing species seed and cone production are shown in Table **5**. Considering all ecotypes together (Overall), except its signification correlation coefficient with diameter at breast height (DBH) (r = 0.370; p<0.05), total height (Ho) had no significant effect on the number and weight of cones produced by the average Aleppo pine tree or on the total seed number and mass yielded per cone or per tree within the arboretum of Korbus. On the contrary, DBH had an only one significant (p<0.05) correlation coefficient (r = 0.318) on the average cone width (ACWd) (Table **5**). Indeed, the results showed that, the cone number per tree (C#/T) didn't have any significant influence on the per tree cone dimensions (average cone width (ACWd) and average cone length (ACL)), and weight (average cone mass (ACM)). However, C#/T showed very highly positive significant correlation (p<0.001) with cone mass per tree (CM/T), seed number per tree (S#/T) and seed mass per tree (SM/T), with respective correlations coefficients of r = 0.964, r = 0.932 and r = 0.879. Nonetheless, the ACL showed very high (p<0.001) positive influence on the ACWd and the ACM with respective correlations coefficients of r = 0.701 and r = 0.799. Similarly, ACL showed also high positive significant effect (p<0.01) on CM/T (r = 0.423), S#/T (r = 0.408) and SM/T (r = 0.532). Likewise, ACL showed significant (p<0.05) relationship with seed number per cone (S#/C (r = 0.385)). Regarding ACWd which results showed its very high significant effect (p<0.001) on the ACM (r = 0.733), and its high significant influence (p<0.01) on the CM/T (r = 0.423), S#/T (r = 0,408) and SM/T (r = 0.532), in addition to a significant relationship on S#/C (r = 0.385; p<0.05). Therefore, 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, the later variable showed significant positives effects on the yielded seed number per tree (S#/T) and per cone (S#/C) with correlations coefficients of, r = 0.354 and r = 0.372, respectively. Additionally, both very high positive and significant influences (p<0.001) were recorded between ACM and the produced per tree seed number (S#/T) and mass (SM/T) with respective correlations coefficients of, r = 0.922 and r = 0.907. This means that diminish in the produced cone mass would create lower seed production per tree. Similarly,

Table 5: Pearson Correlations Matrix Obtained between Epidometric Variables, Cone Dimensions and Weight, in Addition to the Yielded Per Tree Variables of Seeds and Cones within the Arboretum of Korbus (North-East of Tunisia)

	H_o	DHP	*C#/T*	*ACL*	*ACWd*	*ACM*	CM/T	*S#/T*	*SM/T*	*S#/C*	*SM/C*
H_o	1										
DHP	0.370*	1									
C#/T	NS	NS	1								
ACL	NS	NS	NS	1							
ACWd	NS	0.318*	NS	0.701***	1						
ACM	NS	NS	NS	0.799***	0.733***	1					
CM/T	NS	NS	0.964***	0.423**	0.423**	0.468**	1				
S#/T	NS	NS	0.932***	0.408**	0.408**	0.354*	0.922***	1			
SM/T	NS	NS	0.879***	0.532**	0.532**	0.445**	0.907***	0.949***	1		
S#/C	NS	NS	NS	0.385*	0.385*	0.372*	NS	0.318*	NS	1	
SM/C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1

* p<0.05;

**p<0.01;

***p<0.001,

(NS): Non significant (p > 0.05).

results showed high correlation between seed number per tree (S#/T) and seed mass per tree (SM/T) ($r = 0.949$; $p<0.001$). Significant relationship is also recorded between the number of seeds content within a single cone ($r = 0.318$; $p<0.05$).

4. DISCUSSION

The Aleppo pine is main forest tree species used in reforestation and others uses in the Mediterranean basin. Earlier, [35] showed that survival rate of Aleppo pine plantation varied from 18.4% to 36.1% which depends on soil substrate. More recently, Aleppo pine plantations in Algeria showed a survival rate ranging between 50 and 80% [36]. In this study, the survival rate of the 12 Aleppo pine ecotypes plantations within the arboretum of Korbus is of about 82.8%. Likewise, the lower survival rate is observed for the ecotype AB (Ouesletia south) with an average rate of 72.7%. The higher survival rate is recorded for both ecotypes U (Jbel Chehid) and X (Takrouna II) with mean survival rate of about 90.9%. However, this high proportion of survival rate observed for the 12 planted ecotypes is explained by three causes; (*i*) the high quality of seeds used for each ecotype, (*ii*) the space used at the beginning of the plantation within the arboretum where plant are distant of two meters, (*iii*) the well adapted of the planted ecotypes within this arboretum where seedlings developed an effective rooting increasing their exchange with underground [37]. Nonetheless, during the last 50 years for plantation of the 12 assessed ecotypes we recorded an average tree size having a DBH and total height of about 11.6 ± (0.3)cm and 6.1 ± (0.1) m Korbus arboretum. Taller and larger trees are noted for plantations coming from ecotypes AG (Salloum) where total tree heights attain more than seven meters and the DBH is of about 14.6 ± 0.8cm. Recovered rate growth rate is also registered for trees originated from AG (Salloum ecotypes) which may be explained by its better competitive effect to light, water and nutrients availability within the new planting site [32]. Concerning the relationship between total height and diameter at breast height it's a linear curve with a positive trend as it was previously showed within non-coastal (interior) forests of Tunisia and Spain [38]. Indeed, earlier it was shown that pine tree planted in dense forest stands often competes on light which stimulates their growth in height [39, 40]. This competition on water and nutrients allocate growth, rooting and branching simulation. In fact, these simulations activate the cationic exchange where the root absorption rate requires the immediate development of wood (Xylem and Phloem) for conveying absorbed solutes laterally and vertically [41].

Previous studies have shown that seed cone production in conifers trees is influenced mainly by climatic factors [42], geographical factors [43], stand density [44, 45] and the morphology of the tree [46, 47]. However, trees growing in more open areas and low density are often well subjected to well-developed crowns. Similarly, when trees are isolated, they receive more light and nutrient resources and the competition level between them will be less acute [48, 49]. In this study, no significant correlations between epidometric variables (H_o and DBH) and the seed cone productions parameters in terms of number and weights. Similarly, no significant effect was also recorded between epidometric variables on cone size and weight except its width, which is related significantly to DBH ($r = 0.318$). However, according to our database obtained, the average Aleppo pine tree planted with this arboretum produce of about 50 cones per tree weighing about 921g/tree. This yield value registered is less than the half of the mean production value recorded within non-coastal wide-forest of the country which estimated to 113 cones/tree [4, 8]. Nevertheless, seed and cone variability is detected between trees and between assessed Aleppo pine ecotypes. Indeed, it is trees from the AH (M'Guilla) products more significantly ($p<0.05$) cones number and weights in comparison other ecotypes. Within the selected ecotypes, lighter mature cones are produced by ecotypes W (Sodga) and O (Oued El-Bir). The average seed mass and the produced seeds from ecotype W (Sodga) are significantly the most important in terms of number and weight per tree. Therefore, this variability in cone and seed production observed within the arboretum and within the selected ecotype can be explained by the high degree of inter- competition in light sources in addition to water and nutrient resources. Similarly, since the mother rock extension in the arboretum is limestone, so, it's possible that the roots of certain ecotypes-trees have reached a non-cracked limestone block which issued the tree in water and nutrient deficit. Indeed, when trees are in an unfavourable, poor and critical environment, they'll fight for their survival while stimulating vegetative growth from fruiting [40]. Likewise, the cone production decrease was also explained by leaves reduction of photosynthetic activity [50, 51]. The increased stand density added to lower photosynthetic rates result in small developed cones sizes described by the competition between the trees mainly if nutrients resources are limited [52, 53]. However, intra-specific variability is also spied for cone traits (length, width and

weight) within Korbus arboretum. The produced cones have an average measurements of about 58.7 ± (1.2)mm, 25.1 ± (0.4)mm and 17.2 ± (0.8)g for length, width and weight respectively. Better cones are registered here from ecotypes X (Takrouna II) showing its better adaptation to the new planting site. From these traits mean values we concluded that developed matures cones within the arboretum from the selected ecotypes are less significant in comparison to the produced cone in the interior forest of Tunisia [27]. Therefore, earlier research works confirm the high and significant relationships recorded between Aleppo pine cone dimension and its weight [54, 55]. Consequently, filled seeds are associated to the available cone size and to its maturity. Across the selected ecotypes the number of seed content within a single mature cone is estimated to 53 ± (2) seeds/cone weighing about 0.59 ± (0.04)g/cone where the average seed mass of a single seed is of about 11.06 mg ± (0.46). The later values are also lower than those recorded by [7] in interior Aleppo pine forest within the country. The reduction seen in the produced Aleppo pine seed characteristics is related to the observed decrease of cone size and weight. This explanation is confirmed by the high significant correlation recorded in between seed characteristics and cone parameters. However, extracted seeds from X (II Takrouna KEF) are significantly heavier and seeds extracted from ecotype R (Berino, Kasserine) are the lightest in the selected ecotype. Similarly, the per tree and per cone seed production in terms of number and weight registered in the arboretum is lower in comparison to mean valued obtained previously by [8] in the interior forest of the country. Possible more explanation can be also used here that arboretum plantation have maritime effects where several studies have shown that conifer fruiting species are less important in sites close to coastal areas. Indeed, [4] showed that Aleppo pine seed and cone production increase if the distance of the forest from the sea coastal is important.

CONCLUSION

This topic has been continually described by its originality and the obtained results are considered very interesting to study the species seed-cone production in the arboretum and elsewhere. By 12 Aleppo pine assessed ecotypes planted in Korbus arboretum for their intra-specific variability in seed and cone production we identified important findings. First, planted ecotypes are well adapted to their new environment, which is justified by the high survival rate within the arboretum site. Moreover, it's confirmed by elevated epidometric measurements for all ecotypes trees but AG (Salloum) ecotype is characterized by the most important trees dimensions within Korbus arboretum during the last fifty years. Similarly, trees planted from the ecotype Z (Jbel Koumine) have weaker characteristics. An overall result showed a significant effect of the tree's diameter at breast height on the average cone width. Therefore, within this arboretum, we detected an intra-specific variability between ecotypes on seed and cone production. This variability may be explained by competition between ecotypes for light, water and nutrients resources. Previous results showed that the average Aleppo pine tree produces more than twice in comparison to Aleppo pine tree within the arboretum. Hence, trees from ecotype AH (M'Ghuilla) are the most productive, while those from ecotype W (Sodga) are the least productive. Similarly, smaller and lighter cone and seeds were obtained during this study in comparison to their measurement in the interior Aleppo pine forests of Tunisia. But, better correlation was found between the average width of the cone and the weight of seeds produced per tree. Larger cones gets more seeds per tree and the average single seed weight are closely correlated to the number and weight of the cones produced per tree.

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