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# INTERACTION OF GROWTH AND REPRODUCTION CHARACTERISTICS IN CAROB TREE (*CERATONIA SILIQUA* L.) POPULATIONS

## ABSTRACT

This study was carried out in three natural populations of Carob tree (*Ceratonia siliqua* L.) to determine the difference and interaction for reproductive and growth characteristics among populations and within population based on tree height, diameter at base, crown diameter and age, and number and weights of pod and seed for two consecutive years (2013&2014).

Large differences accordance with results of analysis of variance was found among populations and within population, and also between years for reproductive and growth characteristics. Averages of reproductive characteristics were higher in first year than that of second year. For instance, weight of pod was between 9.8 kg and 59.9 kg in a population in first year, while it was between 8.1 kg and 65.2 at the same population for second year. Weights of pod were 3.9 kg and 2.3 kg in polled populations for first and second year, respectively. The most productive ten trees produced more than 30% of total seed and pod productions in the populations. The relations among the characteristics changed for the years and populations.

**Keywords:** Growth, Genetic, Breeding, *Ceratonia siliqua*, Fruit, Population, Reproduction.

## INTRODUCTION

Carob Tree (*Ceratonia siliqua* L.) grows up to 15 meters height is an important tree species produced commercial seed and fruits (Davis, 1969; Alexander and Sheppard, 1989; Battale and Tous, 1997; Taşlıgil, 2011), and also used for different purposes in forestry and agriculture.

The carob tree has been grown since antiquity in most countries of the Mediterranean basin, usually in mild and dry places with poor soils. Its value was recognized by the ancient Greeks, who brought it from its native Middle East to Greece and Italy, and by the Arabs, who disseminated it along the North African coast and north into Spain and Portugal. It was spread in recent times to other Mediterranean-like regions such as California, Arizona, Mexico, Chile and Argentina by Spaniards, to parts of Australia by Mediterranean emigrants and to South Africa and India by the English (Battale and Tous, 1997). Its natural

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distribution is generally upto 300-400 meters, and rarely up to 800-100 m (Zohary, 1996; Günal, 1999).

The species is very resistance to arid and semi-arid areas because of long root systems grows up to 20-25 meters under soil (Grados ve Cruz, 1996; Demirtaş, 2007), and to other poor environmental conditions (Gülpınar, 2006; Şahin *et al.*, 2004), and also to forest fire (Neyişçi, 1996).

The species is widely used in forest plantation and agricultural land because of these advantages given above. Estimation of interaction between growth and reproductive characteristics is one of the most important stages for silvicultural practices such as plantation forestry, breeding, and tending. It is getting importance in plant species which has commercial fruits such as carob tree. However, while many studies were conducted on the interaction between reproductive and growth characteristics in different forest tree species (e.g. Jonsson *et al.*, 1976; Bhumibhamon, 1978; Burczyk and Chalupka, 1997; Nikkanen and Velling, 1987), it has not been studied on carob tree, yet.

This study was conducted to examine the correlation between reproductive and growth characteristics in carob tree populations, and to determine their variations. The results of the study are discussed based on silvicultural and agricultural strategies of the species.

## MATERIAL AND METHODS

The study was carried out in three natural carob tree populations sampled from southern part of Turkey (Table 1).

Table 1. Location of studied populations

| Populations | Latitude (N) | longitude (E) | Altitude (m) | Aspect |
|---|---|---|---|---|
| Tarsus | 37°05’ | 34°47’ | 360 | South-East |
| Erdemli | 36°37’ | 34°08’ | 414 | South-North |
| Silifke | 36°14’ | 34°47’ | 206 | South-East |

Data on the reproductive (number of mature fruits called also pod, PN; weight of fruits/pods PW; number of seeds, SN; weight of seeds, SW) (Figure 1) and growth (tree height, H; diameter at base, $D_0$; Crown diameter, CD; tree age, A) characteristics were collected from fifty trees (Figure 2) randomly chosen each of the three populations in 2013 and 2014.

The following linear analysis of variance (ANOVA) model was used for comparison of cone production in the populations:

$$Y_{i\,j\,k} = \mu + P_i + S_j + P(S)_{i(j)} + e_{ijk}$$

where, $Y_{ijk}$ is the observation from the $k^{th}$ tree of $i^{th}$ population in $j^{th}$ year; $\mu$ is overall mean, $P_i$ is the random effect of the $i^{th}$ population, $S_j$ is effect of the $j^{th}$ year, $P(S)_{i(j)}$ is the population and year interaction, $e_{ij}$ is random error.

Correlations among the reproductive and growth characteristics were also calculated by Pearson’s correlation using SPSS statistical package program.

Figure 1. Pod (left side) and seed (right side) of the species

Figure 2. Views from some sampled trees

## RESULTS AND DISCUSSION

Large differences were found for the growth characteristics within population and among populations (Table 2). For instance, tree heights were between 3.7 meter and 15.9 meter in Erdemli populations, ranged from 4.8 m. to 11.8 m. in Tarsus population, and varied between 2.9 m. and 8.5 m in Silifke population (Table 2). It could arise because of different forms of the species from shrub to long tree (Figure 3), and also biotic damages such as fungus. The differences were also supported by results of ANOVA. According to results of ANOVA, statistically significant ($p<0.05$) differences were found for the growth characteristics among populations, and between years.

Table 2. Averages and ranges of growth characteristics in the populations

| Characteristic | Erdemli | | Tarsus | | Silifke | |
|---|---|---|---|---|---|---|
| | Aver. | Range. | Aver. | Range. | Aver. | Range. |
| H (m) | 8.1 | 3.7-15.9 | 8.3 | 4.8-11.8 | 4.5 | 2.9-8.5 |
| $D_0$ (cm) | 25.8 | 8.0-43.0 | 26.0 | 7.0-54.0 | 13.5 | 7.0-21.0 |
| CD (cm) | 650.5 | 325-1095 | 575.9 | 175-960 | 332.5 | 210-470 |
| A (year) | 26.9 | 5.0-50.0 | 37.6 | 9.0-163.0 | 27.6 | 19.0-77.0 |

Figure 3. Different forms of the species

Crown diameter (CD) was more heterogeneous than other growth characteristics according to results of Duncan's multiple range test (Duncan, 1974) (Table 3). Tarsus and Erdemli populations were similar for tree height and diameter at base, while Erdemli and Silifke populations were similar for age (Table 3). It could be because of different environmental conditions such as soil, altitude.

Table 3. Results of Duncan's multiple range test for growth characteristics

| Populations | Homogenous groups* | | | |
|---|---|---|---|---|
| | H | $D_0$ | CD | A |
| Tarsus | b | b | b | a |
| Erdemli | b | b | c | b |
| Silifke | a | a | a | b |

* The same letters showed not significantly different at $p>0.05$

Averages of studied reproductive characteristics were given for populations and years in Table 4 and Figure 4. Large differences were found for number and weights of pod and seed among populations, and years (Table 4).

Table 4. Averages of pod and seed productions for years in the populations

| Characteristics | Populations/years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Erdemli | | Tarsus | | Silifke | | Total | |
| | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 | 2013 | 2014 |
| **PN** | 2722 | 984 | 3430 | 1708 | 690 | 329 | 2280 | 1007 |
| **PW** (kg) | 27.73 | 15.23 | 36.51 | 26.36 | 45.70 | 21.2 | 22.94 | 14.57 |
| **SN** | 26263 | 10774 | 38497 | 20750 | 5532 | 2702 | 23431 | 11409 |
| **SW** (kg) | 4.49 | 2.32 | 6.48 | 3.98 | 0.82 | 0.44 | 3.93 | 2.25 |

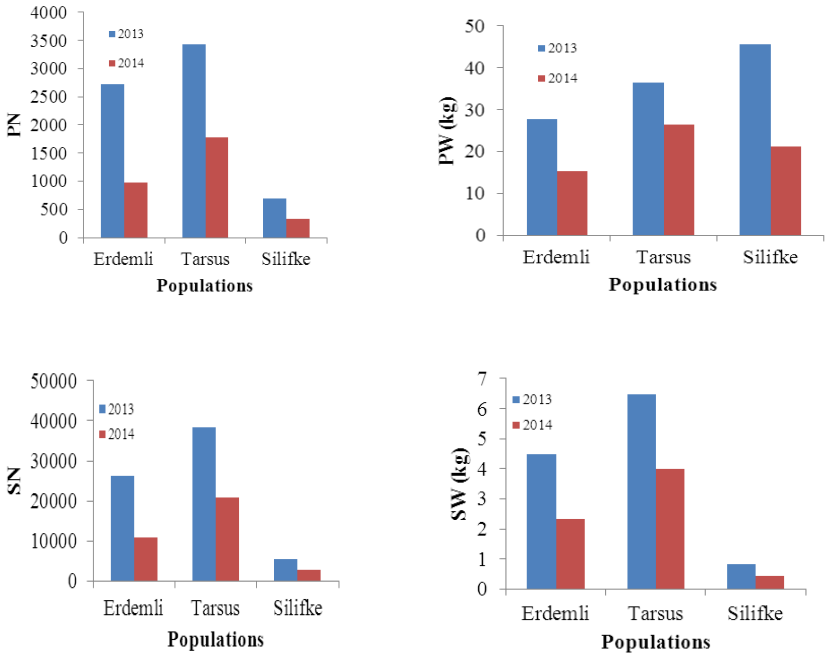


Figure 4. Averages of pod and seed productions for years in the populations

Large differences were also found for the reproductive characteristics within population (Figures 5&6). The most productive ten trees produced more than 30% of total seed and pod productions in the populations. Large differences were also reported for reproductive characteristics within population, among populations and years in different tree species (i.e., Keskin, 1999; Nikkanen ve Ruotsalainen, 2000; Bila, 2000; Almqvist *et al.*, 2001; Hannerz *et al.*, 2001; Kang *et al.*, 2003; Bilir *et al.*, 2003, 2005, 2006 and 2008). The differences showed importance of individual selection instead of mass selection for breeding purposes such as domestication in the species.

Figure 5. Size difference among pods


Figure 6. Size difference among seeds

Statistically significant ($p<0.05$) differences were found for the pod and seed productions characteristics among populations, and between years according to results of ANOVA. Numbers of pod and seeds were heterogeneous than weights according to results of Duncan's multiple range test (Table 5). Tarsus population of 2013 and Silifke population of both years were very different for the characteristics than others (Table 5). It could be important for similar silvicultural practices to similar populations.

Table 5. Results of Duncan's multiple range test for reproductive characteristics

| Populations/ years | Homogenous groups* | | | |
|---|---|---|---|---|
| | PN | PW | SN | SW |
| Tarsus-2013 | e | d | e | d |
| Tarsus-2014 | c | c | c | c |
| Erdemli-2013 | d | c | d | c |
| Erdemli-2014 | b | b | b | b |
| Silifke -2013 | ab | a | a | a |
| Silifke-2014 | a | a | a | a |

* The same letters showed not significantly different at $p>0.05$

Statistically significant ($p<0.05$) relations were found among growth characteristics, and among reproductive characteristics, while the relations among growth and reproductive characteristics changed for the years, populations and characteristics (Table 6).

Table 6. Correlations among the characteristics

| | | H | $D_0$ | CD | A | PN | PW | SN |
|---|---|---|---|---|---|---|---|---|
| | | 0.541 | - | | | | | |
| Tarsus Erdemli Silifke | $D_0$ | 0.597 | - | | | | | |
| | | $0.319^{NS}$ | - | | | | | |
| | | 0.288 | 0.649 | - | | | | |
| Tarsus Erdemli Silifke | CD | 0.412 | 0.595 | - | | | | |
| | | 0.341 | $-0.082^{NS}$ | - | | | | |
| | | 0.403 | 0.753 | 0.541 | - | | | |
| Tarsus Erdemli Silifke | A | 0.395 | 0.441 | $0.051^{NS}$ | - | | | |
| | | $-0.264^{NS}$ | $-0.202^{NS}$ | $-0.156^{NS}$ | - | | | |
| | | $-0.080^{NS}$ | $-0.205^{NS}$ | $-0.145^{NS}$ | $-0.125^{NS}$ | - | | |
| Tarsus Erdemli Silifke | PN | 0.410 | $0.305^{NS}$ | 0.595 | $0.115^{NS}$ | - | | |
| | | $0.200^{NS}$ | $0.180^{NS}$ | $0.28^{NS}$ | -0.360 | - | | |
| | | $-0.135^{NS}$ | $-0.030^{NS}$ | $0.245^{NS}$ | $0.070^{NS}$ | 0.613 | - | |
| Tarsus Erdemli Silifke | PW | 0.530 | 0.485 | 0.730 | $0.140^{NS}$ | 0.817 | - | |
| | | $0.220^{NS}$ | $0.195^{NS}$ | $0.300^{NS}$ | $-0.030^{NS}$ | 0.893 | - | |
| | | $0.020^{NS}$ | $-0.160^{NS}$ | $-0.175^{NS}$ | $-0.110^{NS}$ | 0.925 | 0.590 | - |
| Tarsus Erdemli Silifke | SN | 0.450 | $0.275^{NS}$ | 0.540 | $0.160^{NS}$ | 0.875 | 0.805 | - |
| | | $0.205^{NS}$ | $0.155^{NS}$ | $0.280^{NS}$ | $-0.045^{NS}$ | 0.955 | 0.900 | - |
| | | $0.010^{NS}$ | $-0.120^{NS}$ | $-0.190^{NS}$ | $-0.080^{NS}$ | 0.880 | 0.635 | 0.960 |
| Tarsus Erdemli Silifke | SW | 0.415 | $0.280^{NS}$ | $0.305^{NS}$ | $0.100^{NS}$ | 0.815 | 0.780 | 0.958 |
| | | $0.205^{NS}$ | $0.205^{NS}$ | $0.315^{NS}$ | $-0.065^{NS}$ | 0.910 | 0.910 | 0.966 |

$^{NS}$ correlation was not significant ($p>0.05$).

The positive correlations among growth and reproductive characteristics were reported in different forest tree species (i.e., Bilir *et al.*, 2006; Bhumibhamon,1978; Nikkanen and Ruotsalainen, 2000), while negative correlations were reported by Schmidtling (1981), Nikkanen and Velling (1987). Estimation of interaction between reproductive and growth characteristics had play important roles in management and establishment of forest area (i.e., spacing, pruning).

## CONCLUSIONS

In the present study reproductive and growth data were collected from three populations for two years. Therefore, it is needed to collect more data on fertility variation to draw accurate conclusion. However, early results of the study showed importance of individual selection to produce higher pod and seed productions in the species. Statistically significant ($p<0.05$) relations among growth characteristics showed that future studies could be carried out on less characteristics.

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