

Interactions of Climatic Characteristics x Strobili Productions in Taurus Cedar (*Cedrus libani* A. Rich.) Populations

Nebi BİLİR (✉ nebibilir@isparta.edu.tr)

Isparta University of Applied Sciences

Nilüfer YAZICI

Isparta University of Applied Sciences

Research Article

Keywords: Rainfall, Reproductive, Seed, Temperature

Posted Date: July 11th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-3112383/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Reproductive characteristic (e.g., pollen, strobili, cone, seed, fruit) is one of the main tools in sustainable forestry. However, many biotic (e.g., growth characteristics, species, population) and abiotic (e.g., edaphic, climatic, geographic) factors can be effective on these characteristics. In this study, impact of climatic characteristics including minimum, maximum and average temperatures, annual precipitation, and relative humidity on female and male strobili productions were examined in three natural populations of Taurus cedar (*Cedrus libani* A. Rich.) during three consecutive years (2020–2022). For this purpose, fifty trees were sampled and marked from each population to observe strobilus productions. ANOVA showed that climatic characteristics were similar among years and among populations, while female and male strobili productions showed significant ($p < 0.01$) differences among years and among populations, and also among years within population. Interactions of population x year were not significant ($p > 0.05$) in climatic characteristics opposite to strobili productions. Two populations had the highest strobili productions (155.4 and 82.3 for female, and 889.4 and 186.1 for male) in 2022. The studied climatic characteristics had no significant ($p > 0.05$) impact on strobili productions.

Introduction

Türkiye has 23.3 million ha forest area which of 41% unproductive according to the latest inventory. The area increased about two million hectares against to productive forests during last decade. The areas are 405424 ha and 511164 ha which of 204491 ha unproductive in Taurus cedar also known as cedar of Lebanon (*Cedrus libani* A. Rich.) for the years (OGM, 2023). The species lives up to 1000 years by 3 m stem diameter and 50 m height (Boydak, 2003). Male flowers of Taurus cedar of the dioecious species appear in July and elongate 3–5 cm in August, while female flowers can be seen in September. Pollination takes place in September or early October, depending on the elevation. The following year between April and June, conelets develop to mature cone sizes. Opening of the cone scales begins in October, about 25–26 months after flowering (Odabasi, 1990). Taurus cedar is classified as one of the economically and ecologically important tree species by Turkish forestry and the “National Tree Breeding and Seed Production Program” (Koski & Antola, 1993) because of its social-cultural importance and commercial wood product. The species is also used widely in forestry practices together with landscape planning as monumental tree (Yazici & Bilir, 2023).

Reproductive traits (e.g., pollen, strobili, cone, seed) play important roles in these practices and sustainability forestry and to establish resistance forest to climate change. Number of strobili is a mirror and predictor of seed production by conversion stages from conelet to seed crop. However, many biotic (e.g., growth characteristics, species, population) and abiotic (e.g., edaphic, climatic, geographic) factors and their interactions can be effective on the reproductive characteristics. The impacts of some biotic (e.g., population, crown closure) and abiotic (e.g., aspect) factors on reproductive characteristics were studied in Taurus cedar (Odabasi, 1990; Yazici & Bilir, 2017&2023; Bilir & Kang, 2021), and also in artificial and natural forests of different forest tree species (i.e., Eriksson et al., 1973; Boydak, 1977; Eler, 1990; Kang et al., 2003; Bilir, et al., 2005 & 2017; Kamalakannan et al., 2015). But the impact of climatic factors on strobili and other reproductive characteristics have not been studied in Taurus cedar, yet. It is clear that climatic characteristics are getting importance based on climate change. In the present study, the impacts of some climatic characteristics on strobilus productions were investigated in three natural populations of Taurus cedar during three consecutive years to contribute forestry practices and management of the species.

Materials and Methods

Sampled Populations and Strobilus Data

Three natural populations of the species were sampled from southern Türkiye in this study (Odabasi, 1990; Fig. 1). Some details of the populations were given in Table 1. Numbers of female (N) and male (N) strobilus (Fig. 2) were counted from the fifty phenotypically selected and marked trees during three consecutive years (2020–2022, abbreviated as 20, 21 and 22 in the study).

Table 1
Some details of the populations

Populations	Altitude (m)	Latitude (N)	Longitude (E)	Exposure	Soil (Atalay, 1987)
P1	1550	37°52'	31°17'	E	Lower paleozoic; clayey- limestone
P2	1650	37°40'	31°05'	E	Mesozoic; sandy-limestone
P3	1600	38°05'	30°42'	E	Quaternary; alluvion

Climatic Data

Minimum, maximum and average temperatures (°C), total annual precipitation (mm = kg/m²), and relative humidity (%) for the populations and years were obtained from General Directorate of Meteorology and Climatology of Türkiye (MGM, 2023).

Data Analysis

The following model of ANOVA were used to analyses the difference of climatic characteristics and strobili productions among populations and years by the SAS software (SAS, 2004) in the present study. Comparison of climatic characteristics was performed by monthly data of the years and population.

$$Y_{ijk} = \mu + F_i + B(F)_{j(i)} + e_{ijk} \quad (1)$$

Where Y_{ijk} is the observation from the k^{th} tree/month of the j^{th} population in the i^{th} year, μ is the overall mean of strobili production/climatic characteristics, F_i is the effect of i^{th} year, $B(F)_{j(i)}$ is the effect of the j^{th} population in the i^{th} year, and e_{ijk} is the random error.

The following linear model was used for the ANOVA for comparison of strobili productions /climatic characteristics for years within population.

$$Y_{ij} = \mu + C_i + e_{ij} \quad (2)$$

Where Y_{ij} is the observation from the j^{th} tree of the i^{th} year, μ is overall mean, C_i is the random effect of the i^{th} year, and e_{ij} is environmental error.

The pairwise comparison of populations and years for strobili productions were performed by Games-Howell test.

The relation among strobili productions and climatic characteristics were estimated by Spearman's Rank correlation. Averages of year and sides were used in estimation of the correlations.

Results

Climatic Characteristics

Annual minimum, maximum and average of temperatures, total annual precipitation, and relative humidity for the populations and years were given in Table 2.

Table 2
Annual temperatures, precipitations and humidity for the populations and years

Characteristics	Populations & Years								
	P1			P2			P3		
	20	21	22	20	21	22	20	21	22
Maximum temperatures (°C)	37.8	36.5	35.5	36.5	35	34.2	38.1	37.7	37.0
Minimum temperatures (°C)	-18.8	-16.7	-19.2	-15.0	-20.0	-23.7	-11.1	-9.8	-16.0
Average temperatures (°C)	12.4	12.8	11.9	12.0	11.7	11.0	14.8	14.5	13.8
Annual precipitation (mm = kg/m ²)	420.8	477.2	448.2	434.8	466.8	469.0	392.8	262.8	352.8
Relative humidity (%)	64.0	60.4	62.6	62.2	60.6	62.7	56.7	56.0	57.7

Average temperatures (°C) ranged from 11.0 (22 of P2) to 14.8 (20 of P3). Year 21 of P1 had the highest annual total precipitation (477.2 mm = kg/m²), while it was lowest in 21 of P3 (262.8). Relative humidity of the sides varied between 56.0% (21 of P3) and 64.0% (20 of P1) (Table 2). Populations and pooled years were similar ($p > 0.05$) for the climatic characteristics according to results of analysis of variance. Interactions of population (~ side) x year were not significant ($p > 0.05$) for the characteristics.

Monthly climatic characteristics were showed in Fig. 3. Years within population were similar ($p > 0.05$) according to results of analysis of variance, while monthly climatic characteristics within population and year showed differences (Fig. 3). For example, averages of maximum temperatures (°C) were 6.9, 17.4, and 15.2 for the years in January of P1. They were 9.1, 17.2, and 14.0 in P2 (Fig. 3). The averages of maximum temperatures (°C) were between 6.9 (January of 20 in P1) and 38.1 (September of 20 in P3) in pooled populations and years. They were -23.7 (January of 22 in P2) and 15.9 (July of 20 in P3) for the averages of minimum temperatures (°C). The averages of temperature ranged from -2.8 (January of 22 in P2) and 25.6 (August of 20 in P3) in pooled populations and years. Monthly total precipitation (mm = kg/m²) varied between 0 (July of 20 and 22, and August of 21 in P3) and 138.4 (July of 20 in P2). Relative humidity (%) ranged from 40.5 (July of 20 in P3) to 82.3 (January of 20 in P2) in pooled populations and years (Fig. 3). P3 was the hottest side (14.3 °C), while 20 and 21 were the hottest years (12.9 °C) according to the pooled temperature of years and populations. P2 had higher annual total precipitation (38.1 mm = kg/m²) than other populations, and year 22 was higher precipitation (35.3) than other years.

Strobili Productions

Averages ($\bar{X}$) and coefficient of variations (CV) for female (N) and male (N) strobilus for the populations and years were given in Table 3. Averages of strobilus productions changed for the populations and years (Table 3, Fig. 4). Populations and individual trees within population showed large differences for strobili productions. Female (N) (109.3) and male (N) (540.0) strobili productions were higher in P1 than other populations for pooled years. Year-20 produced the highest strobilus (108.9 & 462.6) in pooled years and populations. Female strobilus was generally more

variable than male strobili based on coefficient of variations (CV). The coefficients of variations (CV) were the highest for N in year 22 of P3 (74.7%), and in year 20 of P2 for N (108.1%) (Table 3).

Table 3
Averages ($\bar{X}$) and coefficient of variations (CV) for female (N) and male (N) strobili for the populations and years

Strobili	N _f						N _m					
Populations	P1		P2		P3		P1		P2		P3	
Years	X	CV %	X	CV %	X	CV %	X	CV %	X	CV %	X	CV %
20	141.2	50.4	122.5	80.0	62.3	47.4	641.2	79.9	621.3	108.1	125.2	51.3
21	31.4	49.7	28.0	48.9	50.5	50.0	89.1	35.4	71.4	55.3	91.4	41.9
22	155.4	40.9	28.4	48.2	82.3	74.7	889.4	90.8	95.2	61.2	186.1	96.7

There were significant ($p < 0.01$) differences for female and male strobili productions among years and among populations, according to results of analysis of variance, and also among years within population. Interactions of population x year were also significant ($p > 0.05$) in strobili productions. P1 was different than P2 & P3 for female strobili (N), while populations were significantly ($p < 0.01$) differences from each other for male strobili (N) according to results of Games-Howell test performed to pairwise comparison of the populations (Table 4). Year 20 and 22 were similar for strobili productions opposite to pairwise comparison of the years 20 and 21, and 21 and 22 (Table 4).

Table 4
Pairwise comparison of populations and years for strobili productions

Populations		N _f				N _m	
(I)	(J)	Mean difference (I-J)	Sig. (P)*	Mean difference (I-J)	Sig. (P)*		
P1	P2	49.7	$P < 0.05$	277.3	$P < 0.05$		
	P3	44.3	$P < 0.05$	405.7	$P < 0.05$		
P2	P3	-5.4	$P > 0.05$	128.4*	$P < 0.05$		
Years		N _f				N _m	
20	21	72.0	$P < 0.05$	378.6	$P < 0.05$		
	22	20.0	$P > 0.05$	72.3	$P > 0.05$		
21	22	-52.1	$P < 0.05$	-306.3	$P < 0.05$		

Correlations

According to results of the Spearman's Rank correlation, climatic characteristics (minimum, maximum and average temperatures, annual precipitation, and relative humidity) were not impact significantly ($p > 0.05$) on female and male strobili productions. However, positive and significant ($p < 0.01$) relations were found between female and male strobili productions in the populations (Fig. 5).

Discussion

Climatic characteristics were similar in the populations (~ sides). They showed that the characteristics were not changed dramatically in local area (Table 2). It could be important for local forestry practices and management strategies. Climatic characteristics of the studied sides were well accordance with results of early studies and ecology of the species (Atalay, 1987; Kantarci, 1991; Boydak, 2003; Yazici & Bilir, 2023). However, annual total precipitations of the sides were generally lower than early results (i.e., Atalay, 1987). For example, averages of annual total precipitation (mm = kg/m²) ranged from 335 mm to 1173 mm in natural distribution area of Taurus cedar, and 447 mm and 619 mm of the sides (Atalay, 1987). Distributions of climatic characteristics could be more important than averages. For example, June-July periods were not expected precipitation in natural distribution areas of the sides (Atalay, 1987), opposite to the climatic data of the sides (Fig. 3). It showed shifting of the months. The results could be used in management strategies of the species such as forest tending and natural regeneration practices of the species.

Populations and individual trees within population, and years showed large differences for strobili productions (Tables 3 & 4, Fig. 4). The results emphasized importance of these factors in strobili productions, management strategies of the species. Similar results were also reported in Taurus cedar (Bilir & Kang, 2014; Yazici & Bilir, 2017 & 2023; Bilir & Kang, 2021), and also in different forest tree species (e.g., Bila & Lindgren, 1998; Bila et al., 1999; Kang et al., 2003; Varghese et al., 2006; Kamalakannan et al., 2015; Park et al., 2017; Jeon et al., 2022). Averages numbers of female strobili ranged from 31 to 150 in three populations and three consecutive years, while they were between 77 and 828 for male strobili (Bilir & Kang, 2021). Averages cone number for varied between 24.6 and 40.3 in two years of four populations of Taurus cedar (Yazici & Bilir, 2023). Coefficient of variation (CV) of strobilus productions (Table 3) were acceptable (CV ≤ 140%) level for natural populations (Kang & Bilir, 2021).

Results of the Spearman's Rank correlation analysis showed positive and significant ($p < 0.01$) relations between female and male strobili productions in individual population, and pooled populations (Fig. 5). Similar relations between female and male strobilus were also found in Taurus cedar (Bilir and Kang, 2014 & 2021; Yazici & Bilir, 2017), and other forest tree species (i.e., Bilir et al., 2003 & 2005; Kang and Lindgren, 1998). Besides, climatic characteristics (minimum, maximum and average temperatures, annual precipitation, and relative humidity) had no significant ($p > 0.05$) impact on strobilus productions. Boydak (1977) reported that temperature was a more limiting factor on the pollen shedding than the relative humidity in Scots pine (*Pinus sylvestris* L.). It was also more effective on growth of female flowers (Boydak, 1977). The present study focused on numbers of strobili productions. We did not collect data of size of strobilus, and pollen contamination in the study. It was clear that climatic characteristics could be effective on other plant characteristics (i.e., Cetin et al., 2018). Besides, many biotic and abiotic factors could be impact on the strobili productions (i.e., Eriksson et al., 1973; Boydak, 1977; Eler, 1990; Odabasi, 1990; Kang et al., 2003; Bilir, et al., 2005 & 2017; Kamalakannan et al., 2015; Yazici & Bilir, 2017&2023; Bilir & Kang, 2021). For instance, aspect, and crown closure classes were effective on strobili and cone productions in Taurus cedar (Yazici and Bilir, 2017 & 2023), and altitude in Brutian pine (*Pinus brutia* Ten.) (Bilir et al., 2005). Eler (1990) reported that growth characteristic and age were effective on cone production in Brutian pine, while they were not effective on cone production in Taurus cedar (Yazici and Bilir, 2023). Catal et.al. (2018) reported that the relations among the growth characteristics and cone/seed productions changed for the years and populations in Taurus cedar.

Conclusions

Results of the study can be used in forestry practices of the species in local area. The present study was carried out in limited area of Taurus cedar to correlate some climatic characteristics and strobilus productions. New studies

should be carried out in large sites and long-term data in the species to give accurate conclusions and considered new reproductive characteristics such as cone and seed productions.

Declarations

Acknowledgement Authors thank to the graduate students for their help during data collection and regional forest directorate in Türkiye.

Authors' Contributions Nebi Bilir and Nilüfer Yazıcı conducted data collection and performed the bibliographic review. Nebi Bilir analyzed data and organized the manuscript. Nilüfer Yazıcı prepared figures and tables. Nebi Bilir edited the final version of the manuscript. Nebi Bilir and Nilüfer Yazıcı authors participated in the discussion and approved the submitted version.

Funding Not applicable.

Data Availability The data presented in this study are available on request from the corresponding author.

Declarations

Ethics approval All authors have read, understood, and have complied as applicable with the statement on “Ethical responsibilities of Authors” as found in the Instructions for Authors.

Competing interests The authors declare no competing interests.

References

1. Atalay, I. (1987). General ecological properties of natural occurrence areas of cedar (*Cedrus libani* A. Rich) forests and regioning of seed transfer of cedar in Turkey. General Directorate of Forestry press, Ankara, Turkey.
2. Bila A.D., Lindgren D., & Mullin T.J. (1999). Fertility variation and its effect on diversity over generations in a Teak plantation (*Tectonia grandis* L.f.). *Silvae Genetica*. 48, 109–114.
3. Bila, A.D., & Lindgren, D. (1998). Fertility variation in *Milletias thuhlmannii*, *Brachystegia spiciformis*, *Brachystegia bohemii* and *Leucaena leucocephala* and its effects on relatedness in seeds. *Forest Genetics*, 5, 119–129
4. Bilir, N., & Kang, K.S. (2021). Fertility variation, seed collection and gene diversity in natural stands of Taurus cedar (*Cedrus libani*). *European Journal of Forest Research*, 40, 199–208.
5. Bilir, N., Kang, K.S., & Lindgren, D. (2003). Fertility variation and effective number in the seed production areas of *Pinus radiata* and *Pinus pinaster*. *Silvae Genetica*, 52, 75–77.
6. Bilir, N., Kang, K.S., & Lindgren, D. (2005). Fertility variation in six populations of Brutian pine (*Pinus brutia* Ten.) over altitudinal ranges. *Euphytica*, 141, 163–168.
7. Bilir, N., Catal, Y., Tekocak, S., & Cercioglu, M. (2017). Fertility variation in endemic populations of Ehrami black pine (*Pinus nigra* Arnold. subsp. *Pallasiana* var. *pyramidata*). *J. For. Res.*, 28(4), 683–686.
8. Bilir, N., & Kang, K.S. (2014). Estimation of fertility variation by strobili and cone productions in Taurus cedar (*Cedrus libani* A. Rich.) populations. IUFRO Forest Tree Breeding Conference August 25–29, Prague, Czech Republic.
9. Boydak, M. (1977). Research on seed crop of Scots pine (*Pinus silvestris* L.) in Eskisehir-Catacik forest region. Istanbul University press, No: 2325, 193 p.

10. Boydak, M. (2003). Regeneration of Lebanon cedar (*Cedrus libani* A. Rich.) on karstic lands in Turkey. *For Ecol Manag.*, 178, 231–243.
11. Catal, Y., Bilir, N., & Ozel, H.B. (2018). Effect of growth characteristics on cone and seed production in Taurus cedar (*Cedrus libani* A. Rich.). *Fresenius Environmental Bulletin*, 27, 3832–3836.
12. Cetin, M., Sevik, H., & Yigit, N. (2018). Climate type-related changes in the leaf micromorphological characters of certain landscape plants. *Environmental Monitoring Assessment*, 190, 404.
13. Eler, U. (1990). Seed yield in Calabrian cluster pine (*Pinus brutia* Ten.) by age. Forest Research Institute, Technical Bulletin No. 225, Antalya.
14. Eriksson, G., Jonsson, A., & Lindgren, D. (1973). Flowering in a clonal trial of *Picea abies* (Karst.). *Studia Forestalia Suecica*, 110, 4–45.
15. Jeon, K., Ro, H. S., Kim, Y. J., Gu, D. E., Park, J. M., Ryu, S., & Kang, K. S. (2022). Genetic variation of flower production in breeding seedling seed orchards of *Quercus acuta* and *Q. glauca*. *Journal of Forest and Environmental Science*, 38(2), 102–109.
16. Kamalakannan, R., Varghese, M., Park, J.M., Kwon, S.H., Song, J.H., & Kang, K.S. (2015). Fertility variation and its impact on effective population size in seed stands of *Tamarindus indica* and *Azadirachta indica*. *Silvae Genetica*, 64, 91–99.
17. Kang, K.S., Bila, A.D., Harju, A.M., & Lindgren, D. (2003) Fertility variation in forest tree populations. *Forestry*, 76, 329–344.
18. Kang, K.S., & Bilir, N. (2021). Seed orchards (Establishment, Management and Genetics). OGEM-VAK Press, Ankara.
19. Kang, K.S., & Lindgren, D. (1998). Fertility variation and its effect on the relatedness of seeds in *Pinus densiflora*, *Pinus thunbergii* and *Pinus koraiensis* clonal seed orchards. *Silvae Genetica*, 47, 196–201.
20. Kantarci, M.D. (1991). Regional habitat classes of Mediterranean region of Turkey. General Directorate of Forestry press, Turkey, Ankara.
21. Koski, V., & Antola, J. (1993). National tree breeding and seed production programme for Turkey 1994–2003. The Research Directorate of Forest Tree Seeds and Tree Breeding, Turkey, Ankara.
22. MGM. (2023). Meteorology of Turkey, Ankara. <https://www.mgm.gov.tr>
23. Odabasi, T. (1990). Research on cone and seed characters of *Cedrus libani*. General Directorate of Forestry. Turkey, Ankara.
24. OGM. (2023). Forest inventory of Turkey, Ankara. <https://www.ogm.gov.tr>
25. Park, J.M., Kwon, S.H., Lee, H.J., Na, S.J., El-Kassaby, Y.A., & Kang, K.S. (2017). Integrating fecundity variation and genetic relatedness in estimating the gene diversity of seed crops: *Pinus koraiensis* seed orchard as an example. *Can. J. For. Res.*, 47(3), 366–370.
26. SAS. (2004). Statistical Analysis System, SAS Institute, Inc. Cary., N.C., USA.
27. Varghese, M., Nicodemus, A., Nagarajan, B., & Lindgren, D. (2006). Impact of fertility variation on gene diversity and drift in two clonal seed orchards of teak (*Tectona grandis* Linn. f.). *New Forests*, 31, 497–512.
28. Yazici, N., & Bilir, N. (2017). Aspectual fertility variation and its effect on gene diversity of seeds in natural stands of Taurus cedar (*Cedrus libani* A. Rich.). *IJ. Genomics*, 2960624.
29. Yazici, N., & Bilir, N. (2023). Impact of crown closure on cone production and effective number of parents in natural stands of Taurus cedar (*Cedrus libani* A. Rich.). *Forests*, 14, 1130.

Figures

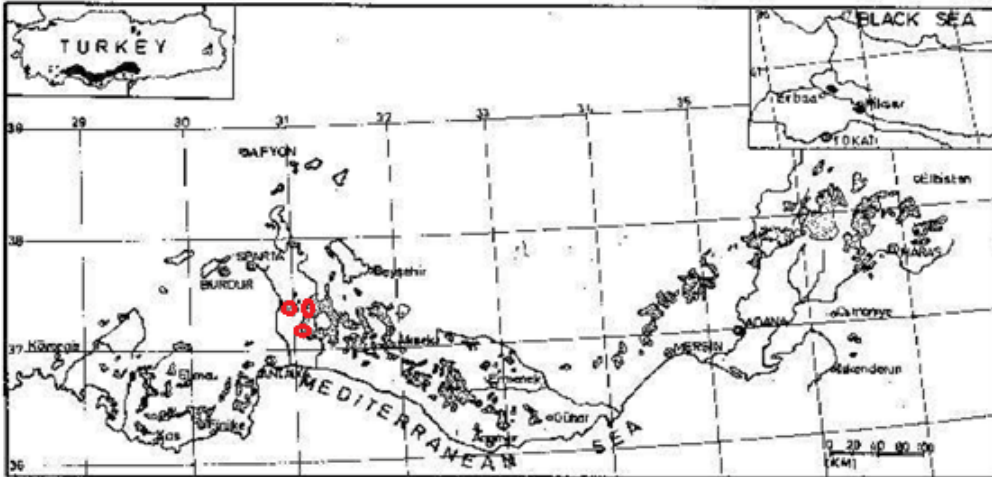


Figure 1

Natural distribution (Odabasi, 1990) and location of the sampled Taurus cedar populations in Turkey



Figure 2

Immature (left side) and mature male strobili (right side) of the species

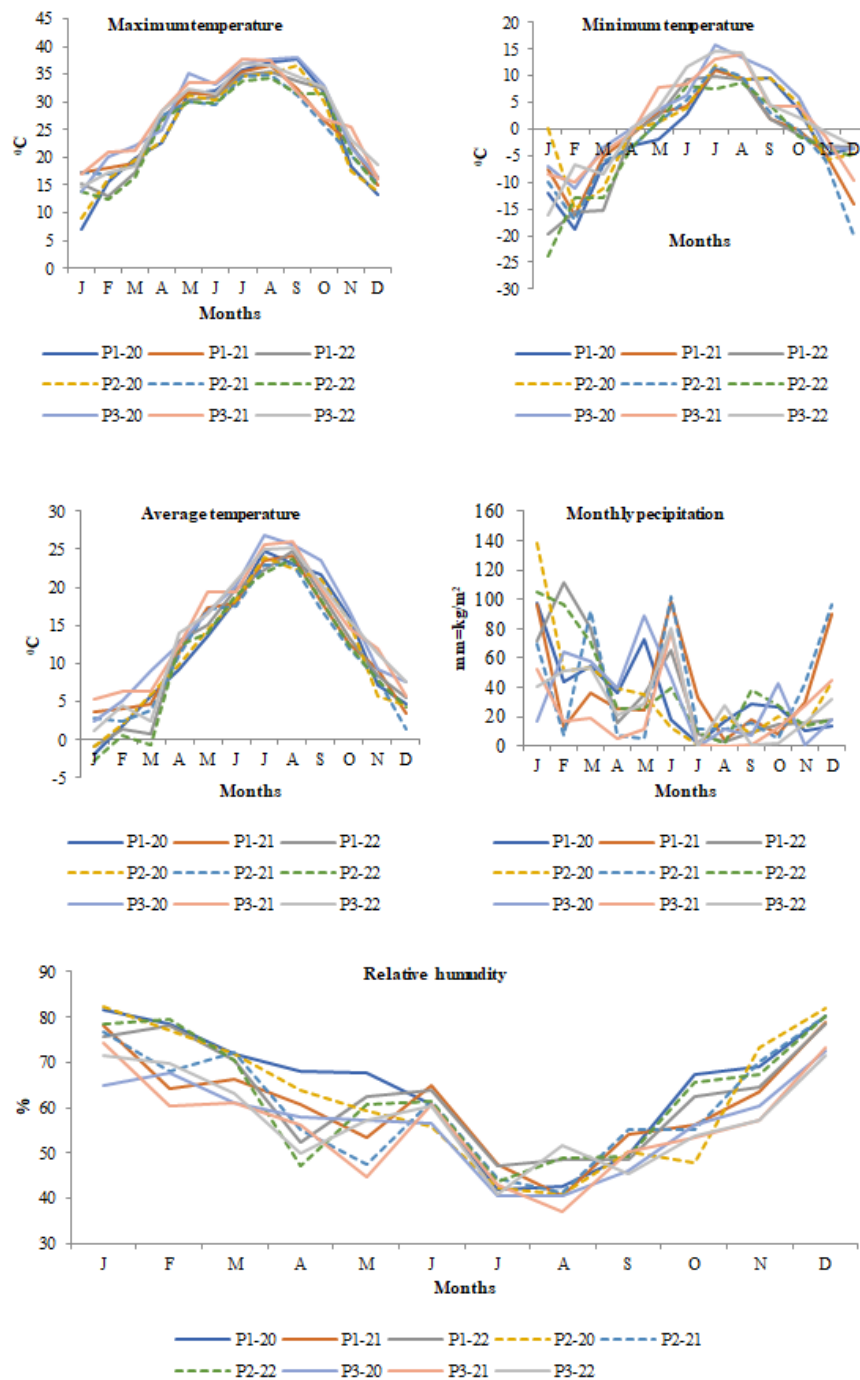


Figure 3

Monthly climatic characteristics for the sides and years

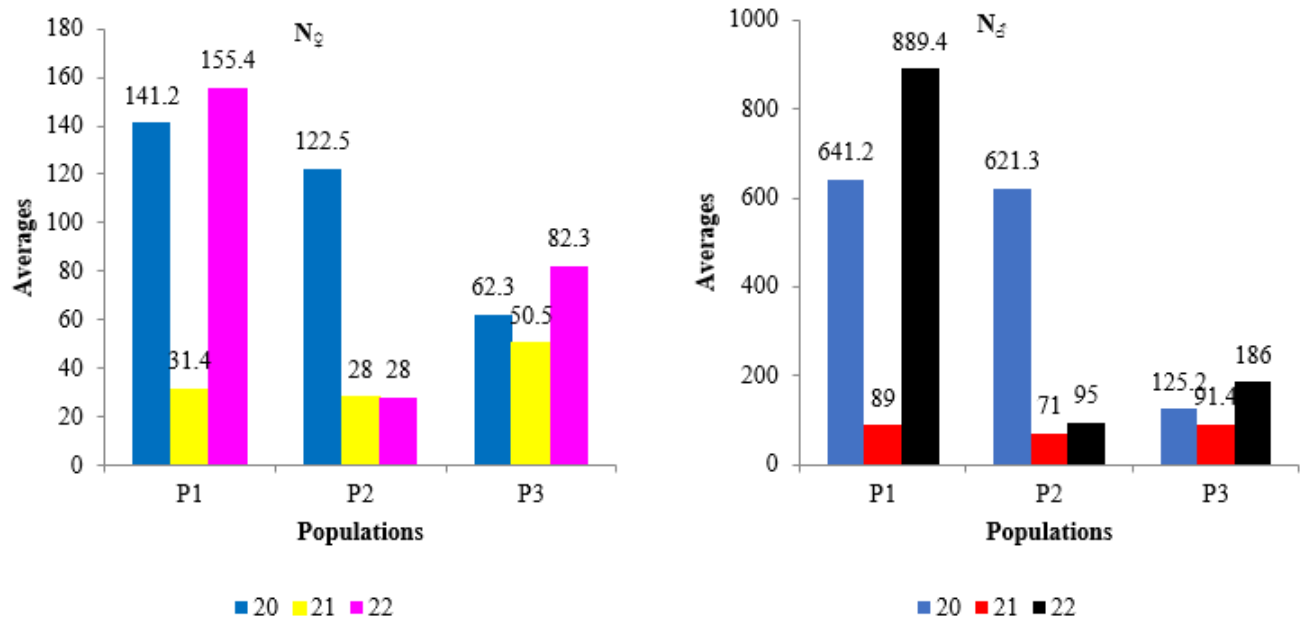


Figure 4

Averages of the strobili productions for the sides and years

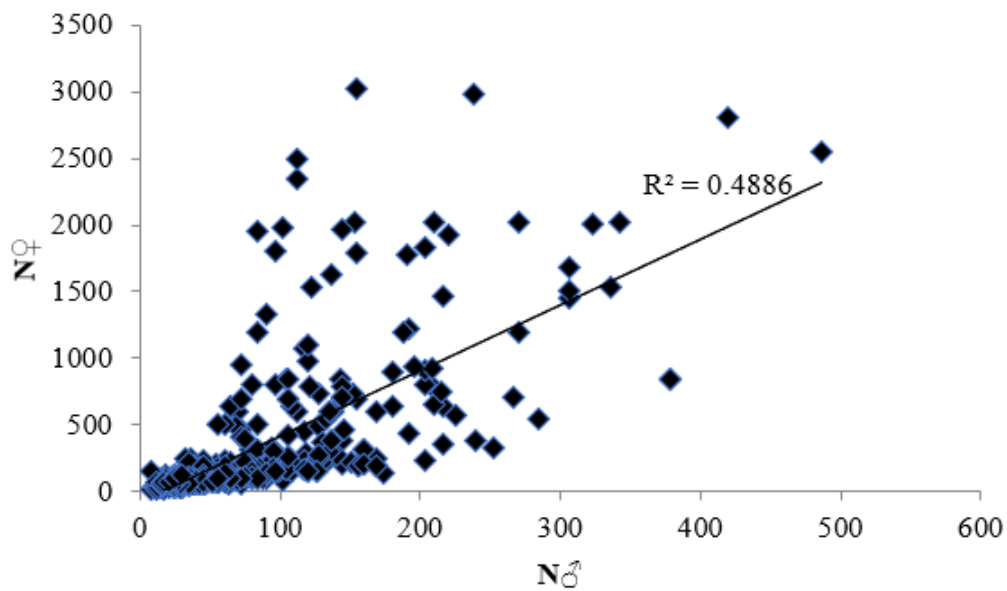


Figure 5

Relations between female ($N_{\text{♀}}$) and male ($N_{\text{♂}}$) strobilus in pooled populations