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Influence of stand and tree attributes and silviculture on cone and seed productions in forests of *Pinus pinea* L. in northern Tunisia

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Abstract. The present work studied if cone and seed productions were related to tree and stand parameters (age, crown size, stand density and tree social status) in stone pine (*Pinus pinea* L.) stands in Mekna forest (III), Northern Tunisia. The cones were collected in summer 2011 on 10% of the trees sampled in the different trunk diameter classes. They were counted, weighted and classified according to their age (two or three-year-old) and healthy or damaged. Three cones (three-year-old) with different sizes (small, medium and large) per sampled tree were harvested and brought to the laboratory. Seeds were extracted from the cones and their number and total weight per cone were determined. Filled or empty seeds were recorded. The findings showed that cone and seed productions are conditioned by tree size, especially crown volume, age and social status. The number of filled or empty seeds depends on the cone weight. Data showed that cone and consequently seed productions in Mekna III forest were low to extremely low for the considered year. Problems could arise from this deficiency in the future, not only for nut market but also for stand regeneration and species conservation on a long term scale.

Keywords. Cone production – Seed number – Stone pine – Mekna forest (III) – Stand attributes.

Influence des caractéristiques du peuplement, des arbres et des pratiques sylvicoles sur la production de cônes et de graines dans une forêt de Pin pignon au nord de la Tunisie

Résumé. *La production de cônes et de graines a été étudiée dans un peuplement de Pin pignon de la forêt de Mekna III au nord de la Tunisie en fonction de certains paramètres des arbres et du peuplement (âge, taille du houppier, densité et situation sociale de l'arbre). Les cônes ont été collectés pendant l'été 2011 sur un échantillon de 10% des arbres selon les différentes classes de diamètre du tronc sur les placettes-échantillons. Ils ont été comptés et classés selon leur âge (deux ou trois ans) ainsi que leur état, sain ou endommagé. Trois cônes de taille différente (petite, moyenne et grande) par arbre ont été pesés et ramenés au laboratoire. Les graines ont été extraites, leur nombre et leur poids ont été déterminés, et les graines pleines et vides ont également été enregistrées. Les résultats montrent que la production de cônes est conditionnée par la dimension, notamment du houppier, l'âge, et l'état social de l'arbre. La quantité de graines, pleines ou vides, dépend du poids du cône. Les données montrent que la production de cônes dans la forêt de Mekna III est très faible pour l'année considérée. Des problèmes pourraient survenir à partir de cette carence dans l'avenir, non seulement pour le marché de pignons destinés à la consommation, mais aussi pour la régénération du peuplement et la conservation de l'espèce à une échelle à plus long terme.*

Mots-clés. *Production de cônes – Nombre de graines – Pin parasol – Forêt de Mekna III – Caractéristiques dendrométriques.*

I – Introduction

The stone pine, *Pinus pinea* L., is a tree species found around the Mediterranean basin. It has been successfully introduced in Tunisia at the beginning of the 20th century along the Mediterranean coast line to consolidate the littoral dunes of Bizerte in the north and along the north east coast in the region of Cap Bon (Hasnaoui, 2000). The success of these first

plantations incited the foresters to use this species to stabilize the littoral dunes of the northwest too. Today *Pinus pinea* covers an area of 21,165 ha (El Khorchani, 2010) and becomes one of the most valuable species in Tunisian reforestation programs, not only for wood production, but also because it is much appreciated for its nuts, widely used in a lot of traditional dishes, such as cakes.

Natural regeneration is difficult to achieve in Tunisia. The yield of cones and the amount of available seeds together with other limiting factors such as livestock and overgrazing often result in the failure of natural regeneration in stone pine stands. Cone yield and seed amount also show great year to year variability, which leads to low masting capacities during long intervals. Therefore a better understanding of the factors controlling cone and seed productions may be key information to provide guidelines for managers to improve both nut production and natural regeneration.

In this study, we report data achieved on the *Pinus pinea* forest of Mekna III, North Tunisia. The aim was to study the effect of tree and stand parameters (tree age, crown volume, stem density, tree social status, pests) as hypothetic key attributes on cone and seed productions.

II – Materials and methods

1. Study area

The study was carried out in the northwest of Tunisia, on coastal dunes of Tabarka (36°57'N, 8°45'E), in the Mekna (III) forest. The climate is Mediterranean with mild winters and long summer dry periods lasting between five and six months. Mean annual temperature is 18.8°C. Average annual rainfall is 934 mm. The area is relatively flat and characterized by a sandy soil with low organic matter, small quantities of sandstone, and a pH above 8. Stone pine constitutes approximately 418 ha of pure or mixed stands.

2. Cone and seed data collection

Two- and three-year-old cones were harvested in late July and 2011. Cones were collected from 97 trees (approximately 10% of trees), sampled in different trunk diameter at breast height (DBH) classes ranging between 10 cm and 65 cm. Tree measurements included DBH, crown height, crown diameter and social status of the tree (i.e. dominated, co-dominant or dominant). The age of the trees was estimated by coring the tree and subsequent ring measurements. Stand tree density and basal area were also calculated.

All cones were manually harvested from each tree, counted, weighted and separated as either healthy or damaged. Three cones (only three-year-old ones) with different sizes (small, medium and large) per tree were chosen and brought to the laboratory. Their length and width were measured (Johnson *et al.*, 2003) with a calliper. Afterwards, the cones were soaked in hot tap water and finally heated in an oven at 60°C for 16 hours to open them. All cones were completely dissected and seeds were extracted. Seeds were counted, weighted and distinguished into filled or empty using the float method (Boydac *et al.,* 2003; Dangasuk and Panetsos, 2004).

III – Results

1. Stands attributes

Pinus pinea stands in Mekna forest (III) presented great differences in their characteristics (Table 1). Tree age was approximately the same in a given stand but varied from 17 to 62 years at the forest scale with a mean value of 36.8. The mean diameter (DBH) was 30 cm and ranged

from 6 to 61 cm, whereas the mean height (H) of the stand was 12.8 m and ranged from 6 to 21 m. Stand density also showed variability, between 140 and 1,820 trees per hectare.

Table 1. Stand characteristics (means ± SD of the thirty seven sampled plots)

	Mean	Min	Max
Tree diameter(cm)	29.6±10.3	6	61
Tree height (m)	12.8±3.7	6	21
Stand density (n/ha)	462±352	140	1.820
Tree age (years)	36.8±11.6	17	62

2. Cone production

Pinus pinea exhibited low cone production. Two-year-old cones averaged 5.6 per tree and three-year-old cones showed an average number of 7 per tree (Table 2). Three-year-old cone weight ranged between 60 and 389 g with a mean value of 202 g (Table 2).

Table 2. Cone and seed productions of *Pinus pinea* stands in Mekna forest (III) (mean value ± standard deviation)

Two-year-old cone number	Three-year-old cone number	Number of filled seed per cone	Percentage of empty seeds (%)	Three year-old cone weight (g)	Total seed weight per cone	Total seed number per cone	Percentage of trees without cones (%)
5.6±6.0	7.0±8.1	52.5±14.4	19.3±6.2	201.7±78.4	57.5±22.5	65.2±18.4	7.2

Number of two and three-year-old cones was positively and linearly correlated with tree crown volume (R^2=0.94 and R^2=0.90, respectively; p<0.0001; Fig.1). The high crown volume of 613 m^3 showed 30 two-year-old cones and 44 three-year-old cones, whereas a small crown volume of 1.5 m^3 resulted in an absence of cone.

The age was a worse predictor for cone number than crown volume (for the two- and three-year-old cones R^2=0.69 and R^2=0.84, respectively; p<0.0001).

The number of cones significantly decreased with increasing stand density (R^2=0.95; p<0.0001). The maximum number of cones found for a density of 140 trees per hectare was 30 and 44 for two- and three-year-old cones, respectively, whereas for a density of 1,820 trees per ha no cone was produced at all. Overall, 7% of trees had no cone.

Crown volume, age and stem density are variables correlated among each other. Results showed a positive correlation between crown volume and age (r=0.31; p<0.01) and a significant negative correlation between stem density and crown volume (r=-0.94, p<0.0001). Tree social status had a significant effect on the cone number (p<0.0001) with the biggest or dominant trees producing more cones than co-dominated and dominated trees.

3. Seed production

The seed number within the cone was positively and highly correlated with the mean dry weight of the cone (R^2=99.9%, p<0.0001; Fig. 2). Larger cones contained more filled seeds. The number of filled seed per cone was 52.5 in mean and ranged from 65.5 to 97.7.Overall mean of empty seeds in this study was 19.3% (Table 2) ranging from 2 to 34%.

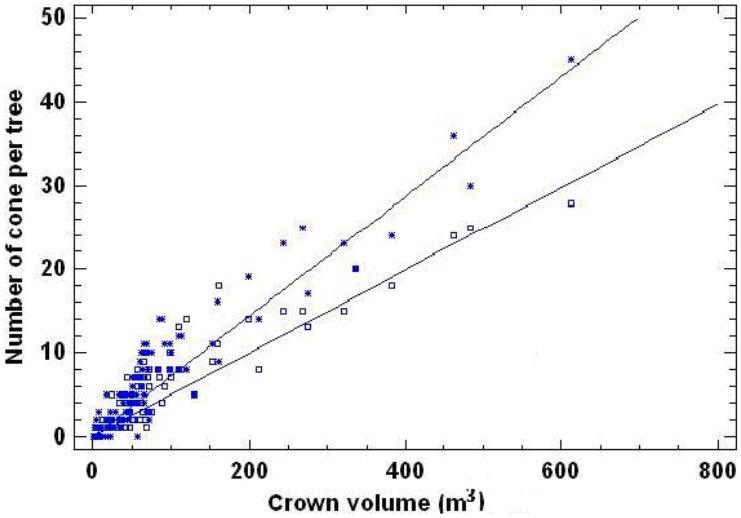

Fig. 1. Cone number relative to crown volume of *Pinus pinea* trees in Mekna (III) forest [▫: two-year-old cones, number of two-year-old cones per tree = (0.0495*crown volume) [*: three-year-old cones, number of three-year-old cones per tree = (0.0716*crown volume).

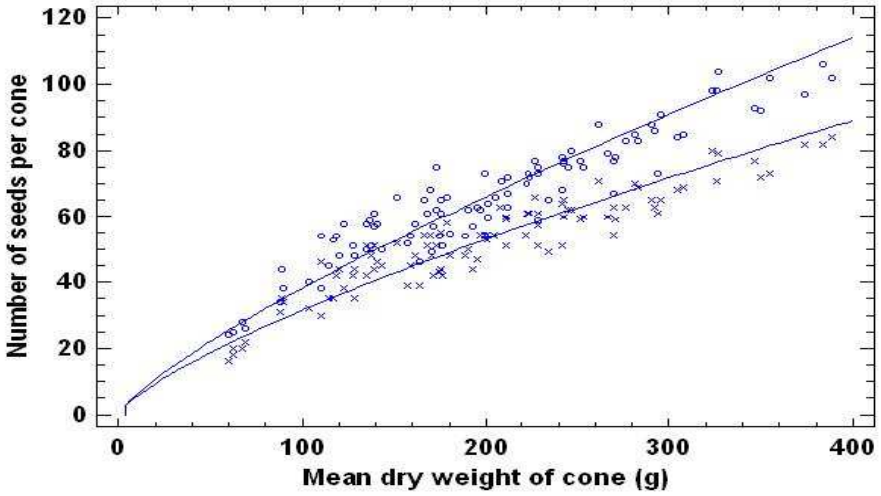

Fig. 2. Number of seeds per three-year-old cone relative to average cone dry weight [o: total seeds, Number of total seeds per cone = exp(0.790*ln(mean dry weight of cone)] [×: only filled seeds, Number of filled seeds per cone = exp(0.749*ln(mean dry weight of cone)].

Our results showed the presence of damages in the sampled two-year-old cones such as a brown colour and small and larger circular wholes. The mean proportion of two-year-old cones attacked by insects was 34.0% in mean for a tree and ranged from 0 to 100%. Infested cones were suspected to have been attacked by *Dioryctria mendacella*, probably *Pissodes validirostris* and Anobidae (genius *Ernobius*) but we need to confirm this hypothesis (Alain Roques, personal communication).

IV – Discussion

The results highlighted that the biggest trees, with an important crown volume, and being in stands with low tree density produced more cones than smaller trees. Therefore crown volume could be the main factor influencing cone production in the Mediterranean stone pine. At least crown volume seems to have more importance in the determinism of cone production than tree age or tree density. However we have to recognize that we were not able to sample young trees in stands having a low tree density. These results are in the line of those of Gonçalves and Pommerening (2011) who showed a good correlation between crown diameters and coning. Indeed, the largest production was attained when dominant trees were particularly frequent. Calama *et al.* (2008) also stated that the lower the density, the bigger is the number of dominant trees and the higher the site quality the larger is the average cone yield. Calama *et al.* (2011) explained as well the spatial variability of cone production between trees and between plots of stone pine like in our study by the presence of large, dominant trees growing in lightly stocked stands with the highest site quality. They reported for *Pinus pinea* forests on the Spanish Northern Plateau a considerable proportion of trees with no cone production. This result is in contrast to Gonçalves and Pommerening (2011) who reports only three trees in the plots of Alcácer do Sal region (Portugal) without cone. Our results showed 7 trees without cones on a total of 97 samples trees (7.2% trees with no cone).

The seed number per cone was variable and mainly explained by the mean weight of cones. Thus larger and heavier cones contain a higher number or filled seeds. These findings are in accordance with those obtained by Calama and Montero (2005). Correlation between filled seeds and total number of seeds has been identified in our study and in several forest studies since Bramlett and Hutchinson (1964). When the trees are stressed, such as in the case of a high tree density in the stand, their reproductive capacities seem to be reduced, with low cone production, and consequently a lower number of filled seeds and many empty seeds.

Dioryctria mendacella, Pissodes Validostris and coleopters (Anobiidae, genus *Ernobius*) seemed to be responsible of many cones attacks but it is necessary to analyse new attacked cones to confirm the presence of these species.

Data showed that cone production by *Pinus pinea* in the Mekna forest was very low and so was consequently the seed production, too. In addition, seeds from the Mekna forest were characterized by a low germination rate (48.5 %, Adili *et al.*, unpublished) in comparison with other studies, such as the site of Strofylia (78 to 98.3%, Ganatsas *et al.*, 2008). Consequently it seems unable to secure species regeneration. In this case appropriate silvicultural practices including pruning and thinning (reduce tree density to increase crown volume) are needed in order to ameliorate cone and seed productions and thus regeneration process.

V – Conclusions

Cone and seed productions of *Pinus pinea* in the Mekna (III) forest, north Tunisia, depend on: (i) the size of the tree and its health; (ii) the number and weight of the cones as factors influencing seed production; and (iii) *Dioryctria mendacella* as a major damaging agent for two-year-old cone. As a result seed and cone productions in the Mekna III forest are low and seem unable to secure species regeneration and nut production.

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