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Morphometrics of *Pinus patula* crown and its effect on cone characteristics and seed yield in Kenya

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***Pinus* species and other conifers have cones as an essential unit for seed production. Cone production in pines is not uniform and often varies among compartments and sectors within the crown. Many countries experience challenges in seed production from orchards due to poor practices. The present study aimed to evaluate within-crown cone production patterns, cone characteristics, and seed yield in a *Pinus patula* clonal seed orchard in Londiani, Kenya. Crown height was divided into three equal portions and a further subdivision done for each of the parts into two sections. There were differences in cone characteristics within the crown, between the sections and compartments. The majority (67.1%) of the cones in the present study were curved. The study also showed that cone shape had no significant influence on seed yield. The present study observed cones collected from the top portion of the crown yielded the highest amount of seed (33.3±4.91 seeds) (p<0.05) while the bottom part had the lowest (14.4±2.76) (p<0.05). The study recommends the collection of *P. patula* seeds from the upper part of the crown in unmanaged stands. Further, it suggests that management through pollarding needs to be done regularly to minimize within-crown differences.**

Key words: *Pinus patula*, crown, cone characteristics, seed yield, clonal seed orchard.

INTRODUCTION

Management practices on seed orchards and seed stands have been postulated to increase the seed yield (Moreno-Fernández et al., 2013; Nguyen et al., 2019). Also observed is the dwindling acreage of seed sources, regionally, especially in sub-Saharan Africa (Marunda et al., 2019). These challenges have led to higher pressure on the production of seeds from the existing seed sources (Owens, 1995). Cones are an essential unit of seed production for *Pinus* species and other conifers (Calama and Montero, 2007; Loewe-Muñoz et al., 2020). *Pinus patula* is an essential commercial plantation species in sub-Saharan Africa (Chamshama and Nwonwu, 2004; Cheboiwo, 2018; Valera and Kageyama, 1991). Some studies have observed that cone production by *Pinus* spp. *(Pinus halepensis* and *Pinus sylvestris)* is not uniform and often varies among compartments within

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the crown (Ayari et al., 2012; Abdelaziz Ayari and Khouja, 2014; Iwaizumi et al., 2008). These variations are considered to be associated with resource-related factors such as collection practices, crown size, stand density, and light intensity (Iwaizumi et al., 2008). It has been studied in other select pine species that the number of cones produced was more significant in the upper layer (Debain et al., 2003; Iwaizumi et al., 2008; Karlsson, 2000). The focus on such studies of pines crown production patterns are generally few and have not included *P. patula.* These studies have also not focused on cone characterization, production, and subsequent seed yield from different parts of the crown or even subsections of the crown of *P. patula* (Dyson, 1964; Nel, 2002).

Seed orchards are established from known materials with the assumption of high performance for industrial, commercial forestry (Hall et al., 2020; Kaviriri et al., 2020). Seed orchards, unlike other commercial plantations, are managed differently in term of wider spacing, pollarding and roguing for robust branching to maximize on seed production (Loewe-Muñoz et al., 2019; Weng et al., 2020; 농업생명과학연구, 2019). Management of seed orchards in most developing countries faces many challenges: (i) lack of assessment on the effectiveness of management practices in established and maintenance of seed orchards, and (ii) poor seed collection practices in terms of where to collect from the crown and yield from the different parts of the crown. There is scanty literature focusing on the crown compartment and sections of *P. patula* for seed collection as such literature, when available, will lead to improved seed orchard management and seed collection practices (Marunda et al., 2019; Tong et al., 2020).

Previous studies have focused on other pines in terms of crown variations by height. There is no literature focusing on the horizontal variability in seed production, especially in *P. patula* seed orchards. Similarly, few studies are focusing on the impacts of cone shape and effects on seed production, with no research focusing on *P. patula* cone shape and effect on seed production (Aniszewska, 2006; Guo et al., 2020; Udval and Batkhuu, 2013).

Conifers such as *P. patula* have huge importance to developing countries such as Kenya (Limpens et al., 2014; Montagnini et al., 2003) for industrial and commercial purposes. The practice of pine seed collection in Kenya relies heavily on seed stands and seed orchard (Dyson, 1964; Kariuki, 1998). However, there is scanty literature on effective collection practice for *P. patula* cones for seed extraction (Albrecht, 1993). The demand for *P. patula* seed in the country is very high and calls for strategies to increase the supply (Ngugi et al., 2000; Onyango et al., 2020). These collection practices have been lacking data in yielding from the crown compartments focusing on where to collect and (Valera and Kageyama, 1991) to improve the overall seed supply for the species.

This paper aimed to compare the crown morphometrics of *P. patula* and its effects on the cone characteristics and seed yield, with specific objectives being (i) to determine cone characteristics in different crown compartments, (ii) to estimate percent opening and seed yield from cones of separate crown compartments, (iii) to correlate the crown compartments to cone characteristics and seed yield in order to derive the best compartment for seed collection.

MATERIALS AND METHODS

A study was conducted in Londiani, Kenya, using *P. patula* cones collected from a 14-year-old clonal seed orchard in the Kamara area. Kamara is located between 00° 34' 00" S latitude and 35° 48' 00" E longitude at an elevation of 2,639 m above sea level. The collection of cones was done in March, which is usually the peak cone production period for *P. patula* in the region (Albrecht, 1993).

The orchard was divided into three equal plots where ten trees from each plot were sampled and measured for diameter at breast height (dbh) and height. An assessment was done on each sample plot to ascertain whether all the crowns and sections were attainable. Only one tree that had seeded well from each of the three plots and had the most recurrent dbh (~1.3 m above ground) was selected and marked for cone collection. From these trees, measurements were taken for dbh (cm), H-height (m), h-crown height (m), and crown radius (m)=D(m)/2 (Figure 1). The tree measurements lead to a division h(m)/3 of the crown in 3 equal portions; top (A), middle (B), and bottom (C). A further subdivision was done for each of the portions into two sections based on distance from the stem (0-2 m=1, >2 m=2). Section 1 comprised the part that is 2 m from the stem (A1, B1, and C1), section 2 comprised part greater than 2 m from the stem (A2, B2, and C2) (Figure 1 (Bilir et al., 2008).

From each of the crown sections, 15 mature cones were collected, making a total of 90 cones per tree as a sample size. The collected cones were put in separate bags for each sector of the crown and transported to the Kenya Forestry Research Institute-Rift Valley Eco-region Research Programme laboratories in Londiani for the study. Each cone was assessed for maturity and insect damage. Those cones without blemish were given an identity depending on the tree and crown sector from which it was collected to a maximum of ten cones per each crown sector.

Before seed extraction, the following characteristics were established for each cone; shape of the cone (straight or curved (Aniszewska, 2006) length (L1) (cm), diameter at widest part (cm) and weight (g). The cones were placed on uncovered glass Petri dishes and put in a preheated (Yamato DS411) oven at temperature 65°C for 24 h.

This extraction method is derived from observations made by Onyango et al. (In print) that cones dried at 65°C open robustly from 4 to 24 h in their study on *P. patula* cone opening and seed yields. After this treatment (drying in the oven), cones were removed and seeds extracted by tapping gently 15 times on a flat wooden bench. Further measurements of length (L2) of the part of the cone that had opened (cm), the weight of the cone without seed (g), and total seed count from each cone were done. Percent of the cone that opens after subjecting to temperature treatment for seed extraction (p) was calculated by Equation 1; this p is used to compare cone opening length in relation to the shape.

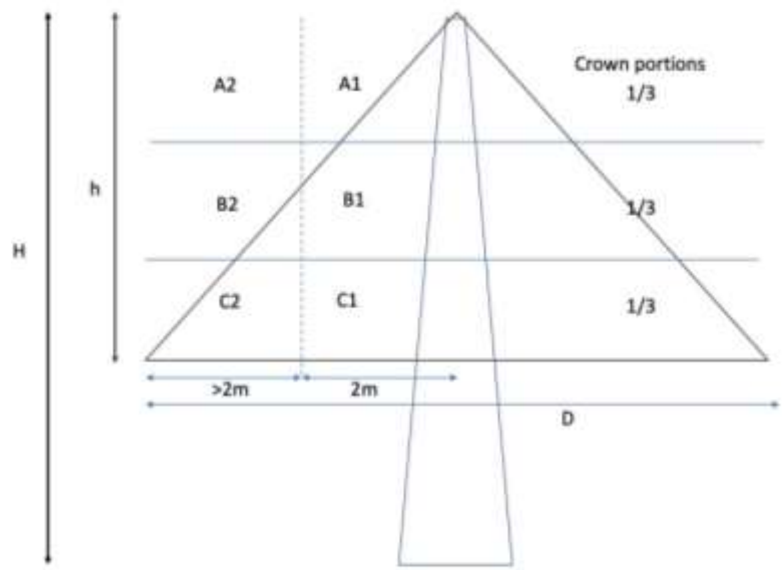

Figure 1. Schematic diagram on crown compartmentalization for sampling area of *Pinus patula* cones. A, B and C show compartments; 1 and 2 show sections.

$$p = \frac{L2\,(cm)}{L1\,(cm)} \times 100 \quad (1)$$

The data was tabulated in the datasheet in MS excel and analysis done for characterization of seed yield (S_y) which was a factor of Y-intercept by crown compartment (β_0); crown sector (β_1); percent opening (β_2) cone shape (β_3) and cone characteristics (β_4) (length, diameter, weight, and percent opened) (Equation 2) (Figure 1).

$$S_y = \beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \varepsilon \quad (2)$$

RStudio Version 1.2.1335 was used for post hoc (Tukey HSD) analysis done to interpret the 2-way ANOVA with crown compartment and cone shape as factors and length, diameter, weight, and seed yield as variables.

RESULTS AND DISCUSSION

The present study observed that the clonal seed orchard after analysis of the crown, compartment A2 was missing in all the trees and this is due to the conical shape of *P. patula* crown when closely spaced in a plantation. The study observed after analysis of the cones from the clonal seed orchard that the majority (67.1%) were curved while a minority (32.9%) were straight (Plate 1). We observed that curved cones were the majority across all compartments in the further description of the shape based on the crown compartment (Figure 2). This observation on cone shape leads to a gap in assessing the seed characteristics at the pine cone's curving location to determine its effects. The present study also observed that the bottom outer part (C1 and C2) of the crown had curved (56%) and straight (44%). We also noted that there was high variability between curved and straight cones in the upper part of the crown (Compartments A and B), ranging from a difference of 43 to 53% between curved and straight cones. While the bottom part (C1 and C2) had a low variability difference of 12% (Figure 2). There is a need to study further the effect of spacing and management practices such as pruning and pollarding on cone shape.

When we measured and analyzed the cone characteristics by compartment, the straight cones from compartment A1 at an average length of 7.9±0.10 cm and diameter of 2.90±0.03 cm and compartment B1 at an average length of 7.6±0.08 cm and diameter of 2.7±0.03 cm were the longest and widest. They showed a significant difference ($p<0.05$) when compared with the others (B2, C1, and C2) (Figure 3a and c). These findings concur with a similar study by Ayari et al. (2012) on *P. halepensis,* showing that the upper crown produces the longest and heaviest cones. Thus, for *P. patula* the observed trend could be attributed to light exposure and space for cone development (Ayari and Khouja, 2014; Iwaizumi et al., 2008).

Analysis of cones by weight revealed that straight cones from compartment B1 and A1 did not show a significant difference in weight ($p>0.05$) (Figure 3e). Overall, compartment A1 had the heaviest (31.6±0.62 g) cones and C2 the lightest (23.1±0.46 g) ($p>0.05$) (Figure 3f). Thereby revealing that superior *P. patula* cone by weight is found at the top part of the crown. Further studies on the effect of management practices need to be

Plate 1. Photograph showing cones of *Pinus patula* ranking based on shape (Straight-top and curved-bottom) with a 30 cm ruler on the side showing scale.

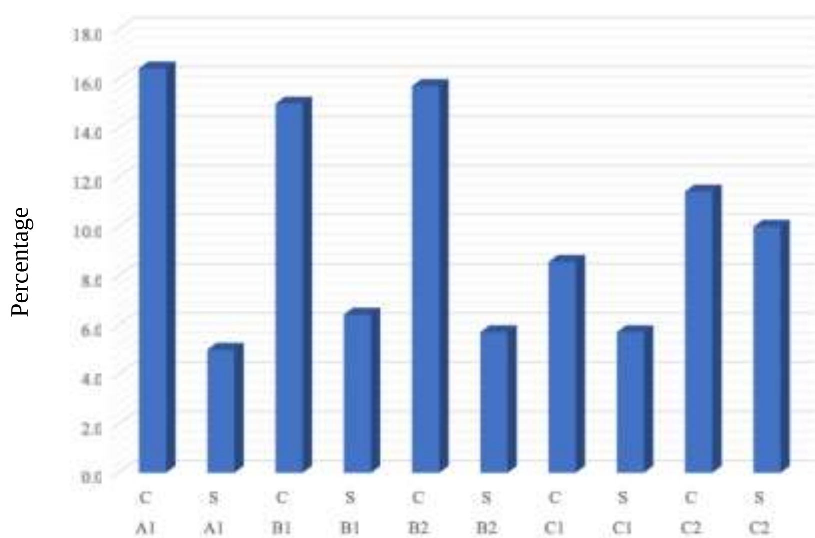

Figure 2. Cone shape by crown compartment and tree.

done. Straight cones of B1 and A1 were not significantly different in weight ($p>0.05$) but were significantly different from all the others ($p<0.05$) (Figure 3e). Curved cones of compartment A1 and straight cones from B1 were also

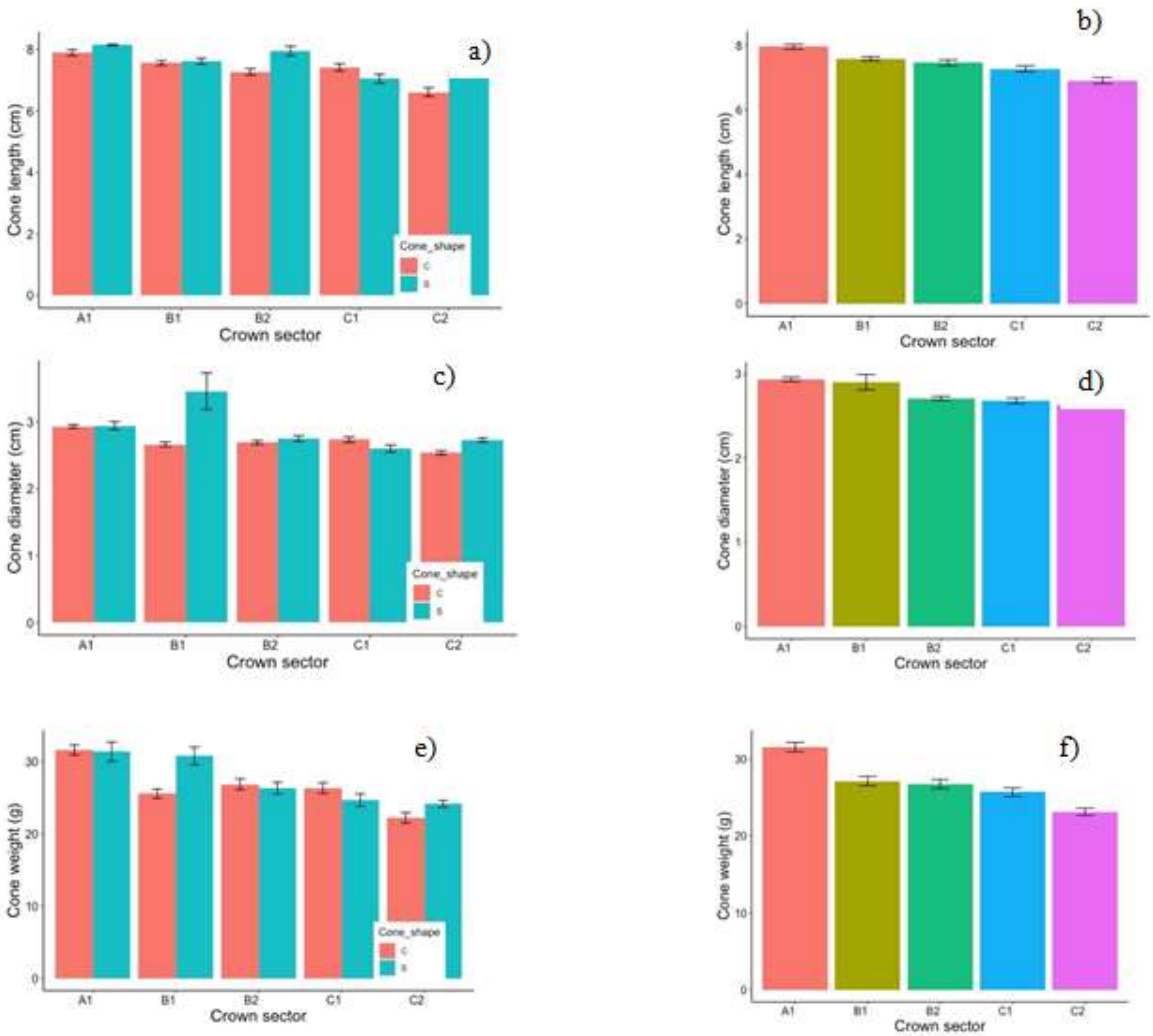

Figure 3. Histograms showing cone length (cm) (a,b), cone diameter (cm) (c,d) and cone weight (g) (e,f) by crown compartment (A1,B1,B2,C1,C2) and shape (C=Curved, S=Straight).

not significantly different in terms of weight ($p>0.05$) but were significantly different from all the others ($p<0.05$) (Figure 3e). These findings are in accordance with observations of Ayari et al. (2012) and Bilir et al. (2008) for other *Pinus* spp. within the same family.

It has been reported from previous studies that from the widest part of the cone to the bottom end, it does not produce viable seed (Bladé and Vallejo, 2008; Valera and Kageyama, 1991). For extraction, it would not be prudent to try to extract from that area of the cone but to try to improve the efficiency of extracting from the other parts. Our study also did not try to extract from that part of the cone but pushed for maximum possible percent opening for rapid seed extraction. With Onyango et al. (In print) obtaining 73% as the highest percentage of opening using temperature and soaking treatment. We observed that cones from compartment C2 had the highest percentage of opening at 46.6±1.98%, which was significantly different ($p<0.05$) when compared with compartment A1, B2, and C1, but there was no significant different ($p>0.05$) when compared with B1 (Figure 4b).

Analysis of seed yield showed no significant difference ($p>0.05$) between straight and curved cones from compartment A1 (Figure 4a and c). Straight cones from compartment A1 and curved cones from B2 showed a

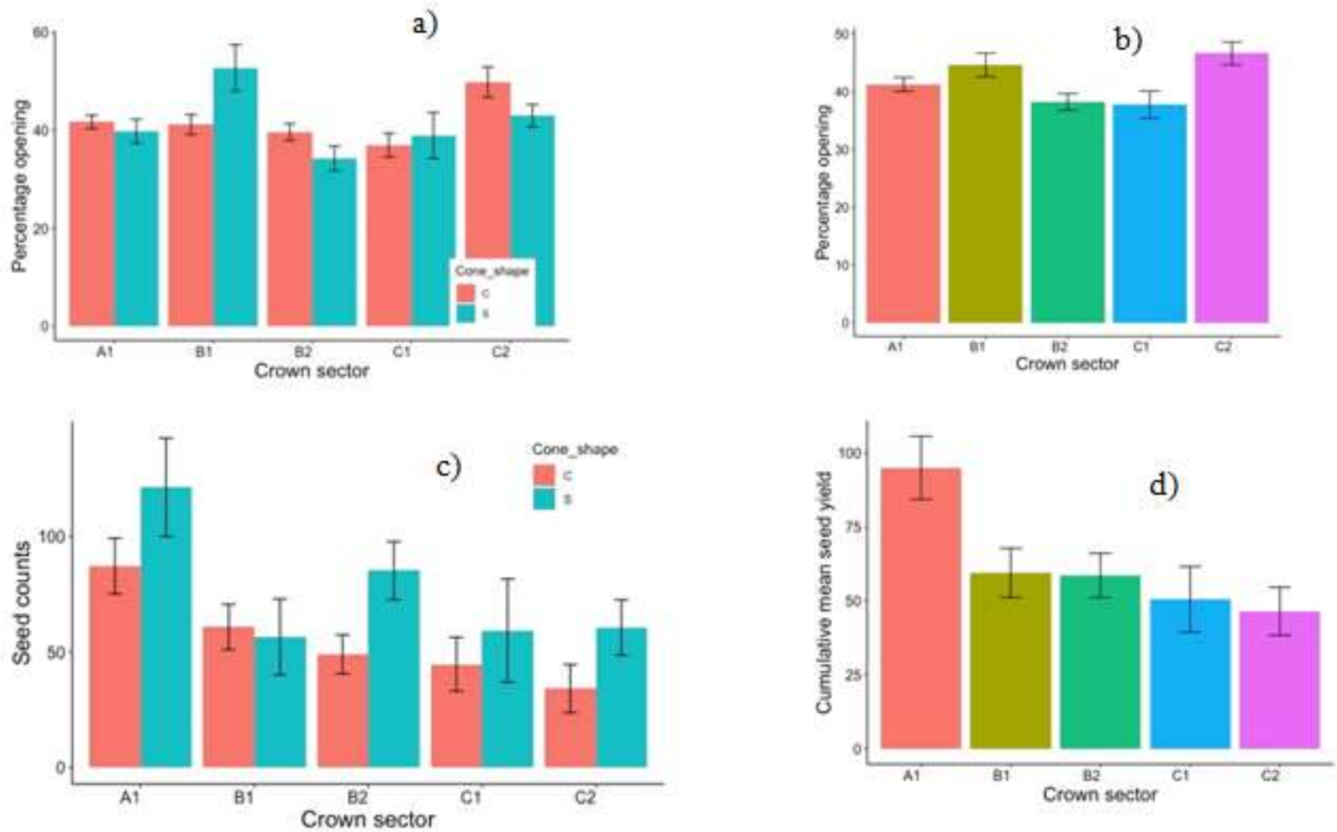

Figure 4. Percent opening of cone and seed yield by crown compartment and cone shape.

significant difference (p<0.05) in seed yield (Figure 4c). The study further revealed that the overall cumulative mean number of seeds was the highest from cones collected from compartment A1 at 33.3±4.91 seeds, while C2 had the lowest at 14.4±2.76 seeds (Figure 4d). These results agree with a similar observation by Iwaizumi et al. (2008) in their study on another pine family, *Pinus densiflora*. The research has also revealed that although compartment C2 had the highest percentage of opening at 46.6±1.98%, which did not translate to high seed yield. Further study of the embryonic development and variation in seed production within an individual cone would be prudent, especially in cones at lower crown compartments.

The upper crown compartments (A and B) was observed to outperform the bottom compartment (C), thereby calling for stands to be managed through pollarding early and regularly to minimize variations in crown compartments, especially for clonal seed orchards. In areas where seed collection is not from clonal seed orchard seed collection for *P. patula* should focus on top (A) and middle (B) parts of the crown compartments to guarantee the quantity and quality seed production. Future studies should focus on comparison within families and genetic variability of *P. patula* clonal seed orchards.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Albrecht J (1993). Tree seed handbook of Kenya. Nairobi, Kenya: GTZ Forestry Seed Centre Muguga (W. Omondi, J. O. Maua, & F. N. Gachathi (eds.); 2nd ed.). Kenya Forestry Research Institute. https://www.worldcat.org/title/tree-seed-handbook-of-kenya/oclc/38979878

Aniszewska M (2006). Connection between shape of Pine (*Pinus sylvestris*) cones and weight, colour and number of seeds extracted from them. Electronic Journal of Polish Agricultural Universities, 03.pdf

Ayari A, Zubizarreta-Gerendiain A, Tome M, Tome J, Garchi S, Henchi B (2012). Stand, tree and crown variables affecting cone crop and seed yield of Aleppo pine forests in different bioclimatic regions of Tunisia. Forest Systems 21(1):128-140. https://doi.org/10.5424/fs/2112211-11463

Ayari A, Khouja ML (2014). Ecophysiological variables influencing Aleppo pine seed and cone production: A review. Tree Physiology 34(4):426-437. https://doi.org/10.1093/treephys/tpu022

Bilir N, Prescher F, Lindgren D, Kroon J (2008). Variation in cone and seed characters in clonal seed orchards of *Pinus sylvestris*. New Forests 36(2):187-199. https://doi.org/10.1007/s11056-008-9092-9

Bladé C, Vallejo VR (2008). Seed mass effects on performance of *Pinus halepensis* Mill. seedlings sown after fire. Forest Ecology and Management 255(7):2362-2372. https://doi.org/10.1016/j.foreco.2007.12.039

Calama R, Montero G (2007). Cone and seed production from stone pine (*Pinus pinea* L.) stands in Central Range (Spain). European Journal of Forest Research 126(1):23-35. https://doi.org/10.1007/s10342-005-0100-8

Chamshama SAO, Nwonwu FOC (2004). Lessons Learnt on Sustainable Forest Management in Africa Forest Plantations In Sub-Saharan Africa Forest plantations in Sub-Saharan Africa, p. 55.

Cheboiwo JK (2018). Public Private Partnerships Opportunities for Forestry Sector Development in Kenya: Synthesis of Primary and Secondary Production. Actors and Trade 8(1):47-69.

Debain S, Curt T, Lepart J, Prevosto B (2003). Reproductive variability in *Pinus sylvestris* in southern France: Implications for invasion. Journal of Vegetation Science 14(4):509. https://doi.org/10.1658/1100-9233(2003)014[0509:rvipsi]2.0.co;2

Dyson WG (1964). Tree Seed Improvement In Kenya. The Commonwealth Forestry Review 213-217. http://www.jstor.org/stable/42603195

Guo Z, Peng B, Liu Y, Li J, Pei W, Li Q, Zheng Y (2020). Extremely Ice-Detached Array of Pine Needle-Inspired Concave-Cone Pillars. Advanced Materials Interfaces 7(2):1-6. https://doi.org/10.1002/admi.201901714

Hall D, Zhao W, Wennström U, Andersson GB, Wang XR (2020). Parentage and relatedness reconstruction in *Pinus sylvestris* using genotyping-by-sequencing. Heredity 124(5):633-646. https://doi.org/10.1038/s41437-020-0302-3

Iwaizumi MG, Ubukata M, Yamada H (2008). Within-crown cone production patterns dependent on cone productivities in *Pinus densiflora:* Effects of vertically differential, pollination-related, cone-growing conditions. Botany 86(6):576-586. https://doi.org/10.1139/B08-024

Kariuki JG (1998). Provenance and family-within-provenance variation in *Pinus patula, Pinus patula* subspecies tecunumanii and *Pinus oocarpa* planted at Turbo, Kenya. Forest Ecology and Management, 107(1-3):127-133. https://doi.org/10.1016/S0378-1127(97)00327-7

Karlsson C (2000). Seed production of *Pinus sylvestris* after release cutting. Canadian Journal of Forest Research 30(6):982-989. https://doi.org/10.1139/x00-035

Kaviriri DK, Liu X, Fan Z, Wang J, Wang Q, Wang L, Khasa D, Zhao X (2020). Genetic variation in growth and cone traits of *Pinus koraiensis* half-sib families in Northeast China. Phyton-International Journal of Experimental Botany 89(1):57-69. https://doi.org/10.32604/phyton.2020.08409

Limpens J, van Egmond E, Li B, Holmgren M (2014). Do plant traits explain tree seedling survival in bogs? Functional Ecology 28(1):283-290. https://doi.org/10.1111/1365-2435.12148

Loewe-Muñoz V, Balzarini M, Del Río R, Delard C (2019). Effects of stone pine (*Pinus pinea* L.) plantation spacing on initial growth and conelet entry into production. New Forests 50(3):489-503. https://doi.org/10.1007/s11056-018-9672-2

Loewe-Muñoz V, Balzarini M, Delard C, Del Río R, Álvarez A (2020). Inter-annual variability of *Pinus pinea* L. cone productivity in a non-native habitat. New Forests 1-14. https://doi.org/10.1007/s11056-020-09774-6.

Marunda C, Fongnzossie EF, Kemeuze VA, Mutta D, Tasmania F, Branch PP, Forum AF (2019). Tree germplasm management systems and their potential for sustaining plantation forestry in West and Central Africa. African Journal of Rural Development 4(1):33-63.

Marunda CT, Mutta D, Gapare WJ, Alves T (2019). Situational analysis of trends in tree improvement and germplasm production and impacts on sustainable forest management in Southern Africa. African Journal of Rural Development 4(1):1-31.

Montagnini F, Ugalde L, Navarro C (2003). Growth characteristics of some native tree species used in silvopastoral systems in the humid lowlands of Costa Rica. Agroforestry Systems 59(2):163-170. https://doi.org/10.1023/A:1026351812036

Moreno-Fernández D, Cañellas I, Calama R, Gordo J, Sánchez-González M (2013). Thinning increases cone production of stone pine (*Pinus pinea* L.) stands in the Northern Plateau (Spain). Annals of Forest Science 70(8):761-768. https://doi.org/10.1007/s13595-013-0319-3.

Nel A (2002). Factors Influencing Controlled Pollination of *Pinus patula* (Doctoral dissertation).

Nguyen TT, Tai DT, Zhang P, Razaq M, Shen HL (2019). Effect of thinning intensity on tree growth and temporal variation of seed and cone production in a *Pinus koraiensis* plantation. Journal of Forestry Research 30(3):835-845. https://doi.org/10.1007/s11676-018-0690-x

Onyango AA, Angaine PM, Inoti SK, Owino JO (2020). Patula pine (*Pinus patula*) cone opening under different treatments for rapid seed extraction in Londiani, Kenya. Journal of Horticulture and Forestry 12(2):63-69. https://doi.org/10.5897/JHF2020.0633.

Owens JN (1995). Constraints to seed production: Temperate and tropical forest trees. Tree Physiology. 15(7-8):477-484. https://doi.org/10.1093/treephys/15.7-8.477

Tong Y, Durka W, Zhou W, Zhou L, Yu D, Dai L (2020). Ex situ conservation of *Pinus koraiensis* can preserve genetic diversity but homogenizes population structure. Forest Ecology and Management 465:117820. https://doi.org/10.1016/j.foreco.2019.117820

Udval B, Batkhuu NO (2013). Seed and Cone Characteristics of Scots pine (*Pinus sylvestris* L.) from Diverse Seed Sources in Northern Mongolia. Eurasian Journal of Forest Research 16(1):57-62.

Valera FP, Kageyama PY (1991). *Pinus patula* Schiede and Deppe. Seedleaflet No. 8A. (Issue 1991).

Weng YH, Liu KJ, Chen YB, Li Y, Wang J, Meng QF (2020). Variation in cone and seed traits in a clonal seed orchard of red pine (*Pinus koraiensis* Sieb. et Zucc.). Scandinavian Journal of Forest Research 35(1-2):1-9. https://doi.org/10.1080/02827581.2020.1725620

농업생명과학연구 (2019). A Study on the Growth Variation of the *Pinus densiflora* and *Prunus serrulata* by the Depth of the Soil Covering. Journal of Agriculture and Life Science. http://db.koreascholar.com/article?code=366932.