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Research Article

Stand Age and Diameter Class Effect on Seed Production of *Pinus kesiya* Royle ex Gordon grown in Malawi

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Abstract: Seed production is the first stage of plant restoration. A study was conducted to investigate the influence of stand age and dbh class on seed production of *Pinus kesiya*, with much emphasis on number of cones, seed weight, seed quantity, and seed viability. Cones were collected from *Pinus kesiya* stands of 20, 25, 30 and 39 years old in Chongoni Forest Plantation, Malawi. The results shows that stand age and dbh class significantly ($p<0.001$) affected seed production. Number of cones, seed weight and quantity increased as the stand age increases and reached the maximum at 25 years (maturity age) up to 30 years of age (rotational age) then gradually decreased. The differences may be attributed to metabolic processes which are highly intensified at maturity age and rotational age. On the other hand, number of cones, seed weight and quantity increased with an increase of dbh class. Neither stand age nor dbh class ($p>0.05$) influenced seed viability. This imply that as long as mature seeds are collected they will germinate irrespective of stand age or dbh class. Stand age and dbh class had strong polynomial ($r>0.99$, $p=0.05$) and linear ($r>0.97$, $p=0.05$) relationship with number of cones, seed weight and quantity per tree respectively. This entails that stand age and dbh class could be used as parameters for predicting seed production. However, there were weak relationship between both stand age ($r=0.259$, $p=0.966$) and dbh class ($r=0.059$, $p=0.941$) on seed viability. Furthermore, the results shows that at individual tree level, dbh class was a better predictor of seed production than stand age, while stand age was a better predictor than dbh class of seed production at stand level. It is therefore, recommended that seeds of *Pinus kesiya* should be collected from the stands of 25 to 30 years old in Malawi and the surrounding countries in order to maximize seed production. However, if seed collection is to be done on individual mother trees, then it is recommended to collect from trees of higher dbh (≥36 cm).
Keywords: Cones, Seed weight, Quantity, Viability, Rotational age, Maturity age

INTRODUCTION

Viglas *et al*. [1] defined a seed as a small-embryonic plant enclosed in a seed coat, commonly with some food stored on it. Seed production is the first stage of plant restoration [2]. However, natural seed production can be influenced by stand and tree characteristics such as tree age, diameter and breast height (dbh) and health of tree crown among others [2, 3]. Therefore, understanding the effect of these factors on seed production is vital to forest management, especially in the production of vigour seedlings [4].

The effect of tree age on seed production in various tree species have been studied by many researchers [1, 3 – 11], but there is no regular trend on tree age and seed production. For example,the seed production of *Pinus pinaster* [5] and *Pinus sylvestris* [6] increased steadily with tree age. Grayson *et al*. [7] and Vidakovich [8] reported that *Pinus echinata* and *Abies normandiana* produced more quantitative and qualitative seeds during the mid-age period, respectively. Contrary, there were no significant differences on seed weight and viability among difference tree ages for *Pinus pongence* [4], *Pinus longaera* [9] and *Cistus albidus* [10].

Pinus kesiya Royle ex Gordon is one of the major exotic plantation species in Malawi and other Southern African countries. It grows naturally in the Himalaya regions of Asia. The morphological description, its uses and application in Malawi has been well explained by [11–13]. Even though, *Pinus kesiya* seeds are being extensively and intensively collected for plantation establishment in Malawi, most of them are from old seed orchards which are at least 40 years old [14].Despite this, there is no information about the relationship between tree age and seed production in *Pinus kesiya*. Therefore, the purpose of this study was to (1) investigate the influence of stand age and dbh class on seed production of *Pinus kesiya*, with much emphasis on number of cones, seed weight, seed quantity, and seed viability, (2) develop equations that would be used to estimate the number of cones, seed weight, seed quantity, and viable seeds based on stand age and dbh of *Pinus kesiya* using regression method. The estimates of parameters would be incorporated into decision support system in Malawi to assist the forestry industry to predict changes in the reproductive potential of *Pinus kesiya* overtime and thus anticipating the impacts.

MATERIALS AND METHODS

Study site

This study was conducted in August 2013 in Malawi near the tropical savannah region in Southern Africa at Chongoni Forest Plantation in Dedza. Chongoni is located between latitudes 14°10'S and 14°21'S and longitudes 34°09'E and 34°17'E and between 1570 m and 1690 m above sea level. It receives 1200 mm to 1800 mm rainfall per annum, with a mean annual temperature of 14°C. It is situated about 85 km south east of Lilongwe the capital.

Forest stands, tree sampling and data collection

Four stands of 2.0 ha each were selected for this study. The stands were 20, 25, 30 and 39 years old. The 30 years old stand acted as a control because the rotation age of *Pinus kesiya* in Malawi is 30 years [11]. A total of 420 trees (105 trees per stand) were systematically selected and measured for total height and diameter at breast height (dbh). Suunto clinometer and calliper were used to measured total height and dbh respectively. The characteristics of the data are presented in Table 1.Cones in each tree were counted physically using a bicycle ladder on each side of the tree. These estimates were then multiplied by two to account for both sides of the tree. Only cones in the period of fruiting were counted and recorded.

The aspect or orientation has an impact on seed production. The upper and middle parts of the crown produces best cones, fruits and seed for many species with the middle portion giving the most productive well-fired viable seeds [15]. Therefore, the present study also considered the factor of branch levels. This led to the incorporation of tree architectural development method [16] as the seed collection sampling method, to mitigate orientation and branch level effects. Therefore, cones were collected from the stands before the opened up so that loss of seed is prevented. As cones mature, they lose moisture and change colour from a purplish-green to brown to grey [1]. Therefore, colour was used as an indicator to distinguish between mature and immature cones, hence only mature cones were collected. Four cones were collected from each of the three branch level of the trees and three cones per cardinal point, totalling to 36 cones per tree.

Cones from each tree were separately air dried until almost opened and the seeds were counted by hand and recorded. Then, 100 seeds per tree were randomly selected, weighed and recorded. The seeds were tested for viability using the procedure as outlined by [1].

Statistical analysis

Data obtained were tested for normality and homogeneity with Kolmogorov-Smirnov D and normal probability plot tests using Statistical Analysis of Systems software version 9.1.3 [17]. After the two criteria were met the data were subjected to analysis of variance (ANOVA) using the same Statistical Analysis of Systems software and means were separated with Fischer's least significant difference (LSD) at the 0.05 level.Regression analysis was used to determine the relationship between the two predictor variables, tree age and dbh and the four response variables, number of cones, seed weight, seed quantity, and seed viability.

Table 1: Characteristics of the growth data set

Stand age (years)	Variable	Mean±s.e.	Standard deviation	CV%
20	Height (m)	20.1±0.9	1.28	6.4
	dbh (cm)	26.3±0.5	2.04	7.8
25	Height (m)	23.7±0.8	1.86	7.8
	dbh (cm)	31.2±0.3	2.91	9.3
30	Height (m)	26.9±0.9	1.84	6.8
	dbh (cm)	36.4±0.4	2.09	5.7
39	Height (m)	28.3±0.7	1.73	6.1
	dbh (cm)	37.6±0.3	2.46	6.5

s.e. is standard error; CV is coefficient of variation

RESULTS AND DISCUSSION

Stand age influence on number of cones, seed weight and quantity and seed viability

Summary of the results on mean number of cones, seed weight and seed quantity and seed viability per tree as influenced by stand age are presented in Table 2. The results shows that there were significant ($p<0.001$) differences on the number of cones, seed weight and quantity per tree among the stand age. Number of cones, seed weight and quantity increased as the stand age increases and reached the maximum at 30 years of age then gradually decreased. The results indicates that number of cones, seed weight and quantity positively increases towards the rotational age and then decline after that. At the rotational age of *Pinus kesiya* the metabolic processes are highly intensified [4] and this explains why the stand age of 30 years gave the highest values. However, there were no significant (p>0.05) differences between the stand age of 25 and 30 years on the number of cones, seed weight and quantity, even though the stand age of 30 years had higher values than the stand age of 25 years. The reason behind this is that 25 years of age is the maturity age of *Pinus kesiya* and fertility of the tree intensifies during that age [4, 5]. Additionally, the results shows higher values of coefficient of variation (CV%) for number of cones (29.1%), seed weight (26.7%) and seed quantity (29.7%) per tree. This means that number of cones, seed weight and quantity were highly dispersed from their means, indicating that the trees in each stand were not from the same mother tree [18].

The present results are in agreement to those in literature [7, 8, 19, 20]. Fryer [19] and Reeves [20] reported high seed quantity production at the mid-age of *Pinus albicaulis* and *Pinus pungens* respectively. Contrary to this, the seed production of *Pinus pinaster*[5] and *Pinus sylvestris* [6] increased steadily with tree age.The reason behind this differences may be attributed to the genotype of the mother trees [2].

The results further shows that there were no significant (*P*>0.05) differences on the seed viability among the different stand ages.This means that viability of seeds for *Pinus kesiya* does not change regardless of stand age provided that quality mature seeds are collected. The present results are in line to those reported by Connor and Lanner [9] for *Pinus longaeva*. However, the results were different from those reported elsewhere [7, 20, 21]. Reeves [20] and Ganatsas *et al*. [21] reported an increase of seed viability with tree age for *Pinus pungens* and *Pinus pinea* respectively, while Grayson *et al*. [7] observed highest seed viability at the middle age of *Pinus echinata*. These differences may be attributed to maternal environment [9].The present study has revealed that maximum seed production of *Pinus kesiya* occurs from stands that have just matured (25 years) up to the stands that have reached the rotational age (30 years). It is therefore, recommended that seeds of *Pinus kesiya* should be collected from the stands of 25 to 30 years old in Malawi and the surrounding countries in order to maximize seed production.

Table 2: Mean number of cones, seed weight, seed quantity and seed viability per tree of *Pinus kesiya*for different stand ages

Stand Age (years)	Number of cones	Weight (g) of 100 seeds	Seed Quantity	Seed Viability (%)
20	126±2.8[b]	1.37±0.08[b]	7700±300[b]	90.5±1.2[a]
25	132±1.4[a]	1.89±0.06[a]	9900±260[a]	90.6±1.4[a]
30	134±1.9[a]	1.94±0.04[a]	10400±250[a]	90.5±1.3[a]
39	128±1.2[b]	1.48±0.11[b]	8200±150[b]	90.6±1.4[a]
CV (%)	29.1	26.7	29.7	6.1

Note: [a,b] means with different subscript within a column significantly differ (*P*<0.001)

Influence of dbh class on number of cones, seed weight and quantity and seed viability

The results for influence of dbh class on number of cones, seed weight and quantity and seed viability are given in Table 3. The results shows that dbh class had a significant (p<0.001) effect on the number of cones, seed weight and seed quantity per tree. Number of cones, seed weight and quantity increased with an increase of dbh. This indicates that trees of *Pinus kesiya* of higher dbh class (≥36 cm) are better than those of lower dbh class (<36cm), hence they are recommended for seed production. In contrast, there were no significant (p>0.05) differences on seed viability among the different dbh class. This implies that viability of seeds for *Pinus kesiya* does not change irrespective of dbh class so long as quality mature seeds are collected. The results are in agreement to those of [1] who reported a significant difference in seed production of *Picea mariana* with respect to tree basal area. Seed production increased with an increase of tree basal area. Similar to the present results, tree basal area of *Picea mariana* had no influence on seed viability [1].

Table 3: Mean number of cones, seed weight, seed quantity and seed viability per tree of *Pinus kesiya* for different dbh class

dbh class (cm)	Number of cones	Weight (g) of 100 seeds	Seed Quantity	Seed Viability (%)
21.0 – 25.9	115±1.6[d]	1.23±0.06[c]	7300±150[d]	90.3±1.1[a]
26.0 – 30.9	127±1.4[c]	1.54±0.04[b]	8000±200[c]	89.2±1.2[a]
31.0 – 35.9	136±1.5[b]	1.90±0.03[a]	10100±150[b]	91.5±1.3[a]
≥36.0	142±1.5[a]	2.01±0.07[a]	10800±125[a]	91.2±1.5[a]
CV (%)	5.8	7.2	5.9	6.6

Note: [a,b,c,d] means with different subscript within a column significantly differ (p<0.001)

The present results reveals that at individual tree level, dbh class was a better predictor of seed production than stand age. However, at stand level, tree age was a better predictor than dbh class of seed production. Since both age and dbh class were significantly associated to seed production, the choice of which variable to use rest on the specific objective of seed production. For example, when seed production is to be estimated in individual mother trees, dbh may be the best choice because it is much easier and quicker to measure. In contrast, if seed production is to be estimated across many stands, stand age is better. Stand age has the advantage of being measured on the same scale as disturbance frequency, therefore it can be easily linked to disturbance interval [1].

Correlation between the two predictor variables, stand age and dbh and the four studied response variables

Correlation and regression equations results of stand age and dbh class on number of cones, seed weight and quantity and seed viability are presented in Table 4. The results show that stand age had strong polynomial relationship ($r>0.99$, $p=0.05$) with number of cones, seed weight and quantity per tree. On the other hand, dbh class had a strong linear relationship ($r>0.97$, $p=0.05$) with the same response variables. This implies that stand age and dbh class could be used as parameters for predicting seed production of *Pinus kesiya*. The results further shows that there were weak relationship between both stand age ($r=0.259$, $p=0.966$) and dbh class ($r=0.059$, $p=0.941$) on seed viability. The weak relationship could imply that as long as mature seeds are collected they will germinate irrespective of stand age or dbh class. Additionally, the weak relationship suggests that there are other dominant effects on seed viability, especially the maternal environment [9]. The present results are in line with those of [19, 20] who reported a strong relationship between tree age and seed production on*Pinus albicaulis* and *Pinus pungens* respectively. The weak relationship between tree age and seed viability on *Pinus longaeva* [9] also support the findings of the present study.

Table 4: Regression equations between the two predictor variables, tree age and dbh and the four response variables, number of cones, seed weight, seed quantity, and seed viability per tree of *Pinus kesiya*

Variable	Number of cones	Weight (g) of 100 seeds	Seed Quantity	Seed viability (%)
Stand age (years)	$Y=63.5+4.68X-0.08X^2$	$Y=-3.5+0.36X-0.006X^2$	$Log_{10}Y=2.8+0.08X-0.001X^2$	$Y=90.4+0.008X-0.0001X^2$
	r=0.999	r=0.990	r=0.997	r=0.259
	p=0.008	p=0.014	p=0.008	p=0.966
dbh (cm)	$Y=1.71X+81.83$	$Y=0.05X+0.23$	$Log_{10}Y=0.012X+3.63$	$Y=0.009X+90.3$
	r=0.994	r=0.984	r=0.973	r=0.059
	p=0.006	p=0.016	p=0.027	p=0.941

CONCLUSION

Stand age and dbh class significantly affected seed production (number of cones, seed weight and quantity) per tree of *Pinus kesiya*. Number of cones, seed weight and quantity increased as the stand age increases and reached the maximum at 25 years (maturity age) up to 30 years of age (rotational age) then gradually decreased. The differences may be attributed to metabolic processes which are highly intensified at maturity age and rotational age. On the other hand, number of cones, seed weight and quantity increased with an increase of dbh class. Neither stand age nor dbh class influenced seed viability of *Pinus kesiya*. This imply thatas long as mature seeds are collected they will germinate irrespective of stand age or dbh class. Stand age and dbh class had strong polynomial and linear relationship with number of cones, seed weight and quantity per tree respectively. This entails that stand age and dbh class could be used as parameters for predicting seed production of *Pinus kesiya*. However, there was weak relationship between both stand age and dbh class on seed viability. Furthermore, the results shows that at individual tree level, dbh class was a better predictor of seed production than stand age, while stand age was a better predictor than dbh class of seed production at stand level. It is therefore, recommended that seeds of *Pinus kesiya* should be collected from the stands of 25 to 30 years old in Malawi and the surrounding countries in order to maximize seed production. However, if seed collection is to be done on individual mother trees, then it is recommended to collect from trees of higher dbh (≥36 cm).

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REFERENCES

1. Viglas JN, Brown CD, Johnstone JF; Age and size effects on seed productivity of northern black spruce. Canadian Journal of Forest Research, 2013; 43(6): 534 – 543.
2. Mao P, Han G, Wang G, Yu J, Shao H; Effects of age and stand density of mother trees in early *Pinus thunbergii* seedlings establishment in the coast zone, China. The Scientific World Journal, 2014; 2014, Article ID 468036, 9 pages.
3. Leadem CL, Gillies SL, Yearsley HK, Sit V, Spittlehouse DL, Burton PJ; Field studies in

seed biology. British Columbia Ministry of Forests, Victoria, BC, 1997.

4. Espahbodi K, Hosseini SM, Mirzaie-Nodoushan H, Tabari M, Akbarinia M, Dehghan-Shooraki Y; Tree age effects on seed germination in *Sorbus torminalis*. General Applied Plant Physiology, 2007; 33(1-2): 107 – 119.
5. Alvarez R, Valbuena L, Calvo L; Influence of tree age on seed germination response to environmental factors and inhibitory substances in *Pinus pinaster*. International Journal of Wildland Fire, 2005; 14(3): 277 – 284.
6. Mukassabi TA, Polwart A., Coleshaw T, Thomas PA; Scots pine seed dynamics on a waterlogged site. Trees, 2012; 26: 1305 – 1315.
7. Grayson KJ, Wittwer RF, Shelton MG; Cone characteristics and seed quality 10 years after an uneven-aged regeneration cut in shortleaf pine stands. General Technical Reports SRC-48, Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC, USA, 2002.
8. Vidakovich M; Conifers, morphology and variation. Graficki Zavod Hrvatske, Coroatia, Zagreb, 1991.
9. Connor KF, Lanner RM; Effects of tree age on pollen, seed and seedling characteristics in Great Basin bristlecone pine. Botanical Gazette, 1991; 152(1): 107 – 113.
10. Muller M, Siles L, Cela J, Munne-Bosch S; Perennially young: seed production and quality in controlled and natural populations of *Cistus albidus* reveal compensatory mechanism that prevent senescence in terms of seed yield and viability. Journal of Experimental Botany, 2014; 65: 287 – 297.
11. Missanjo E, Kamanga-Thole G, Manda V; Estimation of genetic and phenotypic parameters for growth traits in a clonal seed orchard of *Pinus kesiya* in Malawi. ISRN Forestry, 2013; 2013, Article ID 346982, 6 pages.
12. Missanjo E, Mwale G; A mixed-effect Height-Diameter model for *Pinus kesiya* in Malawi. Journal of Biodiversity Management and Forestry, 2104; 3(2): 7pages.
13. Missanjo E, Kamanga-Thole G; Impact of site disturbances from harvesting and logging on soil physical properties and *Pinus kesiya* tree growth. International Scholarly Research Notices, 2014; 2104, Article ID 323626, 7 pages.
14. Chilima CZ; Forestry Research Institute of Malawi Leaflet No. 2012002. FRIM, Malawi, 2012.
15. Mathews JD; Seed production and seed certification. Unasylva No. 73 -74 FAO/IUFRO. Available from http://www.fao.org/docrep/03650e/03650e0b.htm
16. Vennetier M, Girald F, Taugourdeau O, Cailleret M, Caraglio Y, Sabatier SA *et al*.; Climate Change impact on tree architectural development and leaf area. Oceanography and atmospheric sciences, Edited by Bharat Raj Singh, 2013.
17. SAS 9.1.3; Qualification Tools User's Guide. SAS Institute Inc., Cary, NC, USA, 2004.
18. Walck C; Hand-book on Statistical Distributions for experimentalists. University of Stockholm, Sweden, 2007.
19. Fryer JL; *Pinus albicaulis*. Fire Effects Information System, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fires Sciences Laboratory, 2002.
20. Reeves SL; *Pinus pungens*.Fire Effects Information System, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fires Sciences Laboratory, 2007.
21. Ganatsas P, Tsakaldimi M, Thanos C; Seed and cone diversity and seed germination of *Pinus pinea* in Strofylia site of the natura 2000 network. Biodiversity and Conservation, 2008; 17(10): 2427 – 2439.