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Variation in Seed and Cone Characteristics of Loblolly Pine (*Pinus taeda* L.) Families in Southern Part of Korea

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Abstract

Loblolly pine (*Pinus taeda* L.) is widely distributed in the southern part of the United States and it has been used as a major economic species in the region due to its excellent growth and stem straightness. The tree also grows only in the southern part of Korea because it is susceptible to cold. Recently climate changes have had widespread impacts on forest trees. Thus, the use of good quality seeds is prerequisite for assessing assisted migration adaptation trial. In this study, we conducted to investigate its cone and seed characteristics of each family, which is expected to improve seeds productivity for planting valuable timber trees. A total of 14 families were selected from the experimental forest in Boseong, Jeonnam province in 1981. The seed production capacity was estimated to range from 87.2 to 129.4 among families and the average was 111.3. The number of aborted ovules was investigated in the range of 11.4 to 29.5 for the first test and 7.4 to 22.2 for the second test. The average number of empty and filled seeds was 1.4 and 79.2 per cone, respectively. Based on the results, we can conclude that there is a strong correlation between the number of fertile scale and the seed production ability.

Key Words: climate change, cone, seed orchard, loblolly pine, *Pinus taeda* L., provenance test

Introduction

Loblolly pine (*Pinus taeda* L.) is widely distributed in the southern part of the United States and it has been used as a major economic species in the region for its excellent growth and stem straightness (Svensson et al. 1999; Li et al. 1999; Mackay et al. 2006). The tree grows only in the southern part of Korea since it is susceptible to cold (Kim et al. 2003; Kwon et al. 2007). Recently climate changes have had widespread impacts on forest trees. According to the IPCC's fifth evaluation report, the growth rate of atmospheric CO_2 has increased by 35% for the last 100 years and global warming is occurring much more rapidly than expected since 1990s. As a result of climate change, global warming is increasing the frequency and severity of extreme weather events around the world, which has changed forest vegetation zone and vegetation phenology (Kim et al. 2009). The range of loblolly pine growing area has the expandability up to middle part of Korea peninsula. Therefore supply of superior seeds is very important. Tree is known to maintain quantity of cone and seed for survival throughout sexual propagation (Bramlett et al. 1977). In addition, genetic gain is predicted from seeds characteristics in the process of genetic resources preservation and breeding (Giertych 1974; Sorensen and Campball 1985; Isik 1986; Han et al. 1990; Sakai and Harada 2001; Yi et al. 2007).

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There is several research papers regarding the seed characteristics and germination properties according to change of cone production in *Pinus densiflora* stands (Choi et al. 2007). Kim and Hur (2013), documented cone and seed characteristics among different cone abundance classes in a seed orchard of *Pinus koraiensis*. However, there are very few studies of cone and seed characteristics of loblolly pine in South Korea. This study, therefore, was conducted to identify the cone and seed characteristics of loblolly pine on its possible expansion of growing areas according to climate change so that the high quality seeds can be secured and distributed.

Materials and Methods

In this study, we conducted to investigate its cone and seed characteristics of each family, which is expected to improve seeds productivity for planting valuable timber trees. A total of 14 families were selected from the experimental forest in Boseong, Jeonnam province in southern part of Korea in 1981. Within those families, we selected five superior trees which have no damages from pest and total of 70 cones from the trees were collected for this study.

Analysis of cone characteristics

We measured the length, diameter, weight and number of seeds of matured cone; and for the analysis on cone, we referenced US Department of Agriculture Analysis Guidelines (Bramlett et al. 1977). We separated the seeds by taking the scale from the bottom, and categorized them into fertile scale and sterile scale; and the capacity of seed production between aborted ovule and developed seeds were calculated separately. The aborted ovule was classified into the first year and the second year of the harvest depending on the size of the ovule. The developed seeds were divided into two groups by checking the soakage after waterlogging: filled seeds and empty seeds.

Results and Discussion

Cone and seed analysis can be applied to estimate actual seed production and potential seed production capacity. In addition, the analysis can identify and quantify the extent and type of loss in seed development stage (Bramlett et al. 1977). Choi et al. (2007) documented that the seed and cone analysis provides information necessary to evaluate seed production. In the results, the average of fresh weight of cones was 36.9 g with 25.2-42.1 g of different within the families, and the average of dry weight was 15.8 g. The average number of scale cone was 115.7 and the average of number scale of fertile and infertile was 63.2 and 52.6, respectively. The seed production capacity was estimated to range from 87.2 to 129.5 among families and the average was 111.3 (Table 1). In this study, the maximum gap in the seed production capacity among families was about half as much and it is necessary to distinguish between good and bad family for seed production. The seed production capacity refers to the biological limit of the number of seeds that each cone can produce; and as the seeds number of cone increases in each plant, the seed productivity may be lowered (Kim and Hur 2013). The number of aborted ovules was investigated in the range of 11.4 to 29.5 for the first test and 7.4 to 22.2 for the second test. The cause of the first aborted ovule is the lack of pollen and the damage caused in the conelet stage (Lee et al. 1984) and the cause of the secondary aborted ovule is due to the high risk of insect damage before the seed coat is formed (Kim and Hur 2013).

The average number of empty and filled seeds in developed seeds was 1.36 and 79.2 per cone, respectively. The number of empty seeds was ranged from 0 to 12.2, and developed seeds were a difference of about 2 times among the families. Empty seeds are caused by the lethal genes of embryos, cone pests and fungi etc. (Bramlett et al. 1977).

As the result of correlation analysis between cone and seed characteristics was a high positive corre There was a positive correlation between the number of fertility scale and seed production capacity ($r=0.80$, $p<0.01$). There was a high positive correlation between the number of developed seed and filled seed ($r=0.95$, $p<0.01$). In the cone characteristics analysis of pine plus stand, high positive correlation was reported that between the number of fertility scale and seed production effectiveness as the 0.799 (Choi et al. 2007). Correlation between cone length and cone weight (Table 2; $r=0.71$ and $r=0.75$; $p<0.01$). As the total number of scale increased, the number of fertility scale increased but the number of infertile scale increased.

Developed seeds means to fully grow, it need to max-

Table 1. Variation in seed number per cone and seed potential of 14 families of *Pinus taeda*

Families provenance	Fresh cone			Dry cone weight (g)	Number of scale			Seed potential	Number of aborted ovules			Number of developed seeds			Weight of filled seed (g)
	Weight (g)	Length (cm)	Width (cm)		Total	Fertility	Sterility		Total	1^{st} year	2^{nd} year	Total	Empty	Filled	
Floyd/G.A	42.1^{a}	7.8^{abc}	2.9^{bcd}	16.7^{ab}	103.7^{d}	60.4^{cde}	43.3^{d}	106.6^{bcd}	36.3^{a}	27.4^{ab}	8.9^{bc}	70.3^{def}	0.0^{b}	70.3^{cdef}	1.7^{abc}
Monroe/M.S	40.2^{ab}	7.6^{abcd}	2.9^{bcd}	16.3^{abc}	118.1^{abc}	63.2^{bcd}	54.9^{abc}	118.1^{ab}	30.5^{ab}	23.2^{abc}	7.4^{c}	87.5^{abcd}	1.2^{b}	86.2^{abcd}	1.7^{abc}
Chatham/N.C	41.7^{a}	8.0^{a}	3.0^{b}	18.1^{a}	121.0^{ab}	63.6^{abcd}	57.4^{ab}	110.4^{bc}	28.8^{ab}	13.2^{d}	15.6^{abc}	81.6^{bcde}	1.4^{b}	80.2^{bcde}	1.6^{bc}
Columbus/N.C	40.8^{ab}	7.9^{ab}	3.3^{a}	17.0^{ab}	122.6^{ab}	71.5^{a}	51.9^{bcd}	129.2^{a}	39.5^{a}	29.5^{a}	10.0^{bc}	89.7^{abc}	0.7^{b}	89.6^{ab}	2.5^{a}
Durhamn/N.C	40.0^{ab}	7.6^{abcd}	3.0^{b}	17.2^{ab}	122.0^{ab}	71.0^{ab}	51.0^{bcd}	129.5^{a}	28.3^{ab}	15.1^{cd}	13.2^{abc}	101.2^{a}	0.3^{b}	100.9^{a}	2.0^{ab}
Hertford/N.C	34.8^{bc}	7.2^{bcde}	2.6^{e}	13.5^{d}	103.0^{d}	52.6^{f}	50.4^{bcd}	90.8^{e}	33.5^{ab}	15.6^{cd}	17.9^{abc}	57.3^{f}	0.0^{b}	57.3^{f}	1.3^{bc}
Richmond/N.C	41.5^{ab}	7.2^{cde}	2.9^{bc}	16.6^{ab}	114.2^{abcd}	68.3^{abc}	45.9^{cd}	120.7^{ab}	29.8^{ab}	12.0^{d}	17.8^{abc}	90.9^{abc}	0.8^{b}	90.1^{ab}	1.8^{abc}
Kershaw/S.C	41.9^{a}	8.0^{a}	3.4^{a}	17.6^{a}	126.8^{a}	65.3^{abc}	61.5^{a}	122.5^{ab}	30.4^{ab}	17.6^{cd}	12.8^{abc}	92.9^{ab}	0.3^{b}	91.8^{ab}	1.8^{ab}
Southampton/V.A	37.5^{abc}	7.5^{abcd}	2.7^{cde}	14.8^{bcd}	106.4^{cd}	53.4^{ef}	53.0^{abc}	94.3^{de}	25.8^{ab}	15.6^{cd}	10.2^{bc}	68.5^{ef}	0.2^{b}	68.3^{def}	1.5^{bc}
Winston/A.L	25.2^{e}	6.8^{e}	2.7^{cde}	13.9^{cd}	122.0^{ab}	65.1^{abc}	56.9^{ab}	110.5^{bc}	38.0^{a}	15.8^{cd}	22.2^{a}	72.6^{cdef}	12.2^{a}	60.3^{f}	1.0^{c}
Fayette/A.L	33.0^{cd}	7.0^{de}	2.9^{bcd}	14.7^{bcd}	121.8^{ab}	67.6^{abc}	54.6^{abc}	122.4^{ab}	19.2^{b}	11.4^{d}	7.8^{c}	103.2^{a}	0.4b	102.8^{a}	1.9^{ab}
King&Gueen/V.A	36.1^{abc}	7.7^{abc}	2.7^{de}	14.8^{bcd}	107.4^{cd}	57.3^{def}	50.1^{bcd}	97.8^{cde}	33.4^{ab}	19.8^{bcd}	13.6^{abc}	64.4^{ef}	0.6^{b}	63.7^{ef}	1.4^{bc}
Northhampton/N.C	28.2^{de}	7.7^{abc}	2.9^{bcd}	13.9^{cd}	110.7^{bcd}	56.4^{def}	54.3^{abc}	87.2^{e}	27.2^{ab}	17.4^{cd}	9.8^{bc}	59.8^{f}	0.2^{b}	59.8^{f}	1.3^{bc}
Sussex/V.A	33.4^{cd}	7.4^{abcd}	2.8^{bcde}	16.2^{abc}	120.0^{ab}	69.3^{ab}	50.3^{bcd}	118.2^{ab}	30.2^{ab}	11.8^{d}	18.4^{ab}	88.0^{abcd}	1.0^{b}	87.4^{abc}	1.7^{abc}
Mean	36.9	7.5	2.9	15.8	115.7	63.2	52.6	111.3	30.8	17.5	13.3	80.51	1.4	79.2	1.7

The different letters indicate significantly different at $p < 0.05$ by Duncan's multiple range test in respective stands.

Table 2. Correlation coefficients of *Pinus taeda* families between cones and seed characteristics

	LC	WC	FWC	DWC	NTS	NFS	NIS	SP	NTAO	NAO1	NAO2	NTDS	NES	NFIS	WFS
LC	1														
WC	0.52	1													
FWC	0.71*	0.71*	1												
DWC	0.79*	0.71*	0.87**	1											
NTS	0.41	0.39	0.28	0.45	1										
NFS	0.36	0.52*	0.43	0.51	0.73*	1									
NIS	0.24	0.06	-0.02	0.15	0.74*	0.09	1								
SP	0.40	0.59*	0.57*	0.59*	0.56	0.8**	0.02	1							
NTAO	0.41	0.31	0.33	0.31	0.16	0.27	-0.04	0.37	1						
NAO1	0.37	0.30	0.35	0.28	0.09	0.19	-0.06	0.31	0.77*	1					
NAO2	0.26	0.17	0.15	0.18	0.15	0.22	0.00	0.25	0.75*	0.16	1				
NTDS	0.08	0.34	0.30	0.34	0.43	0.58*	0.05	0.7*	-0.41	-0.29	-0.33	1			
NES	-0.03	-0.09	-0.22	-0.04	0.15	0.04	0.19	-0.03	-0.07	-0.06	-0.04	0.03	1		
NFIS	0.08	0.36	0.36	0.34	0.36	0.54	-0.01	0.68*	-0.37	-0.26	-0.30	0.95**	-0.29	1	
WFS	0.18	0.33	0.34	0.31	0.13	0.30	-0.11	0.40	-0.05	0.03	-0.11	0.43	-0.16	0.47	1

*LC, Length of cone; WC, Width of cone; FWC, Fresh weight of cone; DWC, Dry weight of cone; NTS, Number of total scales; NFS, Number of fertility scales; NIS, Number of infertility scales; SP, Seed potential; NTAO, Number of total aborted ovules; NAO1, Number of aborted ovules in 1st year; NAO2, Number of aborted ovules 2nd year; NTDS, Number of developed seed; NES, Number of empty seed; NFIS, Number of filled seed; WFS, Weight of filled seed. *$p < 0.05$, **$p < 0.01$.

imize mature seed production with a high quantity and quality pollen supply. In addition, it need to raise developed seed yields to levels comparable to potential seed production by cone pests control (Bramlett et al. 1977). Quantity and quality of pollen in open pollination may not be constant, so the investigation process will be needed for many years.

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