Cone and seed characteristics in the second generation seed orchard of *Pinus thunbergii*

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1 Introduction

◆What is seed orchard?

- A stand created by selecting trees with excellent traits distributed nationwide
- Stable supply of genetically modified superior seeds
- The bridge of tree breeding result, planting and forestry management

Selective tree breeding phase

◆ Research background

Seed orchard

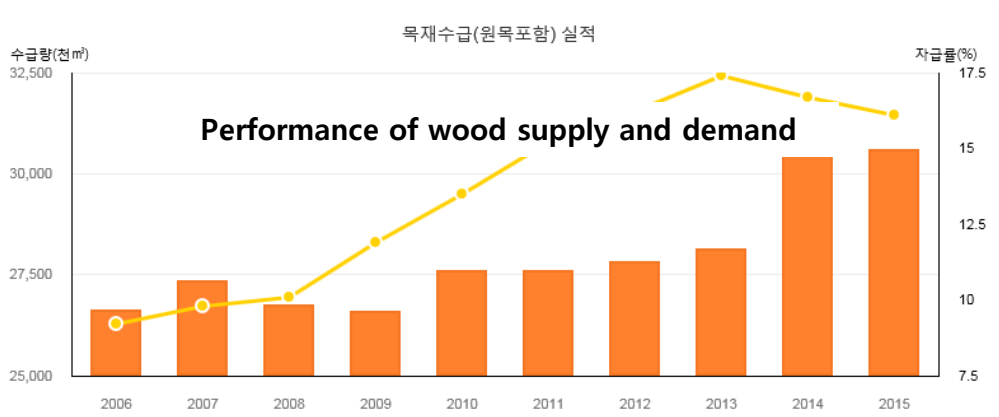
- Improving productivity and quality of seed from Seed orchard
- Fertility, conelet & seed production contribution analysis of constituent species
- Grasp of cone and seed production

Seed

- The seed from seed orchard supply r ate is about 30 percent→ study on ways to increase
- Necessity of establishment a seedling productions system.
- Important of improved seed producti on and supply

Productivity improvement

- Korea's forest area→64.1% of total la nd area
- Self-sufficiency rate of timber →16.1% (2016' statical yearbook of f orestry)
- foster and forestation of commercial forest for stable supply and demand of wood



Performance of wood supply and demand

- **Self-sufficiency rate**
- **Wood supply and demand**

◆ Research subject species

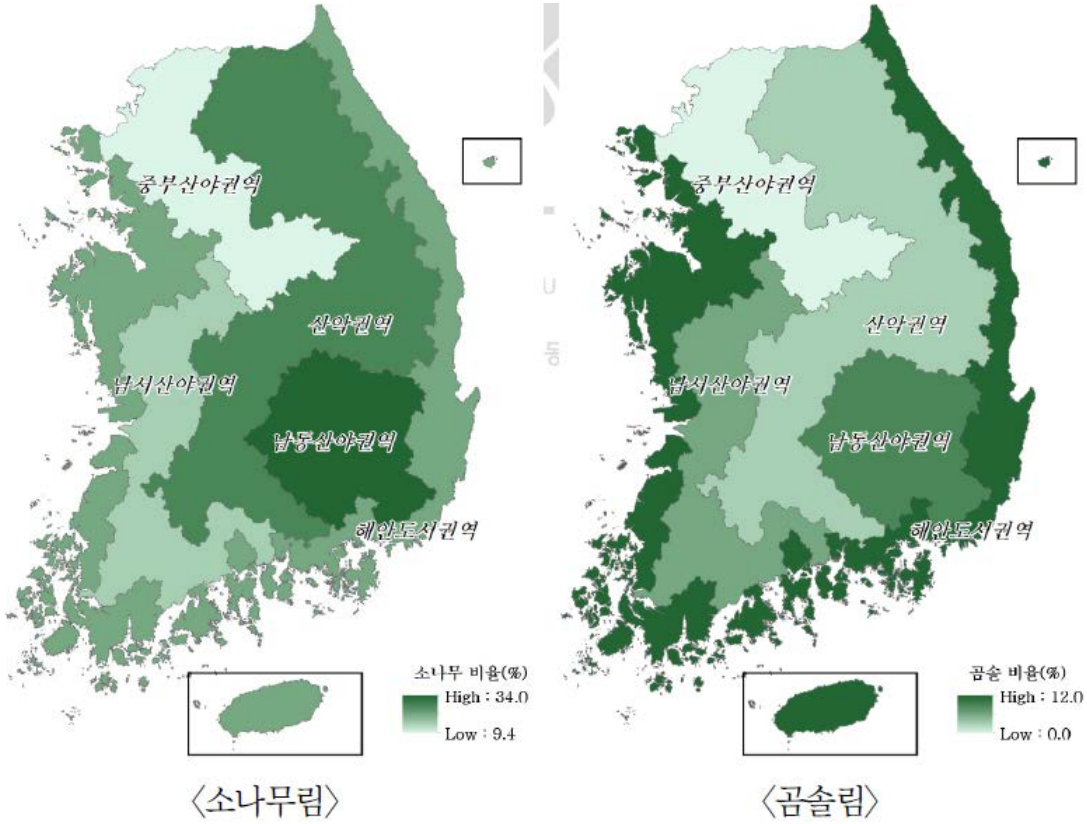
- ***Pinus thunbergii*** **(Korean black pine , 海松)**
  - A representative tree native to the coast of Korea
  - Status of plus tree selection : 151
  - First generation Seed orchard Area : 22 ha
  - Second generation Seed orchard Area : 3 ha

◆ Korean black pine progeny test

- open pollinated progeny test : 69 family, 1.48 ha
- controlled-pollinated progeny test : 317 combination, 3.8 ha

→ As a result of controlled-pollinated progeny test between the composition clone of first generation seed orchard, **create second generations seed orchard** by selecting combinations with excellent growth

◆ Ratio of Pine and Korean Black pine forest to stocking land (%)



〈소나무림〉 〈곰솔림〉

- **Korean black pine**
  - ✓ Physiological and morphological similarities with pine trees.
  - ✓ For the next three years, Fifth of the reforestation plan among conifer trees (249 ha)

◆ Preceding research

- In Korea, there was a study of characteristic of clone, species and seed productions of first generations seed orchard.
- Since the second generations seed orchard in 2006, a lack of research on changes in genetic diversity associated with flowering variations, characteristic of cone or seed.
- Hereafter, it will be necessary to study about advanced generation seed orchard, such as pine trees, nut pine, oak trees which are major commercial species.

◆ Research purpose

1) From seed orchard creations to seed production, proper management plan is important(location selection, arrangement of clone, roguing, etc)
2) Through cone analysis, improving seed quality by analyzing the genetic characteristics of the seeds between matching combinations
3) **As the first** 'second generations seed orchard' of Korea, provide the basic data necessary for the establishment and management(e.g. roguing, artificial pollen supply)

2 Materials and methods

◆ Testing materials : Korean Black pine second-generation seed orchard

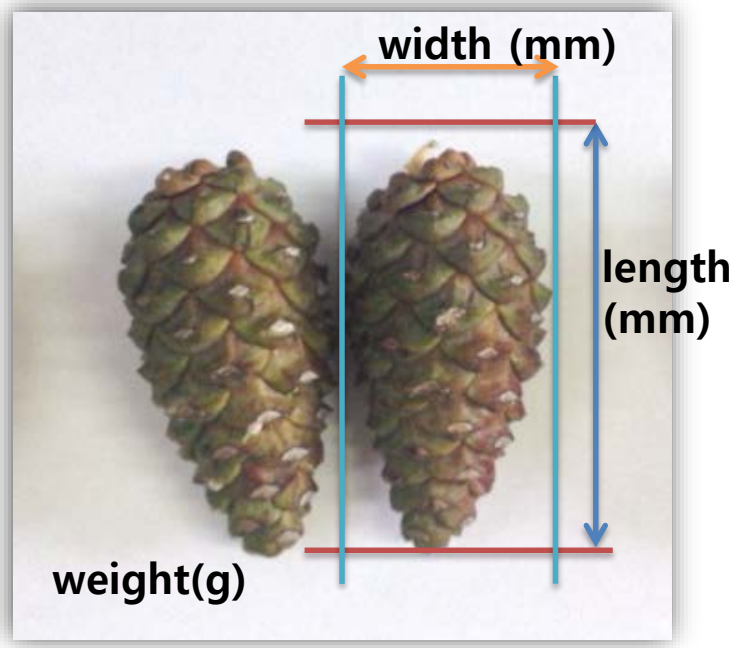
- Creation site : 51-1, Jungjangri, Anmyeon-eup, Taean-gun, Chungcheongnam-do
- Creation year : 2006
- Creation area : 1 ha
- mating combinations : 26 combinations (075 x 0636 etc)
- planting interval : 5m x 5m (square planting)

The frond view of black pine second generation seed orchard

◆ Data collections : Cone collections and morphological characteristic research

- Date and time : September 2014, 2015, 2016 (total 3 times)
- Collection : Total 390 cones(26 combination x 5 cones x 3 times)
- Research traits : lively cone length(mm), width(mm), weight(g) measurement

Korean black pine cone collection and dry

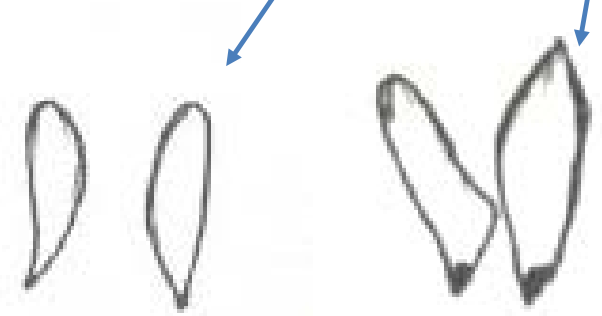


Investigation item of Korean black pine cone characteristics

◆ Cone analysis : Fertile scale elimination and seed separation

Fertile scale elimination and seed separation

Filled seed Empty seed Aborted ovule



Frist-year aborted ovule

Second-year aborted ovule

(Lee et al, 1984)

◆ Analysis item : the number of scale, seed per cone

- scale = fertile scale + non-fertile scale
- seeds = developed ovule + aborted ovule
- seed potential, total developed seeds, % of filled seed, % of aborted ovules, seed efficiency and % of germination (Calculated as follows)
  - ✓ $Seed\ potential = fertile\ scale \times 2$
  - ✓ $Total\ developed\ seeds = filled\ seeds + empty\ seeds$
  - ✓ $Percent\ of\ filled\ seeds = filled\ seeds\ /\ total\ developed\ seeds \times 100$
  - ✓ $Percent\ of\ aborted\ ovules = aborted\ ovules\ /\ seed\ potential \times 100$
  - ✓ $Seed\ efficiency = total\ filled\ seeds\ /\ seed\ potential \times 100$
  - ✓ $Percent\ of\ germination = \frac{Germinated\ seeds}{Filled\ seeds} \times 100$

(USDA Forest service, 1977; Lee et al. 1984)

◆ Statistical analysis : IBM SPSS Statistics 23

1) One-way ANOVA

- Calculate variance component(σ_e^2, σ_c^2) and heritability($\boldsymbol{h^2}$) based on MS

Source of variation	df	EMS	$\boldsymbol{h^2}$
Among clones	C – 1	$\sigma_e^2 + k\sigma_c^2$	$\dfrac{\sigma_e^2}{\sigma_e^2 + \sigma_c^2}$
Within clones	N – C	σ_e^2	

C = Number of clones, N = Number of seed orchard tree

(Kang et al., 2001)

3 Main result

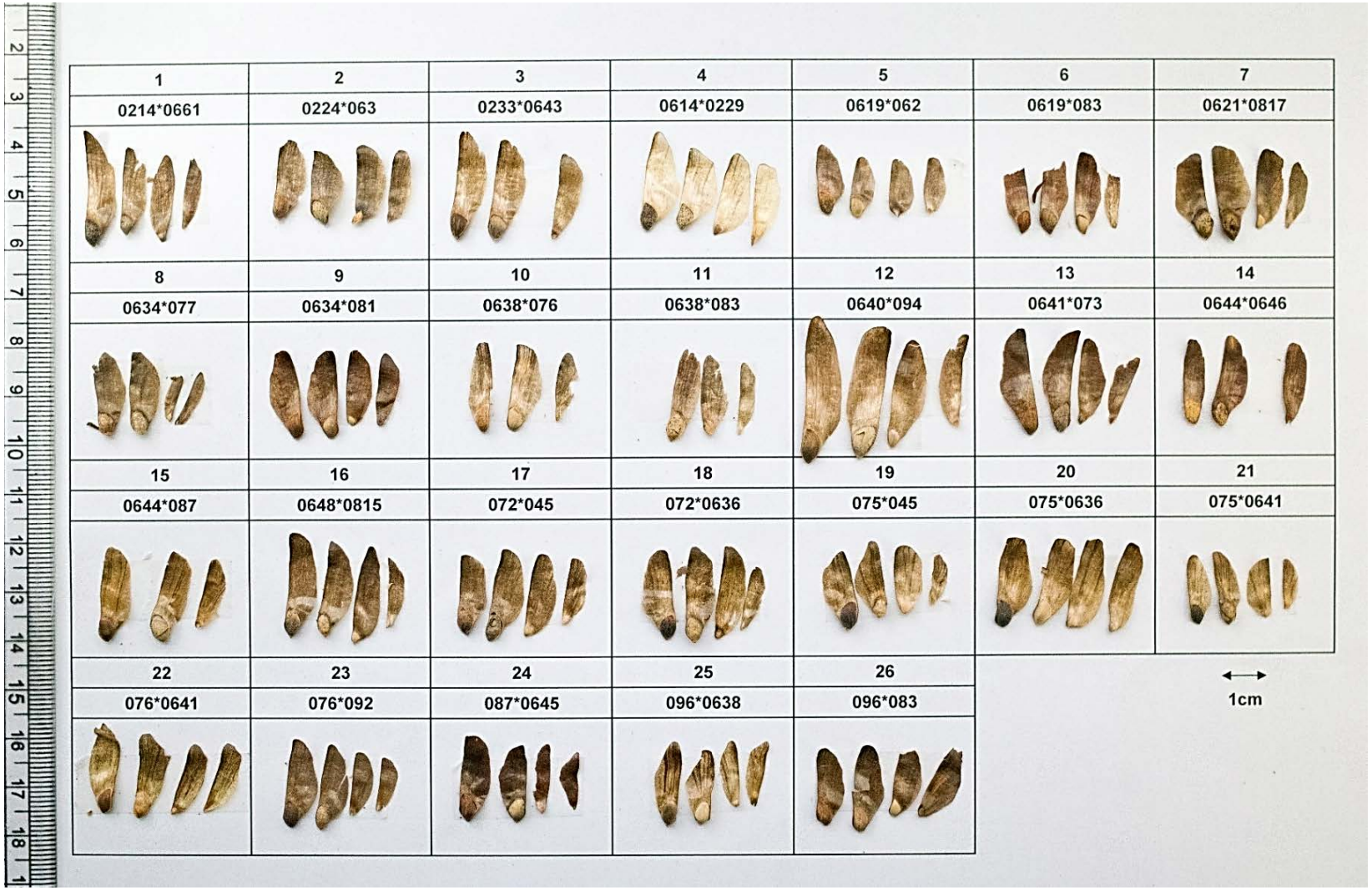
◆ Analysis of cone

Comparison of cone (2015)

◆ Morphological characteristics of cone by year or combination

	Length			Width			Weight		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Mean	55.4	**51.5**	**60.0**	31.4	**29.7**	**31.7**	18.1	22	**28.4**
S.D.	5.32	5.7	6.37	3.31	2.46	2.77	5.13	5.73	6.95
Min	43.3	41.1	52.8	23.7	23.5	23.61	8.6	11.6	16.1
Max	70	73.3	77.8	40.4	38	39.4	31.3	48.9	53.8
CV	0.083	0.098	0.088	0.097	0.072	0.079	0.251	0.224	0.210
Ns	25.8	25.7	25.8	25.8	25.9	25.8	24.5	24.7	24.9
Nr(%)	99.3	99.0	99.3	99.0	99.5	99.4	93.9	95.2	95.8
GD	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

- ✓ 2016 : Cone length, width, weight were excellent
- ✓ 2015 : Most of cones length, width were the lowest



Filled-seed, empty-seed, aborted-ovule forms comparison by combinations (2015)

◆ Analysis of cones by year

year	Seed potential	Aborted ovule	Percent aborted ovule(%)	Number of developed seeds			Percent filled seeds(%)	Seed efficiency (%)
				total	Empty seeds	Filled seeds		
2014	80.4	20.0	24.9	60.4	13.1	47.3	77.6	58.8
2015	80.7	15.8	18.9	65.0	10.0	55.0	84.2	68.5
2016	**96.5**	25.5	23.9	71.0	6.8	64.2	**90.1**	**68.6**

◆Estimation of variance component and heritability(h^2) per year by cone analysis

	2014				2015				2016			
	F	σ_c^2	σ_e^2	h^2	F	σ_c^2	σ_e^2	h^2	F	σ_c^2	σ_e^2	h^2
Length	10.58***	19.1	10.2	**0.651**	12.84***	15.2	28.8	**0.345**	7.09***	201.3	2,292.9	**0.081**
Width	19.43***	8.5	2.7	**0.759**	13.37***	7.2	34.7	**0.171**	10.65***	8.7	18.8	**0.316**
Weight	12.34***	20.9	7.0	**0.748**	12.39***	31.2	37.2	**0.456**	10.60***	37.9	30.0	**0.558**
Seed potential	7.08***	125.8	207.0	**0.378**	4.42***	68.8	141.1	**0.328**	17.48***	293.2	262.1	**0.528**
% developed seeds	11.63***	157.5	67.8	**0.699**	14.13***	113.0	55.0	**0.672**	10.52***	89.4	125.0	**0.417**
% filled seeds	11.49***	159.8	182.8	**0.466**	7.50***	69.3	118.9	**0.368**	4.16***	53.0	162.5	**0.246**
% aborted ovules	16.96***	148.5	50.5	**0.746**	14.13***	154.8	145.5	**0.515**	10.63***	179.8	245.8	**0.422**
Seed efficiency	10.63***	180.3	134.1	**0.573**	13.57***	139.4	71.4	**0.661**	9.82***	182.7	157.1	**0.538**

*** : p<0.05, ** : p<0.01**

- ✓ Cone and seed characteristics show the statistical difference between the combinations.
- ✓ Cone and seed characteristics : under strong genetic control (high heritability)

4 Result summary and conclusion

◆ Result summary

❖ Morphological characteristic of cone :

- 2014 : average cone length 55.4mm, width 31.4mm, weight 18g
- 2015 : average cone length 51.5mm, width 29.7mm, weight 22g
- 2016 : average cone length 60.0mm, width 31.7mm, weight 28.4g

❖ Analysis of cone and seed characteristic :

- 2014 : seed potential 80.4, aborted ovule 24.9%, filled seeds 77.6%, seed efficiency 58%
- 2015 : seed potential 80.7, aborted ovule 18.9, filled seeds 84.2%, seed efficiency 68.5%
- 2016 : seed potential 96.5, aborted ovule 23.9%, filled seeds 90.1%, seed efficiency 68.6%

❖ Estimation of variance analysis and heritability(h^2) :

- Statistical significance is recognized between combinations.
- **Cone and seed characteristics were under strong genetic control.**

  Especially, seed efficiency is more than 0.5 per year

  → under very strong genetic control

◆ Conclusions

1. Cone analysis and seed characteristics analysis result

   ✓ There is a difference in seed quality between year, combinations

   → **Selective cone collection**

   ✓ **Excellent heritability to cone and seed characteristics**

   → Selection index for advanced generation breeding

- **Practical application to the reasonable and efficient management of seed orchard**
- **Need to grading(normal, first or second generation) of seeds from seed orchard and price differential research**

5 Reference

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Thank you