Seed and Cone Characteristics of Scots pine (*Pinus sylvestris* L.) from Diverse Seed Sources in Northern Mongolia

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Abstract

The objective of this study was to determine the variation of seed and cone characteristics of Scots pine (*Pinus sylvestris* L.) from different seed collection sites in the Tujiin nars region of the Selenge province in Northern Mongolia. The cones and seeds of *P. sylvestris* showed significant differences in size and color. There were three major groups in seed coat color, black, brown and light, respectively, that were tested for seed quality. Seed quality was examined by the weight of 1000 seeds, germination energy, and germination capacity. Study results showed considerable disparities in seed quality among the seed color groups. At 92.3 percent, germination of black colored seeds was higher than brown (81.2 percent) and light (60.7 percent) colored seeds. Based on weight of 1000 seeds, average weight of black colored seed was 7.2 g while the weight of brown and light colored seed was 6.4 g and 5.7 g. The highest seed germination energy was observed in the black colored seeds 78.7 percent, and then brown colored seeds 74.3 percent, the lowest germination energy were in light colored seed 46.0 percent, respectively. These findings suggest that seed color group can be considered as one of the crucial indicators for selecting qualified seeds.

Key words: shape of cones, seed color, seed quality, germination energy, germination capacity

Introduction

The forests in Mongolia occur mainly in the northern part of the country, which form a transition between the Siberian taiga forest and the central Asian steppe (World Bank 2002). Closed forests occupy only 8.2 percent of the land area of Mongolia. Most forests in the country are composed of Siberian larch (*Larix sibirica* Ldb.) covering 59 percent of the closed forest area. Other important tree species include Scots pine (*P.sylvestris* L.) covering only 5.2 percent, Siberian pine (*Pinus sibirica* Mayr.), respectively whereas White birch (*Betula platyphylla* Sukacz.) accounts for almost 9 percent.

Scots pine (*P. sylvestris*) is one of the main tree species in Mongolia with great value for water and soil protection as well as equilibrium of an ecosystem. Forest resources in Mongolia have been continuously degraded over the past few years due to improper exploitation for timber and fuel wood, forest and step fires (Tsogtbaatar 2004), insects/pests and diseases, mining, uncontrolled grazing, and inadequate management. Mongolia has lost approximately 1.6 million ha of forests during recent decades including 660 000 ha lost from 1990 to 2000 (World Bank 2002). Therefore, a great interest has developed across Mongolia in reforestation as a result of these significant changes to a limited resource.

Reforestation activity in Mongolia started in 1968. Reforestation activities totaling 100.3 thousand ha cover only 30 percent of all the logged area in the country. For example, reforestation and afforestation activity implemented annually covered about 3.9 thousand ha in 1980-2000, 4.6 thousand ha in 1996-1999 and 8.2 thousand ha in 2002 (MNE 2000, 2002, & 2006). Reforestation success was very low, and survival rate of planted seedlings ranged from 30 to 60 percent (seldom reaching 50 percent). Consequently, the total area that has been successfully replanted represented only 5 percent of the total forest lost, mostly due to low survival rates of the seedlings (World Bank 2002). The main reasons for the poor results of plantations are lack of compatibility between sites and species and seed sources, outdated techniques and inadequate equipment in the nursery, deprived site preparation, poor quality of planting stocks, unavailability of seed orchard, and nearness in grazing lands (JICA, FMC & MNE 1998).

Restoration and reforestation activities encounter numerous challenges caused by both biotic and abiotic factors and success depends on many factors, including seed and seedling quality, site-species compatibility. Improper seed selection is considered as one of the key reasons for challenges faced in reforestation (Bat-Erdene & Dashzeveg 1995). Therefore, seed quality is crucial to promote the quality of planting stocks, to obtain high survival of seedlings and to increase the growth rate in large-scale rehabilitation and reforestation.

The Government of Mongolia has a policy and related tools of governance that encourages contributions from public and private partnerships and initiatives for reforestation. As a consequence of this reforestation campaign at the national level, public participation in this area has been increasing every year.

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Unfortunately, insufficient seed quality testing equipment in rural areas has had serious impacts on effectiveness of reforestation activities. Therefore, the creation of simple and pragmatic tools for the determination of seed quality in local areas is significant to manage forestation efforts in an efficient manner.

Extensive guidelines for the transfer of conifer seeds and seedlings exist worldwide, and were developed based on climatic data as well as geographic and genetic information. However, only a few studies have been conducted in Mongolia on this topic (Milyutin *et al.* 1988, Bat-Erdene & Dashzeveg 1995, Jamiyansuren 1989, Batkhuu 2009). Information regarding seed source control, regulation, transfer and zoning is lacking. Therefore, the objectives of this study were to 1) investigate the variations of cone and seed characteristics of various stands, and 2) determine relationship between seed quality and color group.

Materials and Methods

Description seed collection sites

One hundred cones from 5 different natural *P. sylvestris* stands were collected in 2010 from the Tujiin nars region in the Selenge province (Table 1).

The seed collection sites are part of the northern mountain range and located in the transitional zone where the mountainous zone around Lake Baikal grades into the Mongolian highlands. Most areas are between 800 to 2000 meters elevation and the highest point is in the southern part, while the lowest elevation is around 600 meters along the northern border of the province. The main forest types in the study area are dominated by Scotch pine (*Pinus sylvestris* L.), Siberian larch (*Larix sibirica* Ldb.), Siberian fir (*Picea obovata* Ldb.), Aspen (*Populus tremula* L.) and White birch (*Betula platyphylla* Sukacz.) (Fig.1).

Long term observations from (Sukhbaatar meteorological station) over the period 1985-2010 indicate that the annual mean air temperature is 1.1^{0}C and monthly mean air temperature ranges from -21.3^{0}C to 20.2^{0}C. Average annual precipitation is 276 mm and approximately 70-90 percent of annual precipitation falls between May and September.

Table 1. Characteristics of seed collection sites

No.	Seed collection sites	Age	Average height of stem, (m)	Average diameter of stem, (cm)	Number of trees, (ha)	Lat. (N)	Long. (E)	Alt. (m)	Collection date
1	Oros davaa	24	8.2	15.7	202	50.15	106.39	765	2010. Feb
2	Lukham tolgoi	56	16.5	35.7	49	50.12	106.4	758	2010. Feb
3	Gun nuur	42	11.1	25.1	130	50.15	106.37	647	2010. Feb
4	Taliin nuruu	32	8.9	18.7	272	50.15	106.37	672	2010. Feb
5	Ulaan burgas	39	11.3	25.6	189	50.14	106.27	637	2010. Feb

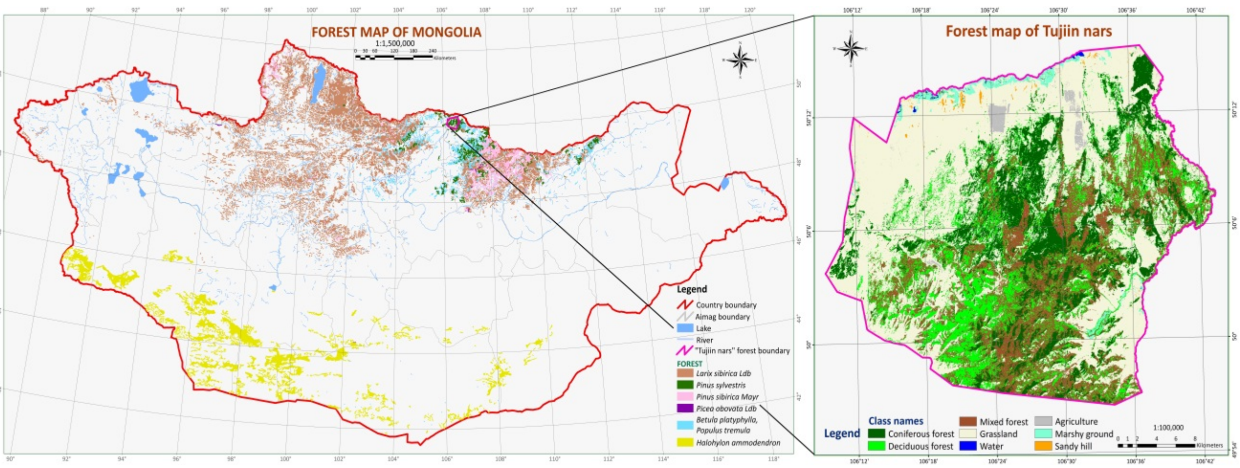

Fig.1. Location of study area.

Measurement of cone and seed size and seed quality test

Before seed extraction the following cone morphological parameters were determined: cone length (mm), width (mm), and number of scales. Then cone index was calculated, as the ratio of cone length and cone width (Pravdin 1964). According to Pravdin`s cone index classification, cones are long-shaped if the index ranges between 2.5-3.0, long and thick-shaped 2.0-2.5, egg-shaped 1.5-2.0, and round-shaped 1.0-1.5.

In the laboratory, the length (distance between the two ends of the cone) and width (at the widest point) of the cones were measured with the use of digital calipers with accuracy 0.001 mm. Seed color was determined directly after extraction by naked eyes and related photos attached as Fig.2.

Other seed morphological parameters, seed length (mm) and width (mm) were directly measured. Seed length, the distance between the two ends of the seed, and width, the widest point of a seed, of seed groups were measured digital calipers with an accuracy of 0.001 mm. One hundred seeds of each color group were randomly selected for the seed size measurement. Laboratory tests of seed quality were conducted by the Internatinal Rules for seed Testing (ISTA 1999). Laboratory tests of seed traits (weight of 1000 seed, germination energy and germination capacity) were conducted by the Seed Testing Laboratory of the Ministry of Nature and Environment of Mongolia.

Data analysis

Parameters were analyzed by one-way analysis of variance (ANOVA) followed by Duncan's multiple range test. The effect of seed color and seed quality was determined by linear regression analysis.

Results and Discussions

The cones of *P.sylvestris* show a large differentiation in size. Cone length ranged from 4.2 to 5.0 cm and width ranged from 2.2-2.5 cm. Overall, mature color is dark and egg shaped. Similar studies on the flowering, seed production, cone and seed size and their color of different *P.sylvestris* stands were investigated in Mongolia. The previous studies, in Western Khentii, Mongolia, reported an average cone length of 5.2 cm, cone width of 2.7 cm, seed length of 0.4 cm, and a weight of 6.8 g for 1000 seeds (Bazarsad 1996).

Cone size is variable and depends on many factors such as climate, soil fertility, type and age of stand or location of cones on the tree crown (Aniszewska 2006). Cone morphology data indicated significant differences among seed collection sites ($p<0.001$) in all measured parameters (Table 2).

Fig.2. Color differences in seed color groups (1-light, 2-black, 3-brown).

Table 2. Means of cone morphological parameters (n=500)

No.	Seed collection sites	Cone length, mm	Cone width, mm	Number of cone scale	Cone index	Cone shape
1	Oros davaa	45.4ab	24.1a	67.02a	1.9	Egg-shaped
2	Lukham tolgoi	46.6ab	25.2a	66.05a	1.8	Egg-shaped
3	Gun nuur	49.8a	22.9ab	63.45ab	2.2	Long and thick-shaped
4	Taliin nuruu	41.8c	22.9ab	61.07b	1.8	Egg-shaped
5	Ulaan burgas	48.4a	21.7b	59.4b	2.2	Long and thick-shaped
	ANOVA for cone morphology of seed collection sites					
6	df	4	4	4	4	-
7	Mean square	950.821	177.365	1076.245	3.827	-
8	F value	44.149^{***}	40.012^{***}	20.247^{***}	116.086^{***}	-

*Note: Means with different letters are significantly different according to Duncan's Multiple Range Test at 5% level

According to cone index by Pravdin, 7 of 500 cones which selected from studied stands were classified as long-shaped, 268 cones as long and thick-shaped and 223 egg-shaped and round-shaped 2, respectively. The most dominant cone shape was long and thick, with proportion of 54 percent compared with other cone shapes. We found two dominant types of cone shape (long and thick-shaped and egg-shaped) among studied stands with 98.2 percent of total investigated cones. Cone index classification is shown in the Table 3.

Our investigation indicates that long-shaped cones have more number of seeds than the other shaped cones, which suggests that cone shape influences the number of seeds in a cone (Table 4).

Long-shaped cones had an average of 23 seeds. Of the 23 seeds, 5 were light colored, 10 were black, and 8 were brown. Long and thick-shaped cones had an average 20 seeds in each with 6 of them light colored, 9 black, and 5 brown. Egg-shaped cones had an average 15 seeds with 3 lights colored, 7 black, and 5 brown colored. On average, black seeds were the most dominant in all cone shapes (nearly 44.8 percent).

These seed color plays key role in germination energy and its capacity as well as weight of 1000 seeds (Table 5, Figure 3, 4 & 5).

Table 3. Cone index classification (n=500)

No.	Seed collection sites	Shape of cones				Sum
		Long-shaped	Long and thick-shaped	Egg shaped	Round-shaped	
1	Oros davaa	0	39	61	0	100
2	Lukham tolgoi	1	24	75	0	100
3	Gun nuur	1	88	11	0	100
4	Taliin nuruu	1	22	75	2	100
5	Ulaan burgas	4	95	1	0	100
	Sum	7	268	223	2	500

Table 4. Cone morphological characteristics (n=500) (n=500)

No.	Shape of cones	Number of cones	Average length, (mm)	Average width, (mm)	Cone index	Average seed number per cone	Average number of seeds in cones by seed color croup		
							light	black	brown
1	Long-shaped	7	50.5	19.7	2.6	23	5	10	8
2	Long and thick-shaped	268	49.9	22.9	2.2	20	6	9	5
3	Egg shaped	223	45.4	24.1	1.9	15	3	7	5
4	Round-shaped	2	35.3	22.8	1.5	8	-	-	-
	Sum	500	-	-	-	-	-	-	-

Table 5. Mean of seed characteristics of seed color groups (n=300)

No.	Seed color groups	Germination capacity, (%)	Germination energy, (%)	Weight of 1000 seeds, (g)	Seed size	
					Average length, (mm)	Average width, (mm)
1	Light	60.7b	46.0b	5.7b	4.8a	2.8a
2	Black	92.3a	78.7a	7.2a	4.9a	2.9a
3	Brown	81.2ab	74.3a	6.4ab	4.8a	2.9a
7	Mean	78.1	66.3	6.43	4.8	2.9

*Note: Means with different letters are significantly different according to Duncan's Multiple Range Test at 5% level

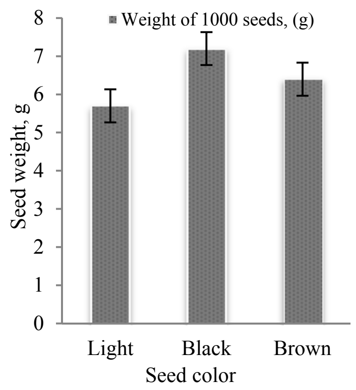

Fig. 3. Weight of 1000 seeds *P. sylvestris* by color groups.

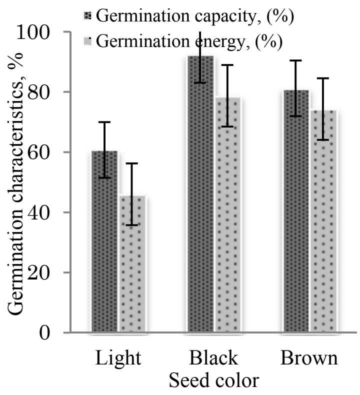

Fig. 4. Germination characteristecs of *P.sylvestris* by color groups.

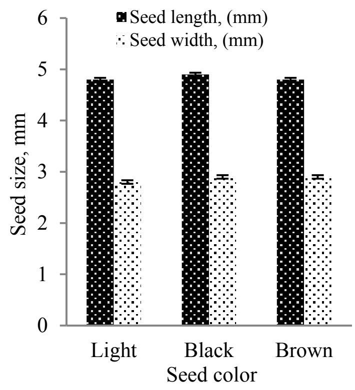

Fig. 5. Seed size of *P.sylvestris* by color groups.

Seed color is also affects various factors, such as water uptake by the seed (Atis *et al.* 2011), seed quality (Mavi 2010, Atis *et al.* 2011), germination (Aniszewska 2006), and seed weight (Mavi 2010). The relationships between the seed color and growth rate in *P.sylvestris* was considered in many studies. Some researchers found that *P.sylvestris* trees with black colored seeds grow best, while others could not find such evidence. For example, studies carried out by Odgerel, show that the color of *P.sylvestris* seeds influences the quality of seedlings. The seedlings grown from black seeds had higher growth performance than seedlings from lighter seeds (Odgerel 2001).

The average weight of 1000 seeds of all studied seed collection sites was 6.43 g. The lowest seed weight of *P.sylvestris* was 5.7 g for light colored seeds, 6.4 g for brown seeds, and 7.2 g for black seeds, respectively (Fig. 3).

Weight of 1000 seeds indicate how much the trees are influenced by external factors and how well they are adapted to it, in other words it shows the important characters of genetics. Light color seeds are usually weak, and have less chance to germinate, and these study findings are same as Mamaev (1972), Aniszewska (2006).

Heavy seeds contain greater reserves of protein, carbohydrate, lipid and energy than intermediate-weight and small seeds (Khan & Shankar 2001). Seed weight is widely used for seedling establishment at the nurseries, while in plant ecology it is, so far, considered as minor importance. The weight of seed is closely related to the local climatic and site conditions. Azniev (1970) stated that pine trees growing in infertile and dry habitats have cone with lighter seeds, while those from fertile and wet habitats have darker seeds. Seed weight is also considered as a key factor for establishing the juvenile phase of the life cycle, especially under harsh conditions (Grubb & Coomes 1997). Variation in seed weight within a species also affects seed germination (Schaal 1980, Weis 1982) and germination rate (Weis 1982). Large seeds usually have greater germination percent or emergence than small seeds (Weis 1982).

According to our seed weight by color groups and evidence that seed weight enhances germination, we found that black colored seeds had higher germination capacity (92.3 percent) than that of brown (81.2 percent), and light (60.7 percent), respectively (Fig. 4). On the other hand seed germination energy of black seeds was higher (78.7 percent) than of brown (74.3 percent) and light (46.0 percent).

Similar results were found in other plant species including *Pinus pinea*, *Larix sibirica*, *Trifolium pratence*, *Texas lupines*, *Citrullus lanatus* (Pichelgas 1973, Aniszewska 2006, Atis 2011, Schaal 1980, Mavi 2010). There is little evidence on the influence of ecological conditions on seed germination, although it was found to decrease under adverse conditions (Abaimov *et al.* 1997). Seed quality depends on time of seed collection though this is expressed less clearly than seed weight (Abaimov *et al.* 1997, Bazarsad 1996).

We found a strong regression with seed color and seed characteristics (Table 6), which is similar to the results observed by Aniszewska (2006). Thus, variation in seed color has great ecological significance in the establishment and maintenance of populations, particularly in harsh environments.

Conclusion

As results of the study, we observed strong relationships between cone and seed morphological characteristics and seed quality. For instance, different sizes of cones influence the number of seeds per cone. And, seed color influences germination energy and germination capacity. Black color seeds showed greater rate and germination percentage compared brown and

Table 6. Regression analysis between the seed haracteristics and seed color groups

No.	Analysis	F value	R^2
1	Germination capacity versus color	21.9***	0.73
2	Germination energy versus color	213.8***	0.96
3	Germination capacity versus germination energy	43.86***	0.84

***-significantly different at 0.001

light colored seeds. Therefore, morphological characteristics should be carefully considered as one of the key prerequisites in the selection of seeds for tree breeding, reforestation, rehabilitation measurement in order to ensure effectiveness and efficiency of National Forest Policy implementation. There are crucial requirements on selection of the high quality seeds in order to ensure efficiency and effectiveness of the National Forest Policy. Reforestation and tree planting measurements are considered as key objectives and coping tools of environmental degradation of National Forest Policy. Aims included selection of seed stands, establishment of seed orchard, development of seedling nurseries, increase of reforestation and forestation in degraded forests. Our study here will, therefore, have direct applicable results for the National Forest Policy.

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