Phenological observations on *Larix principis-rupprechtii* Mayr. in primary seed orchard

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Abstract: Through 5 years of phenological observations on *Larix principis-rupprechtii* Mayr. in primary seed orchard and studies on population and individuals of clones, the annual periodic phenological laws were revealed and the annual phenological periodic table was drawn up. The correlation between various phenophases, the air temperature and active accumulated temperature were analyzed and expounded. The authors also analyzed the similarities and differences of phenophases among clonal individuals as well as the blooming properties of male and female flowers at the same time. This study could provide theoretical reference for working out the production plan of improved varieties and other management measures in seed orchard of *Larix principis-rupprechtii*.

Key words: *Larix principis-rupprechtii* Mayr.; Primary seed orchard; Phenological observation
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Introduction

In last two decades, studies on phenology have got great achievements (Zhu *et al.* 1983) in China. A series of phenological observation methods (Xu *et al.* 1983) have been developed. There was a preliminary achievements at phenological observation of seed orchard of *Larix principis-rupprechtii* Mayr..

It is very necessary to study the phenological laws of population and individuals of clones in seed orchard of *Larix principis-rupprechtii* Mayr. Through revealing periodic annual phenological laws and analyzing relationship between phenological laws and environmental factors (especially the temperature index in climatic factors), we can learn influences of temperature index on phenological phenomena and adaptability of clones to environment. Studies on phenology of clones can provide basic and reference information for intensifying management and establishing next generation seed orchard, forecasting seed yield, working out seed production plan, and preventing occurrence of disaster factors.

Since 1984, we have carried out systematic studies on growth, flowering and cone bearing (Zhang 1990; Fu *et al.* 1989; Shen 1981), and morphological properties (Fu *et al.* 1989; Wang 1992) of *Larix principis-rupprechtii* Mayr. in seed orchard. The article summarized the relationship between air temperature variation, phenological laws of clonal population and clonal individuals of *Larix principis-rupprechtii* Mayr. in seed orchard.

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Methods and materials

Observation plot

Observation plot is in the Zone 1 of seed orchard of *Larix principis-rupprechtii* Mayr.. It is located in the northeast part of Datong City, at 113°25'E and 40°15'N, with an elevation of 1 200 m. The frost-free period of this area is about 100 d. The minimum and the maximum temperatures are –30.3℃ and 36.5℃, respectively. Average temperature of July is 20.6℃. Annual average rainfall is 384 mm and the least rainfall appears in December, only for 1.5 mm; and mostly concentrated in July and August. In winter and spring there is only a little of rainfall. The annual evaporation capacity is 1 940.3 mm, with a maximum value of 2 521 mm, and annual average relative humidity is 53%. The land facing south is open and flat with an inclination of 3-5°. The soil is silt loam with low fertility and normally is more than one meter in depth. The vegetation in the area is sparse and the major species are thyme, needlegrass, etc.

Observation methods

Observed contents

The observation data mainly depended on phenophases appearance of morphological organs in different develop-

ment periods in growing season, such as bud bursting phase, leafing phase, flowering phase (initial stage, pollination stage and last stage), cone stage, sprouting stage and dormant stage. The observation indexes are the same as normal phenological observation.

Observed trees

The trees are 15 years old with a spacing of 4 m×6 m. The land is flat and open. 32 Clones were selected from three hundred clones (Ma_1-Ma_{300}) in the seed orchard. For each clone, 3 healthy and strong trees were selected as observation trees. In sunny side of the middle crown of trees, 10 vegetative buds, 10 female flower buds and 10 male flower buds were selected. The leaves, flowers, branches and cones developed from them were marked and observed.

Observation time

For the same phenophase, the observation date and daily observation time are same, but there is a little difference for different phenophases. In bud bursting stage and flowering stage, observation time was at 13:00-14:00 hour everyday. In cone stage, observation was done in afternoon every two days. And for leafing and sprouting stage, only the starting and ending dates were recorded. Except on marked positions, the appearance of phenophase of peripheral crown was also need to be observed.

Climate data

The climate data (1984-1988) of Datong Weather Station, 20 km apart from the seed orchard, were used.

Results and analysis

Population phenophase

Annual phenological periodic table

The time when more than half of clones began to present a morphological development was determined as the starting date of population phenophase of seed orchard. According to observation data of 3 years, the starting and ending dates of each phenophase for *Larix principis-rupprechtii* Mayr. were summarized in Table 1.

Table 1. The annual phenological period of *Larix principis-rupprechtii* Mayr. in seed orchard

Phenophase		Starting date	Ending date	Lasting days/d	Variation range/d
Bud bursting stage	Vegetative buds	Apr. 2	Apr. 12	11	7-16
	Male flower buds	Apr. 1	Apr. 12	12	5-16
	Female flower buds	Apr. 1	Apr. 11	11	6-17
Flowering stage	Male flowers	Apr. 13	Apr. 22	10	7-13
	Female flowers	Apr. 12	Apr. 25	14	9-17
Leafing stage		Apr. 13	Oct. 11	182	178-186
Cone stage		Apr. 26	Aug. 10	107	81-111
Sprouting stage		May 5	July 22	59	29-77
Dormant stage		July 24	Apr.1, next year	253	217-302

Annual phenological laws

From the point of phenology, the changes of various morphological organs during one year have a definite rule. First, in spring, the buds developed, then flowers appeared, leaves spread and the cone formed. After the trees cease to grow, the cones matured and the leaves fell, and at the last, the trees growth entered dormant period. Each development period comes in turn.

Relationship between annual phenophase and temperature index

The starting date and lasting days of phenophase have very significant correlations with temperature index. According to simple correlation analysis (Fu *et al.* 1980), the starting date of the growing season was correlated positively with average temperature of the lasting days. It is indicated that the earlier the phenophase comes, the lower starting temperature is, whereas a higher starting temperature is needed. The rule should be in line, that is, the faster the temperature in spring goes up, the earlier the phenophase comes; and, the lower the temperature is, the later the phenophase comes. The lasting days of the growing season is positively correlated with the active accumulated temperature (≥0℃) in a very significant level (r=0.99 > $r_{0.01}$ =0.45). That means the longer the growing period is, the more the quantity of heat is. During different growing and developing periods, the quantity of heat in various phenophases is also different. When the quantity of heat meets the needs of given phenophase, the normal growth and development of trees for the phenophase can be ensured. When the accumulation of heat quantity was not enough, the growth and development of trees would be affected.

In Table 2, the starting temperature for bud bursting is 4.5 ℃ (female flower buds) or 4.6℃ (vegetative buds and male flower buds), which is lower than normal biological starting temperature (5℃). The results showed that the starting date of bud bursting in this place was earlier, especially the bursting date of female flower buds. The starting temperature of flowering stage of female flowers (8.8℃) is lower than that of male flowers (9.7℃). The range of

active accumulated temperature (≥0℃) of all phenophases is 92.8-332.5℃. Considering that active accumulated temperature is 3363.1℃ in this place, we can say that the temperature conditions here can meet the needs of normal growth and development of *Larix principis-rupprechtii* Mayr.

Table 2. The starting temperature and the active accumulated temperature of various phenophases

Phenophases		Starting temperature /℃	Active accumulated temperature /℃
Bud bursting stage	Vegetative buds	4.6	98.7
	Male flower buds	4.6	96.4
	Female flower buds	4.5	92.8
Flowering stage	Male flowers	9.7	182.4
	Female flowers	8.8	225.7
Leafing stage		9.1	3332.5
Cone stage		8.2	2309.6
Sprouting stage		16.8	1975.9

According to correlation analysis result of phenophases and temperature index (Table 3), there is a significant or very significant correlation between the starting date and the starting temperature, the lasting days and active accumulated temperature of all phenophases. The correlation difference between the starting date and the starting temperature is very significant for each phenophase. The correlation coefficients of male flower buds and female flower buds in bursting stage with temperature index are 0.76, 0.74 respectively, and that of female flowers in flowering stage is 0.95. The results above showed a moderate strong positive correlation. This means the earlier the starting date is, the lower the starting temperature is. Conversely, the later the starting date is, the higher the starting temperature is needed. But in a special case, the starting date of cone stage is negatively correlated with the starting temperature in a very significant level, that means that the earlier the starting date is, the higher the daily average temperature is needed. The reason for this unusual phenomenon may be the variation of temperature from the end of April to the beginning of May in the place. During this period, the continental monsoon weather alternates with marine climate, resulting in a warm initial stage and a cool later stage in spring. This period is just the initial stage of cone, thus bringing about the result of negative correlation.

Table 3. Simple correlation coefficient of various phenophases and temperature index

Phenophases items	Bud bursting stage	Flower bud stage		Flower stage		Leafing stage	Cone stage	Sprouting stage	Remarks
		Male	Female	Male	Female				
Starting date & starting temperature (℃)	0.62**	0.76**	0.74**	0.57**	0.95**	0.63**	-0.51**	0.62**	$R_{0.05}$=0.35
Lasting days and active accumulated temperature (℃)	0.41*	0.65**	0.50**	0.54**	0.74**	0.66**	0.97**	0.86**	$R_{0.01}$=0.45

Notes: * --Significant deference; ** --Very significant difference.

According to correlation analysis, the lasting days and the active accumulated temperature in most phenophases are positively correlated, except that in vegetative bud bursting stage. Therefore, we can believe that the starting date and starting temperature, the lasting days and the active accumulated temperature of phenophases are significantly correlated.

Relationship between phenophase and temperature

The analysis on starting temperature and active accumulated temperature of various phenophases of *Larix principis-rupprechtii* Mayr., showed that the adaptability of clones to temperature conditions in annual phenological period can be stronger. For example, the clones of bursting stage in a range of 3.4-5.8℃ take up 75%. There are also some clones that their vegetative buds begin to burst at 1.7℃ (Ma_{19} and Ma_{33}), and others at 6.4℃. The clones with bursting stage in a range of 83.2-99.1℃ of active accumulated temperature account for 78%. But there are also a few of clones that the required heat quantity is beyond this range. For example, Ma_{44}, the active accumulated temperature of Ma_{44} is 119.8℃, and that of Ma_{45}, is 146.8℃. In Table 4, the adaptability of various phenophases to temperature condition is similar with this situation.

Phenophases of clones in seed orchard

Annual periodic phenological laws of clones

From observation results on the starting date and the lasting days of various phenophases of clones, it can be seen that the bud bursting date has a special order for trees of the same clone. In normal, the starting date of leaf buds is later than that of the flower buds. But the leaf buds date and the flower buds date can also appear on the same day. For some clones, such as Ma_1, the starting dates of leaf buds, male flower buds and female flower buds are all on April 1, and for Ma_2, all of them begin to burst on April 5. For some clones, the bursting date of female and male flower buds is not identical, such as Ma_{25}, its female flower buds

begin to burst on March 28 and male flower buds on March 31. On the contrary, for Ma_3, the bursting date of male flower buds (March 29) is a little earlier than that of the female flower buds (March 30). In respect to the flowering stage, the initial date of female flowers is earlier than that of the male flowers, also with longer lasting days. But there are also some clones, the initial date of female and male flowers is identical, such as Ma_5, Ma_3 and Ma_2, the female and male flowers come into bloom on April 13. For Ma_{13} and Ma_{51}, the initial date of male flowers is earlier than that of female flowers.

Table 4. Range of requried temperature of various phenophases

Phenophases items	Bud bursting stage	Flower bud stage		Flower stage		Leafing stage	Cone stage	Sprouting stage
		Male	Female	Male	Female			
Starting temperature (℃)	1.7-6.4	1.7-6.4	1.7-6.4	7.3-10.7	7.3-10.7	7.7-10.7	7.0-13.6	14.5-25.2
Active accumulated temperature (℃)	83.2-146.8	66.9-119.8	75.9-109.1	164.9-201.9	181.6-239.5	3297-3358.6	1865.5-2359.1	865.9-2734.3

Blossom phase of male and female flower

Among clones, whether the pollen dispersion phase of male flowers and the pollination phases of female flowers appear at the same time is a key point to ensure the fully pollination and improve yield of seed orchard. According to observation data of 19 clones, the flowering phase of female and male flowers are basically identical, that is, the pollen dispersion phase of male flowers is just right the pollination phase of female flowers. But for some clones, their flowering phases of female and male flowers are not identical with a little difference in the time. The widest time range of pollination phase of female flowers is from April 17 to 26 and that of the pollen dispersion phase of male flowers is from April 18 to 25. During this period, the pollination is effective. The range of the starting date of pollination phase of female flowers is from April 17 (Ma_{29}) to 22 (Ma_{30}) and that of the pollen dispersion phase of male flowers is from April 18 (Ma_{10}) to 23 (Ma_{18}). Therefore, in spite of the difference of the starting date of flowers, the pollination can be ensured. The pollination phase of female flowers usually lasts about 6 days, 8 days for the longest (Ma_{10}) and 4 days for the shortest (Ma_{18}). The pollen dispersion phase of male flowers usually lasts about 3 days, 6 days for the longest (Ma_{10}) and 2 days for the shortest (Ma_{18}). Since the lasting days of the pollination phase of female flowers are longer than those of the pollen dispersion phase of male flowers, the pollination and fertilization of female flowers can be ensured during the very short pollen dispersion phase.

Conclusions

Larix principis-rupprechtii Mayr. clones have a stronger adaptation to temperature conditions. There is a close relationship between phenophases and temperature. Their starting temperature is obviously lower than biological starting temperature. The correlation difference between their lasting days and active accumulated temperature is also significant.

The different clones have a different adaptation to temperature conditions. Therefore, we have to pay close attention to conditions in introduction and cultivation.

The flowering period of male and female flowers of many clones is basically identical, that is to say, the pollen dispersion phase is just right the pollination phase. So, the normal self-pollination can go on without any problems. But there are also some clones that their pollen dispersion phase and the pollination phase are not identical. The studies on phenological laws are very significant to management of seed orchard. The relationship of starting date and lasting days of phenophases with seed yield still need further research.

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