RECENT TRENDS IN BLOOMING DATE OF SPRING FLOWERS IN KOREA

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1. Foreword

Temperate spring flowering date represents seasonal change when winter turns into spring, and it is important factor to sense a climate change in accordance to late or early spring (Chmielewskiet al., 2004). Korea's spring has dynamic scenery that variety of flowers such as Japanese cornlian cherry, plum blossom, magnolia, azalea, forsythia, cherry blossoms and royal azalea flowers in turn. Thus many local governments obtain tourism incomes through the spring flower festivals, and the bee keepers also get nectar sources over a long period of time, while they are traveling for it regarding the spring flowering times. In the spring of 2014, however, the schedules of spring flower festival are conflicted that were hold annually from the southern to northern areas, due to the late spring flowering times. And different kinds of flowers bloom in same region, so that the opportunity to enjoy various flowers in order was decreased. It may exert a bad influence on natural ecosystem as well economic and public values, if this chaos of blossoming season is frequently occurred. Temperate flowering trees that flower buds are speciated from spring to autumn and then come into flowers in next year, enter into endodormancy, and they can be passed this resting stage and then germinated at a low temperature for a certain period of time. Major developmental stage such as beginning and end of endodormancy, germination and florescence is called as plant phenology, and it is a kind of climatic elements for the Korea Meteorological Administration (KMA, 1994). Among the various environmental factors which influence complexly on the floral weather, temperature is the most important factor (Oh, 2014; Kim et all., 2013). Accordingly, a method that quantifies the effect of temperature with calendar date to analyze and predict floral weather was studied (Richardson et al., 1974; Aron, 1983; Cesaraccioet al., 2004; Jung et al., 2005; Kim et al., 2013). In this research, the characteristic of the spring florescence was examined comparing with documents written for the past 60 years, and reviewed the predictability of the spring flowering times

2. Materials and Methods

2.1 Data

florescence of forsythia and cherry blossoms have been using to observe the season by the weather center. And citizens are habituated to see the observation and forecast that notice the expected flowering times, and it is easy to collect the data. The materials used to study was collected from six regions such as Seoul, Incheon, Daegu, Jeongju, Busan and Mokpo considering the early and late flowering times, and data collecting period. For the blooming time of forsythia and cherry blossoms in seasonal observation data of each region, the materials of flowering date collected for 60 years from 1951 to 2010, and 2014 were used. The data for the daily maximum and minimum temperatures during same period in these regions was also used

2.2 Analysis

It is performed to divide the observational data of flowering times collected for 60 years(1951-2010) into two climatological normal year(1951-1980, 1981-2010), and to calculate a quartile of flowering times of normal year for forsythia and cherry blossoms in each region(25%, median value, 75%, extreme value). It was decided to relational position comparing calculated flowering times of normal year with observation flowering times in 2014. Amount of plant growth depends on temperature, so that cumulative

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temperature or growing degree day (GDD) which was accumulated thermal time above growth temperature than daily calendar date, was used. In this research, it was set the end of resting period on every February 15th, and reference temperature was 5℃. It was integrated by the daily GDD calculated by follow formula on the basis of 5℃ of growth beginning temperature after every February 15th, from 1591 to 2010.

$GDD = (T_{Max}+T_{Min}) / 2 - T_{Base}$---------- (1)

In this formula, T_{Max}, T_{Min} and T_{Base} represent daily maximum and minimum temperature, and growth beginning temperature

Fig. 1. Geographical locations of 6 sites where both air temperature and plant phenology data are available for the 1951-2010 period

3. Result

3.1 Change of flowering date

The flowering times of cherry blossoms were uniformly reduced about 3 to 7 days at all regions, but it has irregular characteristics in a teach regions, when It was divided recent 60 years into two periods of climatological normal year(1951-1980, 1981-2010) (Fig. 2). The flowering times of cherry blossoms were March 31th, and April 19th in the South and North from 1951 to 1980(last normal years). It had 20 days difference between Busan and Incheon. And flowering times of cherry blossom were March 28th and April 12th, and it was reduced about 4 days from 1981 to 2010(Recent normal years). In 2014, especially, its times were March 25th to March 30th, and the range of fluctuation was only 6 days (Fig. 3).

The flowering times of forsythia were March 17th in Busan, and April 5th in Seoul from 1951 to 1980(last normal years), so forsythia was bloomed two weeks early than cherry blossoms. The range of fluctuation was 20 days between regions just like cherry blossoms. The flowering times were March 17th to April 2nd from 1981 to 2010(recent normal years), and the range of fluctuation is about 12 days in 2014, so that it maintains florescence interval in regions, while cherry blossoms is 12 days (Fig. 2).

Flowering delaying times of forsythia to cherry blossom was maximum 30 days and averagely 14 days in last normal years(1951-1980), but it was reduced maximum 21 days and 11 days in recent normal years(1981-2010). In 2014, especially, it was reduced within 10 days, so that it was available to see cherry blossoms with forsythia at the same place simultaneously. (Fig. 3)

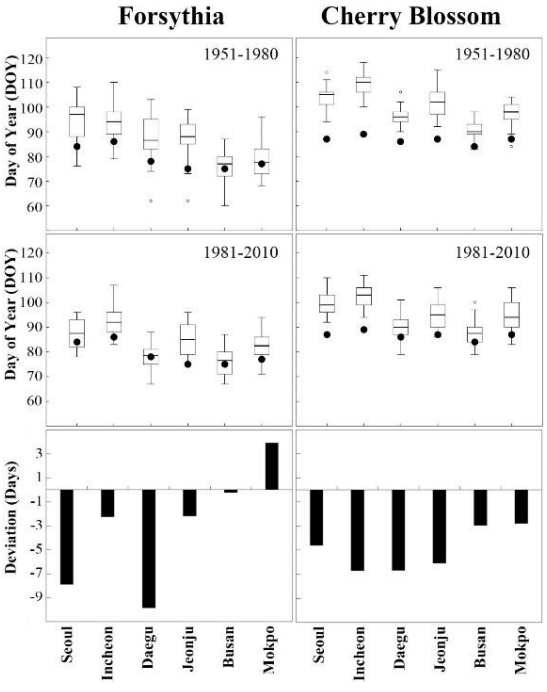

Fig. 2. Flowering date variation of 2 species at 6 sites for the past (1951-1980) and the current (1981-2010) period. Circles (●) indicate observed flowering dates in 2014. Bottom panel shows delay (+) or shortening (-) in flowering date of the current period compared with the past period.

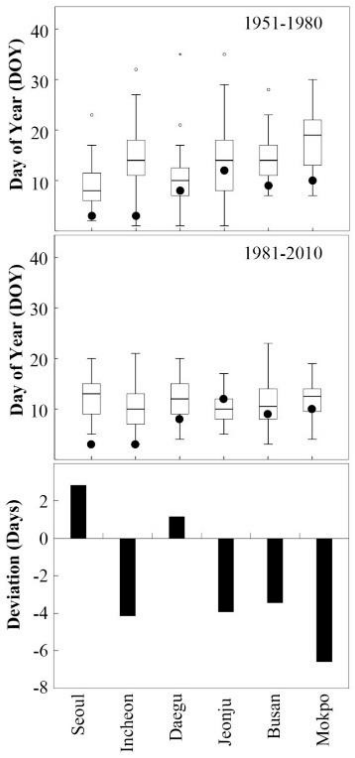

Fig. 3. Delay in cherry blossom relative to forsythia flowering date in the past (1951-1980) and the current (1981-2010) period at 6 sites. Bottom panel shows the change in the delay between 2 periods.

3.2 Change of temperature-time

According to theory, temperate perennials those are germinated and blossomed after flower buds was in a low temperature for a good period of time, reach to the particular stage such as leaf-emergence date and flowering when the value(growth increment) that was calculated from daily temperature times after dormancy, reaches to certain scale(Jung et al., 2005). Kim et al.,(2013) expressed the lead time that flower

Fig. 2. Geographical locations of 6 sites where both air temperature and plant phenology data are available for the 1951-2010 period

bud of temperature fruit tree is germinated and then be blossomed as growing degree days(GDD), and he called it as heating requirement against chill requirement for the end of dormancy. Size of GDD from two normal years(1951-1980, 1981-2010) and 2014 was 2014 > recent normal years > last normal years, when it was calculated the daily growth increment with GDD and accumulated it till April 30th on the basis of 5℃ of growth beginning temperature after every February 15th from 1951 to 2010 according to the method of Kim et al.(2013). Normal flowering times of two normal years were different, but growth increment (GDD) accumulated to the flowering times were almost same. This trend was maintained in 2014 when the flowering date was brought forward.

It was calculated GDD from every February 15th to the flowering date of relevant year during 1951-2010, and taken an average for last 60 years, so that used it to heating requirement by regions. As a result of the data that calculated each heating requirement of two normal years(1951-1980, 1981-2010), any results did not break deviation range and 60 years average (Table 1). It is able to explain the synchronization (simultaneous flowering of forsythia and cherry blossoms at a region, simultaneous flowering of same flower in the North and South)(as 2014 flowering characteristic) using temperature time instead of calendar date.

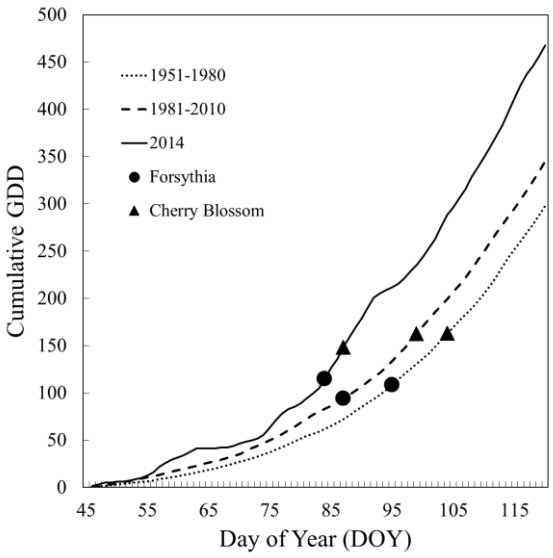

Fig. 4. Accumulation of growing degree days (GDD) over 5°C at Seoul weather station since February 15 averaged for the past (1951-1980) and the current (1981-2010) period. Solid line represents the same for the year 2014. Symbols indicate observed flowering dates.

3.3 Predictability of spring flowering date

It was compared actual flowering date with temperature time to draw derivability of predictive model of flowering date as independent variable calculating reaching date of heating requirement from two normal years and 2014.

As a result, correlation coefficients between actual and expected flowering dates were 0.95 and 0.99 for forsythia and cherry blossoms. And Root mean squared error (RMSE) was 2.43 and 1.46 days, When only the 2014 data was collected, RMSE of forsythia was improved to 1.18 days, and cherry blossom also 1.61 days

Table 1. Cumulative growing degree days (base temperature of 5°C) from dormancy release to flowering date at 6 locations averaged for the last 60 years.

	Forsythia						Cherry Blossom					
	1951-1980		1981-2010		1951-2010		1951-1980		1981-2010		1951-2010	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Seoul	107	35.5	97	14.6	102	26.7	165	17.0	164	11.0	164	14.1
Incheon	80	22.1	102	25.5	91	25.9	158	16.7	156	41.8	157	31.8
Daegu	128	42.2	107	31.5	117	38.1	173	38.9	169	16.1	171	29.4
Jeonju	113	29.4	121	15.9	117	23.9	201	24.8	180	17.8	191	23.6
Busan	95	23.7	114	20.8	104	23.8	166	18.9	174	11.4	171	15.7
Mokpo	80	29.2	108	17.0	94	27.3	165	17.6	170	27.0	168	22.4
Mean	100	30.3	108	20.9	104	27.6	172	22.3	169	20.8	170	22.8

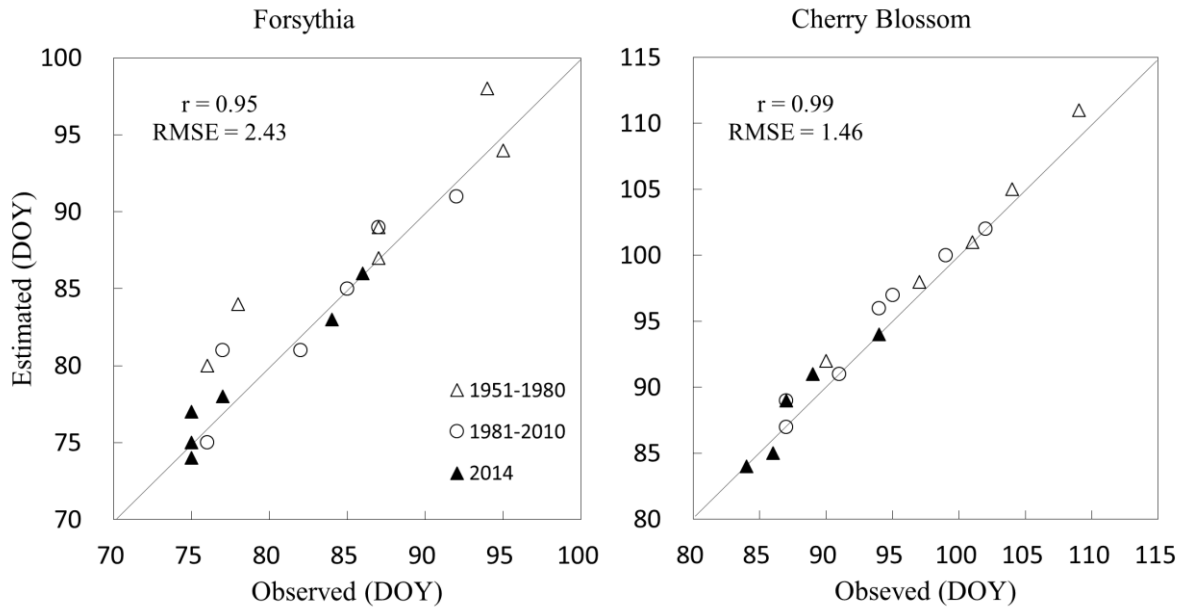

Fig. 5. Performance of the GDD-based heating requirement in estimating average flowering dates of forsythia and cherry blossom for the past (1951-1980, empty triangle) and the current (1981-2010, empty circle) period. The filled triangle represents the case for the year 2014.

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