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Relationship between Phenological Stages and Cumulative Air Temperature in Spring Time at Namsan

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ABSTRACT: To certify predictability for the times of phenological stages from cumulative air temperature in springtime, the first times of budding, leafing, flower budding, flowering and deflowering for 14 woody plants were monitored and air temperature was measured from 2005 to 2006 at Namsan. Year day index (YDI) and Nuttonson's Index (Tn) were calculated from daily mean air temperature. Of the 14 woody species, mean coefficient of variation was 0.04 in *Robinia pseudo-acacia* and 0.09 in *Alnus hirsuta*. However, mean coefficient of variation was 0.30 in *Forsythia koreana* and *Stephanandra incisa* and 0.32 in *Zanthoxylum schinifolium*. Therefore, the times of each phenological stage could be predicted in the former two species but not in latter three species by two indices. Of the five phenological stages, mean coefficient of variation was the smallest at deflowering time and the largest at budding time. In five phenological stages, mean coefficient of variation of YDI was in the range of 0.11~0.21 but that of Tn was in the range of 0.15~0.26. Therefore, the former was a better index than the latter. Of the species-phenological stage pair, coefficient of variation of YDI was 0.01 in *Acer pseudo-sieboldianum* - flower budding and below 0.05 in 11 pairs, whereas the YDIs over 0.40 were 4 pairs comprising of *Prunus leveilleana* - budding (0.51). Coefficient of variation of Tn was 0.01 in *A. hirsuta* - budding and below 0.05 in 8 pairs. The Tns over 0.40 were 5 pairs comprising of *F. koreana* - flower budding (0.66).

Key words: Budding, Deflowering, Flowering, Leafing, Nuttonson's Index (Tn), Phenology, Woody plant, Year day index

INTRODUCTION

The environmental factors affecting on leafing and flowering are air temperature, soil moisture, day length and plant water potential (Garner and Allard 1920, Flint 1974). Of the these, main factor is various with the species and macroclimate. For example, soil water content or plant water potential is main factor in Mediterranean area (Nilsen and Muller 1981), arid area (Jackson and Bliss 1984, Gill and Mahall 1986) and tropical area (Opler et al. 1980, Fleming et al. 1985, Hegarty 1990, Wright 1991). However, the air temperature in springtime is main factor in temperate deciduous forest (Brown 1953). That is, in northern hemisphere, organisms begin to their behavior in accordance with increase of air temperature in springtime. Hopkins (1920) reported phenology on the insect behavior in springtime. Insect behavior is delayed on increase of altitude and latitude and coincident with increase of air temperature in springtime (Hopkins 1920). As animal, plant shows the phenological phenomena of budding, leafing and flowering in according to increase of air temperature in springtime. In this viewpoint, air temperature is thus a good index to predict the time of phenological stages, so that the relation between plant's phenological stage and air temperature expanded to temperature-time concept. In this concept, cumulative temperature-day is calculated from daily mean air temperature. Methods calculating the cumulative temperature-day are two: one is based on physical zero temperature (0℃), the other physiological zero one (5℃). The former is year day index (Yim et al. 1983, Yim 1986, 1987), and the latter is Nuttonson's index (Tn) (Nuttonson 1948, Lindley and Newman 1956). Thereafter, phenological phenomenon have been interpreted by cumulative air temperature and the relationship between two properties was clarified (Taylor 1974). In parallel with collaborating of index, Lieth et al. (1974) classified plant growth stage into leafing, flowering, deflowering and defoliation, and regarded each stage as phenological stage. Schirone et al. (1990) classified the phenological stage into many stages and applied this method for *Quercus cerris*. However, up to now, phenological phenomenon have been interpreted by data based on macroclimate only and studies for phenology were a few in Korea. Moreover, Yim (1983, 1987) reported that YDI was more useful than Tn in predicting flowering phenology in Korea. However, by Diekmann (1996), the accumulation of daily mean air temperatures (degree- days) above 5℃ from January 1 was a very accurate model in predicting flowering for plant species in deciduous forests of Sweden. Rathcke and Lacey (1985) and Kudo

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(1992) supported the latter model. Therefore, these two models are in need of certification in Korea. In this time, the more the index range, variation among individuals, of a species was narrow regardless of areas or years, the more model was useful.

The aim of this study is to certify relationship between phenological stage of several woody plant species and cumulative air temperature in springtime, to select a species or species-phenological stage showing the narrow range of index and to find more useful model of the two (YDI and Tn). In addition to two indices, relationship between phenological time and year day (YD) was analyzed.

STUDY AREA

The study area was Namsan, located between Choong-gu and Yongsan-gu, Seoul City. Namsan is 262 m in altitude and 2,958,864 m^2 in area. Namsan is located in center of urban, so that is confronted with waste heat emitted from automobile, residence and building. Annual mean air temperature and precipitation are 1,369.8 mm and 11.8℃, respectively (Korea Meteorological Administration 1991). Study sites were two in 2005 and three in 2006 (Fig. 1). About 50 m × 50 m quadrat which was interpretable by an air temperature was set up in each site.

Site 1 is located at 37°38'00.8"N, 126°59'27.0"E, faced to southeast, 157 m in altitude and 10° in slope. Height and coverage of tree layer are 20 m and 80%, respectively. This layer is composed of *Quercus acutissima*, *Q. mongolica*, *Prunus leveilleana*, *Q. dentata*, *Q. serrata*, *Robinia pseudo-acacia* and *Pinus densiflora*. Height and coverage of subtree layer are 6 m and 50%, respectively. This layer is composed of *Sorbus alnifolia*, *Styrax japonica* and *Acer pseudo-sieboldianum*. Height and coverage of shrub layer are 1.5 m and 30%, respectively. This layer is composed of *Stephanandra incisa* and *Rhododendron mucronulatum*. There is no plant in herb layer and litter layer is 20 cm depth.

Site 2 is located at 37°38'00.8"N, 126°59'27.0"E, faced to northeast, 236 m in altitude and 30° in slope. Height and coverage of tree layer are 18 m and 90%, respectively. Dominant species is *Q. mongolica*. Subtree layer is 60% in coverage, 7 m in height and composed *P. leveilleana*, *S. japonica*, *A. pseudo-sieboldianum*, *S. alnifolia*, *Prunus padus* and *Kalopanax pictus*. Shrub layer is 10% in coverage and composed of *Rhododendron yedoense* var. *poukhanense*, *R. mucronulatum*, *Zanthoxylum ailanthoides* and *Forsythia koreana*. There is no plant in herb layer. Depth of litter layer is 5 cm.

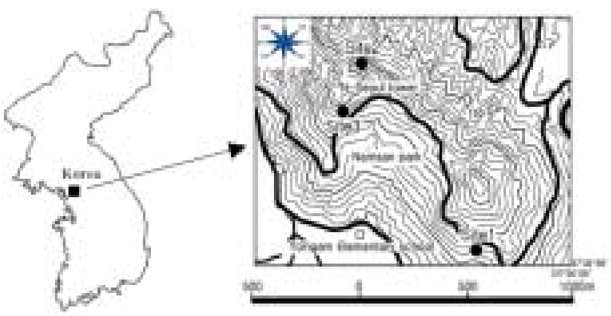

Fig. 1. The map showing the study area.

Site 3 is located at 37°32'56.6"N, 126°59'30.3"E, faced to southwest, 236 m in altitude and 15° in slope. Height and coverage of tree layer are 15 m and 80%, respectively. In this layer, dominant species is *Q. acutissima*. Height and coverage of subtree layer are 6 m and 70%, respectively. This layer is composed of *A. pseudo-sieboldianum*, *P. leveilleana*, *Q. serrata*, *P. padus*, and *P. densiflora*. Shrub layer is 1.2 m in height, 20% in coverage and composed of *S. incisa*, *R. mucronulatum* and *Rosa multiflora*. There is no herb layer. Depth of litter layer is 5 cm.

MATERIALS AND METHODS

To measure the microclimate, automatic thermometer (LogTag, TRIX-8) was set up at 4 m height from soil surface at each site on February 23, 2005 and collected on July 1, 2006. Thermometer was set up to measure air temperature by 0.1℃ unit at each time. The daily lowest and mean air temperature were selected or calculated from data recorded in automatic thermometer from January to May. Cumulative temperature-day indices were calculated by following formula. That was, YDI was calculated by summing temperature of daily mean air temperature over 0℃ from January 1 to date of each phenological stage. Tn was calculated by summing temperature of daily mean air temperature over 5℃ minus 5 from January 1 to date of each phenological stage. YDI and Tn of 2005 and 2006 were separately calculated from January 1 to each date of phenological stage each year. The date when each phenological phenomenon appeared was converted into year day (YD).

$$\mathrm{YDI} = \sum^{n_1} (t > 0℃) \quad \text{(Yim 1983)}$$

$$\mathrm{Tn} = \sum^{n_2} (t - 5℃) \quad \text{(Lieth et al. 1974)}$$

t : daily mean air temperature

n_1 : date over 0℃ from January 1 to date of each phenological stage

n_2 : date over 5℃ from January 1 to date of each phenological stage

The monitoring plant was chosen on three criterions; 1) the plant

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which was healthy and grew vigorously, 2) the plant which was not shaded by other materials, 3) the plant which the scrutiny with the naked eye was possible, except for plant over 5 m in height. The species chosen were *Quercus acutissima*, *Q. mongolica*, *Prunus leveilleana*, *P. serrulata* var. *spontanea, Robinia pseudo-acacia, Sorbus alnifolia*, *Styrax japonica, Acer pseudo-sieboldianum, Stephanandra incisa, Rhododendron mucronulatum, Forsythia koreana, Symplocos chinensis* for. *pilosa*, *Alnus hirsuta* and *Zanthoxylum schinifolium*. Phenological stages were certified at the end of three fixed twigs. The plant's twig located high from soil surface was certified by telescope. In case that female flower was small or could not be certified, male flower was surveyed. That was, male flowers in *Q. mongolica*, *Q. acutissima* and *A. hirsuta* were surveyed.

Field survey was carried out three times a week from February 20 to June 10 in 2005 and 2006. Phenological stages were classified into five; budding, leafing, flower budding, flowering and deflowering. Criterion for each phenological stage was as Table 1. The case that phenological stage was not clear or there was no flower in a site was leaved to blank. To certify variation in a species - a phenological stage, coefficients of variation (standard deviation/mean) over three variables (individuals) were calculated. We regarded small coefficient of variation among the sites or between years as a good index or species.

RESULT AND DISCUSSION

Changes of Air Temperature from March to May

In 2005, changing patterns of the daily lowest air temperature were similar in two sites in 2005 (Site 2 and Site 3). That was, the first date that the daily lowest air temperature was over 5℃ was same and March 9 in two sites. Moreover, from March 9 to March 31, the period that the daily lowest air temperature decreased below 0℃ was three times; from 11th to 15th, 19th and from 24th to 25th. Therefore, the high (over 5℃) and low (below 0℃) air temperature repeatedly appeared in March. The time when the daily lowest air temperature was continuously maintained over 5℃ was after March 30. In 2006, changing patterns of the daily lowest air temperature were similar in three sites. The date when the daily lowest air temperature was over 5℃ was in February and earlier 15 days than 2005 (not shown in Fig. 2). However, the period that the daily lowest air temperature decreased below 0℃ was four times in Site 1, and six times in Site 2 and Site 3. The last time that the daily lowest air temperature decreased below 0℃ was March 30. Fluctuation of air temperature was thus more remarkable in 2006 than in 2005 in March. On March 31, YDIs were 154.0℃・day (Site 2), 158.8℃・day (Site 3) in 2005 and 265.6℃・day (Site 1), 211.1℃・day (Site 2), 226.4℃・day (Site 3) in 2006. At this time, Tn was 25.2℃・day (Site 2), 27.2℃・day (Site 3) in 2005 and 60.5℃・day (Site 1), 39.6℃・day (Site 2), 42.3℃・day (Site 3) in 2006. Therefore, till March 31, Tn was higher in 2006 than in 2005.

This changing pattern of air temperature was thought to affect on early sprouting organ. Especially, organ vulnerable to low temperature (below 0℃) was thought to be retarded in growth, in case of the worst, frozen to death. By this reason, the disorder in phenological phenomenon might be raised. That was, phenological stages which appeared in the early springtime retarded and those in the late spring time processed on time, so that period between two phenological groups was thought to be shortened. Moreover, phe-

Table 1. Criterion of each phenological stages

Phenological event	Criterion
Budding	the time when bud's outermost capsule is ruptured
Unfolding	the time when leaf is flat, regardless of size
Flower budding	the time when petal or male flower bud is shown
Flowering	the time when petal burst open or pollen is shown
Deflowering	the time when petal fall or fade or pollen is not shown

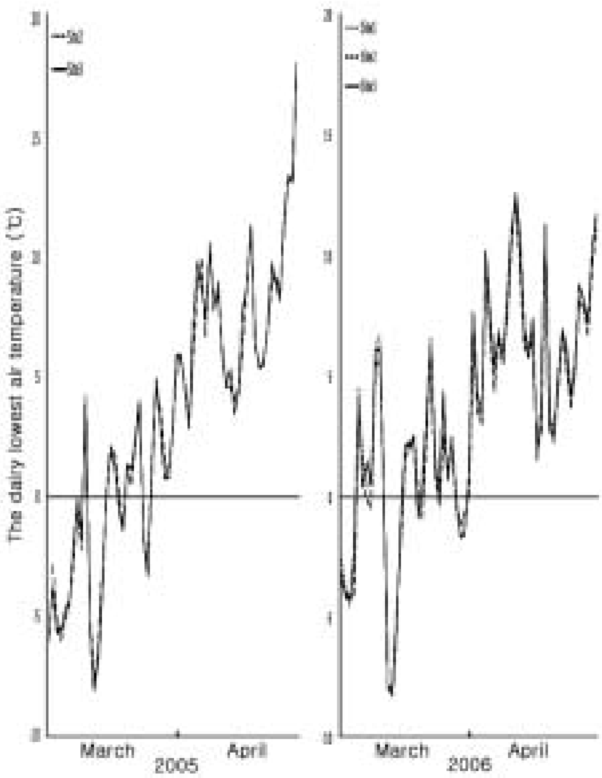

Fig. 2. The daily lowest air temperature from March, 1 to May, 31 in 2005 and 2006.

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nological stages which appeared in the early springtime were thought to be elongated.

Time of Each Phenological Stage and Indices

For 14 woody plant species, YD, YDI and Tn at time of each phenological stage were as Table 2.

For *Q. mongolica*, at a budding time, the ranges of YD, YDI and Tn were 95～98 days, 210.8～327.2℃・day and 54.2～92.2℃・day, respectively. At leafing time, the ranges of YD, YDI and Tn were 104～109 days, 363.0～421.1℃・day and 122.9～154.9℃・day, respectively. At flowering time, the ranges of YD, YDI and Tn were 107～116 days, 379.7～466.9℃・day and 124.6～172.2℃・day, respectively. Therefore, the indices of phenological stage appeared in late season were more different than ones in early season with the year or site. The range of YD was narrower than that of other two indices, so that, main factors on each phenological stage were thought to be others rather than cumulative air temperature.

In *P. leveilleana*, the trends among the phenological stages were different, showing that the indices of Site 2 in 2006 were severely high at budding and leafing time. However, three indices of flower budding and flowering times were similar. This result was thought to be originated from the daily lowest air temperature of March in 2006. Therefore, vegetative organ was thought be unpredictable but sexual one predicable on theses indices.

At budding time of *A. pseudo-sieboldianum*, YD and YDI were various but Tn was similar among sites or between years. Three indices at leafing time were lower at Site 2 than other sites in 2006. By this result, other factors rather than cumulative air temperature might affected on leafing of *A. pseudo-sieboldianum*, Three indices of flower budding, flowering and deflowering times were thought be useful to predict the phenological stages of *A. pseudo-sieboldianum*.

In *S. chinensis* for. *pilosa*, the times of leafing, flower budding, flowering and deflowering were thought to predict by indices of YD, YDI and Tn.

In *F. koreana,* the YD, YDI and Tn at the time of budding, leafing, flower budding, flowering and deflowering were various. YD, YDI and Tn at the budding time were 52～85 days, 48.7～121.7℃・day and 0℃・day at the flowering time 72～102 days, 210.3～300.2℃・day and 39.8～108.6℃・day, respectively. On this result, the times of each phenological stage could not be predicted on these indices. Especially, Tn at the budding time was 0℃・day. By Yim (1986), YD and YDI at budding time were 74.8 days and 150.7℃・day in Seoul, 76.5 ± 7.6 days and 193.3 ± 77.7 ℃・day in Korea, respectively. Moreover, YD and YDI at flowering time were 84～100 days and 211.7℃・day in Seoul, 86.3 ± 7.6days and 255.1 ± 80.2℃・day in Korea, respectively. Therefore, the indices of this study were higher than those of Yim (1986), however, the result of this study were roughly coincident with Yim (1986).

YD, YDI and Tn at the budding and flowering times of *R. mucronulatum* were dissimilar between years but similar among the sites in a same year. YD, YDI and Tn at the budding time were 52～60 days, 36.6～65.1℃・day and 0℃・day, at the leafing time 97～108 days, 282.1～379.7℃・day and 75.2～146.5℃・day, respectively. Therefore, the budding and leafing time could not be predicted on these indices. The indices of flower budding, flowering and deflowering times in 2005 were dissimilar to those in 2006 but there were no different among the sites in a same year. For example, at flowering time, YD, YDI and Tn ranges were 103～105 days, 310.3～322.4℃・day and 113.7～118.6℃・day in 2005 and 95～97 days, 276.0～317.5℃・day and 66.9～87.4℃・day in 2006, respectively. By Yim (1986), YD and YDI were 87.4 days and 171.8℃・day in Seoul, 81.7 ± 8.4 days and 223.6 ± 112.0℃・day in Korea at budding time, 86～104 days and 269.4℃・day in Seoul, 90.5 ± 7.9 days and 301.2 ± 126.72℃・day in Korea at flowering time, respectively. Therefore, the ranges in this study were narrower than those of Yim (1986) but two results were roughly similar.

The each phenological stage of *R. pseudo-acacia* appeared later than that of other species. The ranges of YD, YDI and Tn were 118～121 days, 574.4-594.3℃・day and 235.3～249.2℃・day at the budding time, 121～123 days, 606.6～642.5℃・day and 257.4～282.4℃・day at leafing time, 128～131 days, 736.8～769.9℃・day and 355.9～374.8℃・day at flower budding time, 136～144 days, 876.1～969.6℃・day and 456.0～515.5℃・day at flowering time, respectively. By this result, each phenological stage was thought to be predicted by these indices. By Yim (1986), YD and YDI of *R. pseudo-acacia* were 103.3 days and 382.3℃・day in Seoul and 106.2 ± 7.3 days and 457.8 ± 129.7℃・day in Korea at budding time, 130.9 days and 819.44℃・day in Seoul, 132.7 ± 3.9 days and 833.6 ± 185.8℃・day in Korea at flowering time. Therefore, YD and YDI at budding and flowering time of *R. pseudo-acacia* checked in this study were similar to those in Yim (1986).

In *S. alnifolia*, YDI and Tn at the budding and leafing time in 2005 were larger than those in 2006. However, YDI and Tn at the flower budding, flowering and deflowering time in 2005 were similar to those in 2006. Therefore, the vegetative and sexual organs were dissimilar each other in adaptation pattern for air temperature in spring time. YDI and Tn of latter ones were more useful than former ones in prediction for phenological stage. Especially, YD, YDI and Tn at flowering time were 124～127 days, 615.5～694.9℃・day and 283.8～319.8℃・day, respectively, so that these indices might be useful for prediction of phenological stages.

In *S. incisa*, YD, YDI and Tn at the budding, leafing and flower

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Table 2. YD, YDI and Tn at budding and leafing times of 14 species at Namsan

Scientific name	Year	Site	Budding			Leafing			Flower budding			Flowering			Deflowering		
			YD	YDI	Tn	YD	YDI	Tn	YD	YDI	Tn	YD	YDI	Tn	YD	YDI	Tn
Q. mongolica	2005	2	97	230.2	66.5	109	378.6	154.9	109	378.6	154.9	116	466.9	171.2	124	615.5	316.8
		3	95	210.8	54.2	108	368.1	146.5									
	2006	1	96	327.2	92.2	103	421.1	151.0				100	379.7	124.6	122	660.3	295.2
		2	98	296.7	79.3	103	363.0	122.9				107	405.6	143.7	123	676.6	262.4
		3	97	294.7	75.5	104	384.0	129.9				110	440.8	156.7	118	528.2	204.1
P. leveilleana	2005	2	79	85.5	5.8	105	322.4	118.6	105	322.4	118.6	109	378.6	154.9	116	466.9	208.2
		3	85	121.7	15.1	109	385.0	158.4	105	329.3	122.7	109	385.0	158.4	112	415.6	174.0
	2006	2	74	109.7	14.7	118	525.1	208.2	107	405.6	143.7	112	452.0	170.1	116	498.4	193.1
		3	95	276.0	16.9	110	440.8	156.7	103	371.9	122.8	108	426.2	152.1	112	462.9	168.8
A. pseudo-sieboldianum	2005	2	81	99.3	9.6	112	411.0	172.2	112	411.0	172.2	123	596.4	302.7	130	693.9	365.2
		3	99	263.3	16.7	112	415.6	174.0	112	415.6	174.0	116	471.7	210.1	120	546.1	264.5
	2006	2	68	87.0	9.0	113	363.0	122.9	107	405.6	143.7	114	473.9	179.9	128	701.4	327.6
		3	72	125.8	16.3	107	412.5	143.4	107	412.5	143.4	114	481.1	177.0	128	694.3	320.2
S. chinensis for. *pilosa*	2005	3	94	197.6	46.0	102	300.2	108.6	120	546.1	264.5	127	666.5	349.9	134	761.3	409.7
	2006	3	65	89.2	4.7	97	294.7	75.5	114	481.1	177.0	128	691.3	320.2	138	867.0	442.9
F. koreana	2005	2	60	36.9	0	109	378.6	154.9	97	230.2	66.5	102	293.2	104.5	112	411.0	172.2
		3	85	121.7	0	102	300.2	108.6	92	180.3	38.7	102	300.2	108.6	112	415.6	174.0
	2006	1	52	65.1	0	95	317.5	87.4	65	103.3	15.7	72	211.1	43.9	102	411.9	146.8
		2	52	48.7	0	101	341.8	109.0	72	106.8	14.7	93	240.3	51.3	105	382.0	137.2
		3	52	56.8	0	95	276.0	66.9	72	125.8	16.3	86	210.3	39.8	100	332.0	97.9
R. mucronulatum	2005	2	60	36.9	0	107	347.5	133.7	101	281.9	98.2	105	322.4	118.6	112	411.0	172.2
		3	60	36.6	0	108	368.1	146.5	102	180.3	38.7	103	310.3	113.7	109	385.0	154.4
	2006	1	52	65.1	0	100	379.7	124.6	86	244.1	56.8	95	317.5	87.4	104	434.2	159.1
		2	52	48.7	0	100	326.8	98.2	93	240.3	51.3	97	282.1	74.2	104	375.0	130.2
		3	52	56.8	0	97	282.1	75.5	82	183.4	32.9	95	276.0	66.9	100	332.0	97.9
R. pseudo-acacia	2006	1	118	594.3	249.2	121	642.5	282.4	128	769.9	374.8	136	912.0	476.9	142	1025.7	560.6
		2	121	574.7	240.3	123	607.7	262.4	130	736.8	355.9	138	876.1	456.0	144	983.7	532.8
		3	121	574.4	235.3	123	606.6	257.4	131	749.1	360.0	144	969.6	515.5	161	1294.6	580.3
S. alnifolia	2005	2	89	145.3	21.6	109	378.6	154.9	109	378.6	154.9	124	615.5	316.8	127	656.7	343.0
	2006	1	72	144.2	21.6	107	465.5	175.4	114	541.1	216.0	124	694.9	319.8	128	769.9	374.8
		2	74	109.7	14.7	99	311.0	88.9	112	452.0	170.1	127	680.4	312.4	129	718.7	343.6
		3	68	110.0	10.5	100	332.0	97.9	114	481.1	177.0	125	642.9	283.8	128	694.3	320.2
S. incisa	2005	2	85	117.8	13.9	97	230.2	66.5	120	539.8	261.0	144	913.0	514.1	158	1185.6	726.9
		3	79	88.5	11.0	97	235.7	69.1	124	624.7	323.1	144	925.3	523.7	158	1198.4	716.9
	2006	1	65	103.3	5.7	81	211.1	43.9	114	541.1	216.0	136	912.0	476.9	221	2759.9	1899.8
		2	65	71.3	4.1	81	163.6	30.1	114	473.9	179.9	198	1905.5	452.2	241	3199.5	2258.0
		3	65	89.2	4.7	81	183.4	32.9	114	481.1	177.0	138	867.0	442.9	144	969.6	515.5
S. japonica	2005	2	102	293.2	104.5	108	361.5	142.7	128	668.9	350.2	147	967.7	440.4	151	1051.4	617.7
		3	102	300.2	108.6	105	329.3	122.7	124	624.7	323.1	146	960.8	549.2	153	1100.7	636.2
	2006	1	93	293.6	73.5	97	338.7	98.6	114	541.1	216.0	136	912.0	476.9	144	1058.2	583.1
		2	95	261.2	64.1	102	350.7	129.0	114	473.9	179.9	142	747.8	510.1	144	983.7	532.8
		3	93	252.7	53.6	98	304.3	80.1									
Q. acutissima	2005	3	107	354.0	137.4	118	504.0	232.4				124	624.7	323.1	130	704.1	372.5
	2006	1	95	317.5	87.4	110	496.3	191.2				110	496.3	191.2	121	642.5	282.4
		3	97	294.7	75.5	110	440.8	156.7				114	440.8	177.0	123	606.6	257.4
P. serrulata var. *spontanea*	2005	3	79	88.5	22.0				102	300.2	215.5	109	385.0	156.0	112	415.6	168.8
	2006	1	72	144.2	21.6	109	489.5	189.4	101	395.5	135.4	105	446.0	165.9	108	480.2	185.1
		3	68	110.0	10.5	104	384.0	129.9	97	294.7	75.5	102	363.0	118.9	110	440.8	156.7
A. hirsuta	2005	2	97	230.2	66.5	109	378.6	154.9									
		3	102	300.2	108.6	112	415.6	174.0									
	2006	2	97	282.1	74.2	112	350.7	119.0				68	87.0	9.0	76	125.5	17.0
		3	97	294.7	75.5	112	363.0	118.9				68	110.0	10.5	76	140.9	14.4
Z. schinifolium	2005	2	120	539.8	261.0	137	804.1	440.4									
	2006	2	104	375.0	130.2	118	525.1	208.2	133	783.3	122.9	188	1905.5	1228.3	236	3082.0	2165.2
		3	104	384.0	129.9	118	528.3	204.1	188	1487.6	1175.3	221	2609.0	1769.9	236	2991.5	2077.4

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budding time were larger in 2005 than in 2006. Moreover, the ranges of YD, YDI and Tn at the flowering and deflowering time were broad. Therefore, phenological stage was not coincided with these indices. Moreover, because that the stage from flowering to deflowering slowly progressed, the border of two stages was not clear. YD at the flowering time was 131∼143 days in Seoul by Yim (1986) and 136∼198 days in this study.

In *S. japonica*, YDI and Tn at the budding, flower budding and deflowering time were larger in 2005 than in 2006. However, YD, YDI and Tn at the leafing and flowering time were no different between 2005 and 2006. Of the three sites, three indices of Site 2 were larger than those of other sites. YD at flowering time was 131∼141 days in Yim (1986) or 136∼141 days in this study. However, because that *S. japonica* flowered in alternate year by field survey, monitoring for the same plant needed three or five years.

Each phenological stage of *Q. acutissima* appeared in earlier time in 2006 than in 2005. Except for budding, YDs at the leafing, flower budding, flowering and deflowering time were relatively constant regardless of site and year. However, YDI and Tn at the each phenological stage were various with the site or year. YD was thought be the most pertinent index to predict the time of phenological stages.

The phenological data for *P. serrulata* var. *spontanea* and *Z. schinifolium* were insufficient and three indices at each phenological stage were various with sites or years, so that the relation between phenological stages and indices was not clear.

YDs at the budding, leafing, flower budding, flowering and deflowering time in *A. hirsuta* were relatively constant regardless of years or sites. However, YDI and Tn at each stage were various with the sites and years. Therefore, YD was thought be useful for prediction the time of each phenological stage.

Coefficients of variation (CV) of YDI and Tn at the time of each phenological stage were as Table 3. In this case, the more CV was, the more the variation among the individuals was large. Large CV meant that index was not useful to predict the time of phenological stage. Of the 14 species, mean coefficient of variations was 0.04 in *R. pseudo-acacia* and 0.09 in *A. hirsuta*, so that phenological stages of these two species were thought to be predictable by two indices. However, mean coefficient of variation was 0.30 in *F. koreana* and *S. incisa* and 0.32 in *Z. schinifolium*, so that phenological stages of these three species were thought to be unpredictable by two indices. These three species had a long flowering duration. Except for these five species, mean coefficients of variation in the nine species were in the range of 0.12 and 0.19. Of the five phenological stages, mean coefficient of variation was the smallest at deflowering time and the largest at budding time. Phenological stage appeared in the early time thus showed large variation and that in the late time small one among the sites or between the years. This result was thought that the daily lowest air temperature in the early spring time decreased below physical zero

Table 3. Coefficient of variations (standard deviation/mean) of YDI and Tn at each phenological stage

Scientific name	Budding		Leafing		Flower budding		Flowering		Deflowering		Mean
	YDI	Tn	YDI	Tn	YDI	Tn	YDI	Tn	YDI	Tn	
Q. mongolica	0.16	0.17	0.05	0.09			0.08	0.12	0.09	0.16	0.12
P. leveilleana	0.51	0.33	0.18	0.20	0.09	0.08	0.07	0.04	0.06	0.08	0.16
A. pseudo-sieboldianum	0.49	0.28	0.05	0.13	0.01	0.09	0.10	0.23	0.10	0.11	0.16
F. koreana	0.45		0.11	0.28	0.33	0.66	0.15	0.44	0.08	0.19	0.30
R. mucronulatum	0.23		0.10	0.22	0.17	0.41	0.06	0.22	0.09	0.19	0.19
R. pseudo-acacia	0.02	0.02	0.03	0.04	0.02	0.02	0.04	0.05	0.13	0.03	0.04
S. alnifolia	0.14	0.28	0.16	0.18	0.13	0.13	0.05	0.05	0.06	0.06	0.12
S. incisa	0.17	0.49	0.13	0.34	0.10	0.24	0.36	0.07	0.50	0.58	0.30
S. japonica	0.07	0.27	0.06	0.20	0.13	0.27	0.02	0.08	0.04	0.07	0.12
Q. acutissima	0.08	0.27	0.06	0.16			0.15	0.29	0.06	0.16	0.15
P. serrulata var. *spontanea*	0.20	0.38	0.12	0.19	0.02	0.23	0.09	0.47	0.06	0.07	0.18
A. hirsuta	0.10	0.01	0.06	0.17							0.09
Z. schinifolium	0.17	0.36	0.35	0.39							0.32
Mean	0.21	0.26	0.11	0.20	0.11	0.24	0.11	0.19	0.12	0.15	

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(0℃) or physiological zero (5℃) and plant growth was not constant. In five phenological stages, mean coefficient of variation of YDI was in the range of 0.11～0.21 and that of Tn was in the range of 0.15～0.26. Mean coefficient of variation of YDI was thus smaller than that of Tn, so that the former was thought to be better indicator than the latter. As above mentioned, Tns at *F. koreana* and *R. mucronulatum*'s budding time were below 0℃・day and could not be calculated. By this result, plant species sprouting in the early spring time were thought be affected by air temperature of 0～5℃. In general, Tn performed better for the late-flowering species than for the early-flowering species (Diekmann 1996). Of the species- phenological stage pair, coefficient of variation of YDI was 0.01 in *A. pseudo-sieboldianum* - flower budding and below 0.05 in 11 pairs. These pairs were thought be pertinent to predict for the phenological stage by YDI. The YDIs over 0.40 were 4 pairs, comprising of *P. leveilleana* - budding (0.51). These pairs were thought be impertinent to predict for the phenological stage by YDI. Coefficient of variations of Tn was 0.01 in *A. hirsuta* - budding and below 0.05 in 8 pairs. These pairs were thought be pertinent to predict for the phenological stage by Tn. The Tns over 0.40 were 5 pairs comprising of *F. koreana* - flower budding (0.66). These pairs were thought be impertinent to predict for the phenological stage by Tn. Therefore, to predict for phenological stage of a species, YDI was more pertinent than Tn. It was worthy of study that result from two indices was different each other. Moreover, the reason why two indices were impertinent to predict each phenological time in five pairs was in need of study, comprising of other factors affecting on plant phenology except for cumulative air temperature.

LITERATURE CITED

Brown DS. 1953. Climate in relation to deciduous fruit production in California. Ⅵ. The apparent efficiencies of different temperatures for the development of apricot fruit. Proc Am Soc Hort Sci 62: 173-183.

Diekmann M. 1996. Relationship between flowering phenology of perennial herbs and meteorological data in deciduous forests of Sweden. Can J Bot 74: 528-537.

Fleming TH, Williams CF, Bonaccorso FJ, Herbst LH. 1985. Phenology, seed dispersal, and colonization in Muntigia Calabura, a neotropical pioneer tree. Amer J Bot 72: 383-391.

Flint HL. 1974. Phenology and genecology of woody plants. In: Phenology and Seasonality Modeling, (Lieth H ed). Springer-Verlag, New York, pp 83-97.

Garner WW, Allard HA. 1920. Effect of the relative length of the day and night and other factors of the environment on growth and reproduction in plant. J Agri Res 18: 553-606.

Gill DS, Mahall BE. 1986. Quantitative phenology and water relations of an evergreen and a deciduous chaparral shrub. Ecol Monogr 56: 127-143.

Hegarty EE. 1990. Leaf life-span and leafing phenology of lianes and associated trees during a rainforest succession. J Ecol 78: 300-312.

Hopkins AD. 1920. The bioclimatic law. J Wash Acad Sci 10: 34-40.

Jackson LE, Bliss LC. 1984. Phenology and water relations of three plant life forms in a dry tree-line meadow. Ecol 65: 1302-1314.

Korea Meteorological Administration. 1991. Climatological standard normals of Korea. Dongjinmoonwhasa, Seoul. p 14.

Kudo G. 1992. Pre-flowering and fruiting periods of alpine plants inhabiting a snow-bed. J Phytogeogr Taxon 40: 99-106.

Lieth H. 1974. Penology and seasonality modeling. Springer-Verlag, New York, 444 p.

Lindley AA, Newman JE. 1956. Use of official weather data in springtime temperature analysis of an Indiana phenological record. Ecol 37: 812-823.

Nilsen ET, Muller WH. 1981. Phenology of the drought-deciduous shrub *Lotus scoparius*: climatic controls and adaptive significance. Ecol Monogr 51: 323-341.

Nuttonson MY. 1948. Some preliminary observation of phenological data as a tool in the study of phenoperiodic and thermal requirements of various plant materials. In: Vernalization and photoperiodism, (Mureek AE, Whyte RO eds). Chronica Botanika Watham, Mass. pp 129-143.

Opler PA, Frankie GW, Baker HG. 1980. Comparative phenological studies of threelet and shrub species in tropical wet and dry forests in the lowlands of Costa Rica. J Ecol 68: 167-188.

Ratchke B, Lacey EP. 1985. Phenological patterns of terrestrial plants. Ann Rev Ecol Syst 16: 179-214.

Schirone B, Leone A, Mazzoleni S, Spada F. 1990. A new method of survey and data analysis in phenology. J Vegetation Sci 2: 27-34.

Taylor FG. Jr. 1974. Phenodynamics of production in a mesic deciduous forest. In: Phenology and Seasonality Modeling, (Lieth H ed). Springer-Verlag, New York, pp 23-54.

Wright SJ. 1991. Seasonal drought and the phenology of understory shrubs in a tropical moist forest. Ecol 72: 1643-1657.

Yim Y-J, Rim M-K, Shim J-K. 1983. The thermal climate and phenology in Korea. Kor J Bot 26: 101-117.

Yim YJ. 1986. The effects of thermal climate on the flowering dates of plants in South Korea. Kor J Apiculture 1: 67-84.

Yim YJ. 1987. The effects of thermal climate on the flowering dates of plants in South Korea. - For the exploitation of honey and pollen resource plants-. Kor J Apiculture 2: 9-28.

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