The Phenological Response of Five Perennial Plant Species at Five Locations in Indiana to Climatic Variations 1966-1972[1]

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Abstract

The appearance of first leaf (phenophase) of five perennial species at five locations in Indiana was reported. Location of planting varied from Johnson (south) to Wanatah (north) and from Johnson (west) to Farmland (east). All sites had different soil type, elevation and climate pattern.

The appearance of the first leaf of the species observed varied from 24 to 29 days from south to north. The extremes in days to appearance of first leaf among species and years varied from 20 days in big bluestem (*Andropogon gerardi* L.), the most uniform to leaf, to 29 days in fall aster (*Aster azurena* L.). Considering all species, Dubois was the most consistent location having the least variation (18 days) and Johnson and Wanatah the greatest (29 days), to appearance of first leaf.

The 3-4 week earlier start in growth in the south strongly supports culturing earlier planting of cool season agronomic and horticulture crops. This indicates that double cropping, the practice of following a first crop of wheat, barley or winter oats with a second crop of soybeans or sorghum, should be encouraged. This would be a more preferable alternative than increasing the acreage of highly erosive land which is presently under permanent cover. Such areas have been in a concerted program of erosion and flood control for the past 30 years, and cultivation of these areas not only may induce flooding and severe erosion but in some instances may disrupt current domestic water supplies.

Introduction

The seasonal response of organisms to the total environment varies from species to species and year to year. Certain specific events, which can be observed by date each year with a degree of precision such as budding, flowering, fruiting, etc., are referred to as stages of development or phenophases. Observation of such events, as they vary from year to year in plants, were probably noted before man domesticated economic animals and cultivated economic species from the plant kingdom. Isolation, selection, culturing and natural genetic manipulation of these species over time has given man his present food supply.

Plants native or adapted to a range of climatic belts can be useful in interpreting seasonal phenophase variations. This paper is an introduction to the observations on phenophase responses in the appearance of the first leaf of both economic and native plant species in Indiana.

Review of Literature

One of the earliest efforts to organize a network system for observing plants as they developed from season to season was reported

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by Linneaus in "Philosophea Botanica" in 1751 (7). He described a network of 18 stations in Sweden. Early attempts (such as he described) were hampered and limited by lack of interest, communication and transportation. Those systems initiated were usually intensive individual efforts made by devoted naturalists (5, 9, 10) and confined to limited areas. In 1905, the U.S. Department of Agriculture (then a part of the U.S. Weather Bureau) attempted a rather elaborate phenology program, but terminated it after four years (13).

Since 1945, advancements in communication, transportation and a change in research techniques have fostered renewed interest in phenological research in both Europe and the United States. Studies by individual scientists have grown into cooperative network endeavors. Caprio's 1,300 station network in the western United States and Schnelling's studies in Central Europe are examples of the new approach which employs the organization, communication, and cooperation of many people for completing observations over large areas (2, 3, 11).

Successful application of the results of phenological studies in making economic decisions has also encouraged continued effort in collecting data on seasonal variation in perennial plants. Coaker and Wright in England and Fulton in North Carolina related certain phenophases of plants to the appearance of the cabbage maggot (*Hylemyia brassicae* Bouché) (4, 6). In Indiana the heading of orchardgrass (*Dactylis glomerata* L.) can be closely associated with the appearance of the adult European corn borer (*Ostrinia nubilalis* Hubner) while ripening of the fruits of bush honeysuckle (*Lonicera tatarica* L.) appears to correlate with the maturation of the current varieties of soft red winter wheat. The evolution of appearance of first leaf and full bloom of Persian lilac "Red Rothamogensis" (*Syringia persian* L.) in Eastern and Central North America during 1960-72, which included phenological data from over 1,700 locations, was reported by Hopp and Blair (8).

The purpose of this study was to describe the influence of year-to-year climatic variations on initiation of the first leaf of five species at five different locations in Indiana (from 1966-72). The organization of the Indiana phenology garden network was published previously (1).

Materials and Methods

In 1960, the Indiana Phenology garden system began as a part of a regional project with four locations and one species. In 1964, eight additional locations and 11 new species were introduced. Perennial plants were selected so that two species would flower each month throughout the growing season. The original study was confined to observation on Persian lilac, 'Red Rothmagensis'.

The gardens involved in this paper and their locations are listed in Table 1. Species reported herein represent those which provided the most complete information to date. They include the following:

Persian lilac (*Syringa persian* L. "Rothomagensis")	— flowering early spring
Spirea (*Spirea spec* L.)	— spring
Orchardgrass (*Dactylis glomerata* L.)	— spring
Big bluestem (*Andropogon gerardi* L.)	— summer
Aster (*Aster azurens* L.)	— late summer

All species except lilac were established from an original cutting or clone, started in the greenhouse, transplanted to a nursery, then later transferred to the field in the fall of 1964. Lilac plants were purchased from a commercial nursery in Nebraska.

TABLE 1. *Location of the five gardens reported in study and yearly climatic variation.*

	Johnson	Dubois	Farmland	Columbia City	Wanatah
County	Gibson	Dubois	Randolph	Whitley	LaPorte
Latitude	38°16′N	38°27′N	40°08′W	41°09′W	41°31′N
Longitude	87°45′N	86°42′W	85°12′W	85°25′W	87°02′W
Elevation	131 m	210 m	294 m	269 m	246 m
Mean Temp.	14°C	12°C	12.5°C	10°C	9°C
Max. Temp.	43°C	40°C	41°C	39°C	40°C
Min. Temp.	—28°C	—29°C	—27°C	—27°C	—29°C
Mean Precip.	107.0 cm	107.0 cm	100.2 cm	94.3 cm	93.9 cm
Soil Type	Princeton Fine Sand	Tilsit Silt Loam	Blount Silt Loam	St Clair Silt Loam	Trace Sandy Loam

All plantings were located near official weather stations. Official Weather Observers, with the aid of a specially prepared manual of color photos of all phenophases, reported the dates of all observed phenophase events each year.

FIGURE 1. *Planting arrangement of a typical phenology garden.*

An established phenology garden is shown in Figure 1. Observations of the appearance of the first leaf by years, species and locations are summarized in Table 2.

TABLE 2. *Appearance of the first leaf on five species at five locations in Indiana 1966-72.*

Locations	Persian Lilac				Spirea				Orchardgrass				Big bluestem				Aster				Mean differences Among Species
	M	E	L	D	M	E	L	D	M	E	L	D	M	E	L	D	M	E	L	D	
Johnson	3/19	3/12	4/10	(29)	4/2	3/18	4/12	(25)	3/22	3/10	4/2	(23)	4/13	4/1	4/20	(19)	3/29	3/11	4/8	(28)	[29]
Dubois	3/18	3/13	3/25	(12*)	4/26	3/15	4/11	(27)	3/20	3/13	3/27	(14)	4/8	3/25	4/20	(26)	4/14	4/7	4/20	(13)	[18]*
Farmland	4/8	3/23	4/21	(29)	4/15	4/6	4/21	(15)	3/30	3/18	4/14	(27)	5/3	4/25	5/7	(13)	4/13	3/21	5/1	(41**)	[25]
Columbia City	4/9	3/27	4/23	(27)	4/16	4/4	4/23	(19)	4/2	3/11	4/15	(35)	5/2	4/21	5/8	(17)	4/10	4/4	4/17	(13)	[22]
Wanatah	4/12	3/25	4/30	(36)	4/18	4/6	4/28	(22)	4/28	4/15	5/11	(26)	5/7	4/10	5/14	(24)	4/26	4/8	5/13	(35)	[29]
Range in appearance of first leaf South-North	24				24				29				29				28				
Mean days among locations in appearance of first leaf				(26)				(22)				(26)				***(20)				(26)	

M – Mean date E – Earliest date L – Latest date D – Range

* Least difference in days to appearance of first leaf (among years)
** Greatest difference in days to appearance of first leaf (among years)
*** Most uniform in appearance of first leaf (among species)

Results

The location of the five stations reported in this paper vary from Johnson (south) to Wanatah (north) and from Johnson (west) to Farmland (east) with elevations varying from 131 to 294 m and soil types varying from sand to silt loam (Table 1). Southern locations average 54 more days of frost free growing conditions than in the north, and total precipitation increases about 13 cm from north to south. Drought stress is more frequently a problem at Johnson, however, than at Wanatah due to the additional growing days with only 13 cm added rainfall at this location.

Temperature extremes among the locations varied little over a 27-year period. However, temperature variation within given years results in considerable differences in timing of first leaf appearance. The average dates of appearance of the first leaf of each species at each location are presented in Table 2. Species which flower in early spring and summer tend to generate vegetative growth earlier than later flowering species. The first leaf on some species (*i.e.*, Persian lilac, Spirea) arises from secondary tissue generated the previous year, whereas the grasses and aster generate new leaf tissue from crown buds. The latter species might be expected to develop leaf tissue earlier as such growth may be more directly related to soil temperature which in spring is warmer than mean air temperature. Species with leaf tissue generating from buds in the soil also may have advantage in that diurnal soil temperature fluctuations are not as great as above-ground air temperatures, nor do water and nutrients have to be translocated as far to reach and activate growing regions (12). Since the point of origin of new leaf tissue differs among these species, no attempt has been made to relate a degree day or heat unit approach to this data as described by Lindsey and Newman (11). Evaluation of soil and air temperature to the appearance of first leaf and first bloom are in progress.

The extremes in average appearance of first leaves of the 1966-72 period for all species varied from 24-29 days among species from north to south (Table 2). This suggests that at Johnson, the season starts about 4 weeks earlier on the average than at Wanatah.

In considering the appearance of the first leaf among the five species, especially since they differ in growth habit, differences in air temperature in early spring among the various locations may have imposed limitations on growth. A summary of the mean temperature and precipitation values for March and April which correlate with this phenophase are shown in Table 3. The climatic conditions during this period obviously are critical to the timing of leafing.

March and April air temperatures averaged about 4°C warmer at Johnson than at Columbia City and Wanatah. The 4°C temperature difference over this 60-day period accounts for the early and rapid development of a given plant species located at the constrasting sites. More information is needed on the contribution of soil temperature to this phenophase. Precipitation was adequate at all locations during the beginning of growth.

TABLE 3. *Mean March and April air temperature and precipitation during 1966-72.*

Location	Temperature °C		Precipitation cm	
	March	April	March	April
Johnson	5.7	12.7	8.23	13.16
Dubois	5.0	12.4	7.62	12.67
Farmland	1.8	9.0	5.41	9.02
Columbia City	1.3	8.8	5.61	10.05
Wanatah	1.7	8.8	5.86	9.42
Mean of all locations	3.1	10.5	6.55	10.87
Range in mean temperature and precipitation	4.4	3.9	2.82	3.74

The dates of initiation of first leaf of these five species (although they all flower at a different period in the season and vary in growth form) give information regarding the response of genetically controlled specimens to variation in Indiana climate.

These data, in general, support Hopkin's Bioclimatic Law with regard to latitude. The elevation and longitude dimensions are too limiting to expect close correlation.

The variation (range) in first phenophase for each species is shown in Table 2. These data show that big bluestem has the fewest days (20) or least variation to appearance of first leaf over all locations. This may result from the residue from the previous year's growth offering protection from less diurnal soil temperature fluctuations. Other species were more prominently or totally exposed and have little protection from normal air temperature modifications, suggesting again that more stable environmental conditions in the soil contribute to a more uniform start of leaf bud growth.

The greatest variation in appearance of first leaf at a given location occurred in aster which has a similar growth habit to big bluestem, but leaves no stubble residue, with an exposure similar to bare soil. This occurred in Farmland, the highest in elevation and one of the coldest locations in the spring. Soils at this location are high in clay and also have poorer drainage than soils from the other four sites.

Among the five locations, Dubois on the average shows the least variation in appearance of the first leaf for the five plant species studied. Average variation in first leaf appearance was 18 days for Dubois as compared with 29 days for Johnson and Wanatah.

Additional data for this phenophase at these locations is needed before more detailed conclusions can be made. Evaluation of other phenophases may also contribute additional useful information for describing variations among locations over years.

Conclusions

Observations of the dates of appearance of the first leaf were made on five species at five different locations in Indiana on several soil types. It was found that: 1) variation in first leafing was 24-29 days (3-4 weeks) later in northern than in southern Indiana, due pri-

marily to temperature differences; and 2) large within-location variation in first leafing existed over the periods observed.

Practical application of this information indicates that cool season spring-planted crops and vegetables can be safely started in mid-March in southern Indiana, at least 3 weeks earlier than in northern Indiana.

Double cropping (the practice of following a winter small grain crop that matures in late June with a summer annual such as soybeans or sorghum) is well suited to the longer growing season of southern Indiana and should be encouraged to help overcome the present food and feed grain shortages. This cropping practice would be more effective than expanding production to less desirable acreages, many of which have been under a successful conservation program for more than 30 years.

The year to year within-location variation that occurred in this study would indicate that cool season perennials should have a better overall performance record than summer annual crops with higher temperature and water requirements.

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