NEW YORK'S FOOD AND LIFE SCIENCES BULLETIN NO. 17, JUNE 1972

PLANT SCIENCES

VEGETABLE CROPS (GENEVA) • NUMBER 3

NEW YORK STATE AGRICULTURAL EXPERIMENT STATION, GENEVA, A DIVISION OF THE NEW YORK STATE COLLEGE OF AGRICULTURE AND LIFE SCIENCES, A STATUTORY COLLEGE OF THE STATE UNIVERSITY, CORNELL UNIVERSITY, ITHACA

Regional phenological studies with Persian lilac *(Syringa persica)*[1]

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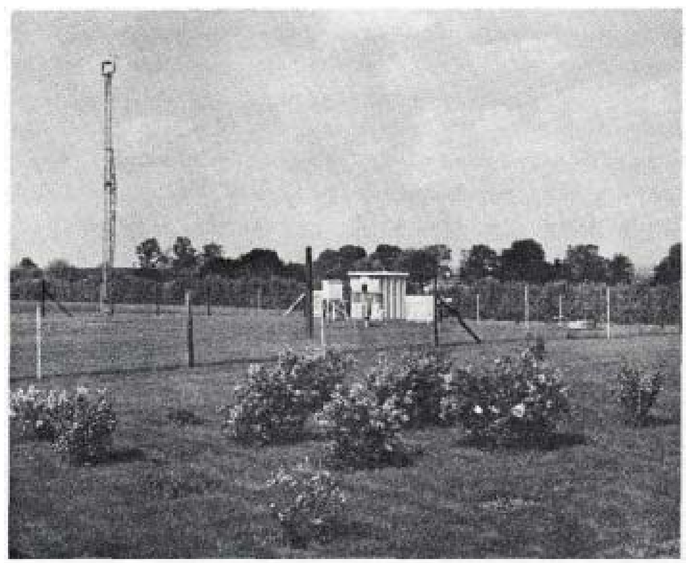
Phenology, derived from the Greek word "phaino" meaning to show or to appear, is the science concerned with periodic biological events in the animal and plant world as they are influenced by climate and weather. It is known as the science of appearances because emphasis is placed on dates of various occurrences. Bird migration, hibernation of animals, sprouting and flowering of plants in the spring, and maturation and senescence of plants in the fall are examples of phenological events.

The term "phenology" appears to have been first applied in 1853 by a Belgian botanist, Charles Morren, to that branch of science which studies periodic phenomena in the plant and animal world and their dependence upon the climate of any locality. Plants are excellent indicators of climatic differences because the times of occurrence of phenological events of many plants are, to a large degree, controlled by the weather. Thus, phenology represents a merging of the meteorological and biological sciences, each contributing something to the other.



Phenology is nothing new—phenological calendars for agricultural purposes were in use several thousand years ago. In recent years, however, phenology has received increased attention from agricultural and biological scientists (1,7,8).

PLANT PHENOLOGY

Plants can be observed methodically year after year and dates can be recorded when certain distinguish-

[1]This project is supported in part by Hatch Regional Research funds as a part of NE-69: Atmospheric influences on ecosystems and satellite sensing.

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able growth stages, such as opening of leaf buds or appearance of first flowers, occur. These plants may be considered as special, highly sensitive meteorological instruments that integrate the composite effect of weather factors such as temperature, rainfall, humidity, wind, and sunshine in their growth response. Using indicator plants that are genetically alike and observing them at numerous locations creates a network that supplements the cooperative weather observations of the National Weather Service. From the annual phenological reports, average dates for certain events can be established. Data can then be related to these averages for purposes of monitoring and characterizing individual seasons.

Dates of planting, blooming, and harvest for agricultural crops have been kept for many years at agricultural experiment stations throughout the country. These data are valuable to the agricultural scientist because they provide a basis for comparing relative earliness or lateness of developmental stages of crop varieties—effects of weather on crops depend on concomitant stages of plant development. Such comparisons are often used as a basis for selecting varieties most adapted for specific locations. But once a crop variety has been proved adaptable for the places where it has been tested, it is not always possible to specify where it will grow most successfully. Too little is known about the nature of climate and the developmental behavior of plants in areas away from the experimental sites. This gap of information can be narrowed by the use of phenological indicator plants that reflect climatic contrasts between locations through their differential rate of seasonal development.

Observations on selected indicator plants can be used to forecast or estimate the occurrence of succeeding phenological events on the same or other plants, or to predict the effect of weather on insects or other organisms. Agricultural and horticultural applications include the timing of particular cultural practices such as planting, spraying, and harvesting. In Montana, for example, some farmers make their first cutting of alfalfa hay within 10 days after the common lilac begins to bloom, thus harvesting it before the overwintering alfalfa weevil eggs begin to hatch.

PERSIAN LILAC

Persian lilac *(Syringa persica)* was chosen for the regional project described here because it has a number of characteristics that make it desirable as a phenological indicator plant. Widely adapted because of its cold hardiness, it is also resistant to both heat and drought. It is easily propagated vegetatively, and it is relatively resistant to insects and diseases. Furthermore, it has conspicuous phenological phases that are easy to observe, and it usually flowers the first year after transplanting.

This shrub normally grows 8 to 10 feet tall. The leaves are lance-shaped and much longer than broad. Leafbud opening in spring may vary from March in the southern part to May in the northern part of the region. Flowers are initiated in the flowerbuds during the summer; normally, these buds will not produce bloom until the following spring. In spring, the date of beginning of bloom may vary from April in the south to June in the north. The flowers are borne in clusters called panicles, 4 to 6 inches long, which arise from lateral buds. The panicles consist of many individual flowers about 3/8 inch in diameter.

Persian lilacs lose their leaves in the fall and require a period of winter chilling before normal growth can resume the following spring. The exact chilling conditions required—threshold temperature and length of exposure below this temperature—are not exactly known. The beginning of vegetative growth and the time of flowering in spring are delayed in plants that do not receive sufficient cold exposure after leaf fall. In the northern United States this is normally not a problem because adequate winter chilling occurs each year. But, in the southern part of the country, an abnormally early opening of leafbuds and blossoms may result from a very cold winter that fulfilled the plant's chilling requirement earlier than normal. A delay of these dates, on the other hand, may be due to a relatively mild winter. In these situations, dates of phenological events do not strictly reflect spring weather conditions.

REGIONAL PROJECTS

Phenology is a logical subject for regional and interregional studies because plant growth and development are not restricted by state boundaries. Localized phenological observations have been made in the United States for a number of years by individuals interested in specific species. Usually these observations have ended with the death of the individual involved. However, a phenological network started in Montana in the mid 1950's, in which common purple lilacs were observed by about 1,000 cooperators throughout the western United States (1,3,4), provided the impetus for the establishment of phenological networks in the North Central and Northeast regions of our country (5,6). In 1961, Agricultural Experiment Stations in the North Central States initiated a regional research project, NC-26, "Weather information for agriculture," which included a phenology objective. Observational sites were established in 12 states of the region. In the Northeast, regional project NE-35, "Climate of the Northeast—analysis and relationship to plant response," added a similar phenology objective in 1964 and developed a phenological network extending from Maine to West Virginia.

In both NC-26 and NE-35, the Persian lilac *(Syringa persica)*, cultivar 'Red Rothomagensis,' was used as a living integrator of environmental factors. All plants in these two projects were vegetatively propagated from the same parent stock or clone to avoid differences in their response to environmental factors that might occur if the plants were not genetically alike. Standardized instructions were developed to ensure uniformity in recording dates of first leaf, first flowers, full bloom, and end of bloom (6). Most observation sites are located near weather stations to allow comparisons between phenological data and meteorological observations. In July 1970, the phenological efforts conducted under NC-26 and NE-35 were combined as one of the objectives of a new regional project NE-69: "Atmospheric influences on ecosystems and satellite sensing." The program has expanded, and Alaska, North Carolina, and the Canadian Province of Quebec were added to the original cooperating states. Thus at present, Laval University in Quebec and 28 experiment stations in the United States are participating in the phenology objective of the NE-69 project.

In areas where the Persian lilac cultivar may be of doubtful adaptation, two honeysuckle cultivars, 'Arnold Red' and 'Zabelii,' were added to the network, specifically in Alaska, Quebec, and North Carolina. These honeysuckle cultivars are from the same parent stock as used in the companion study in the western region of the United States (4). The combined phenological networks now consist of about 500 sites (Table 1), and more locations are being added. Persian lilac is used at 396 of these sites. Phenological observations on genetically identical indicator plants are thus made on about 36 per cent of the land surface of the contiguous United States.

Figure 1 shows the distribution of the NE-69 phenology sites. The network extends from near the 49°N latitude (48° 51' Matane, Quebec, and 48° 45' Langdon, North Dakota) to 34°N latitude (34° 01'

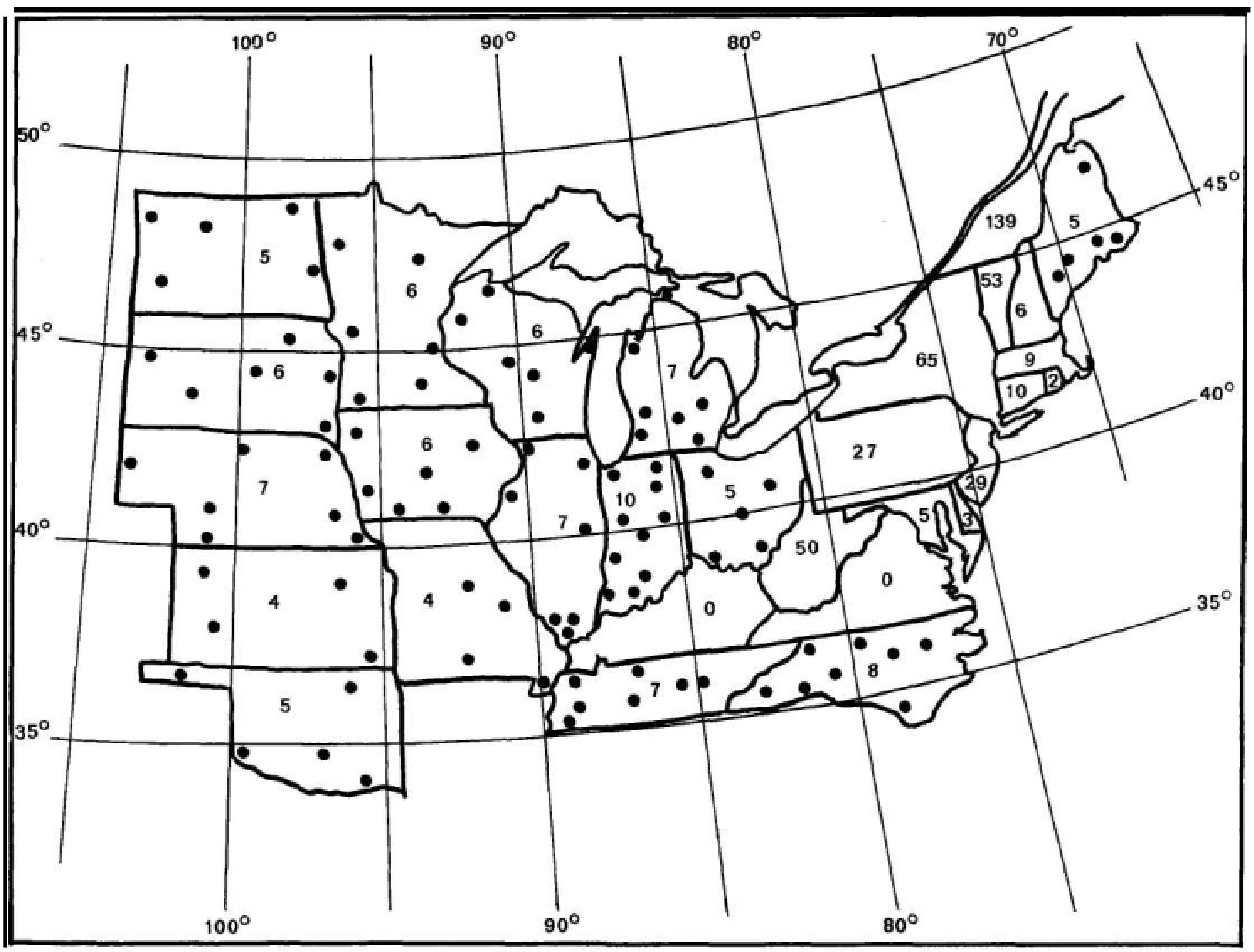

Figure 1.—Distribution of phenological sites contributing to the NE-69 phenology study (Alaska not shown).

Table 1.—Distribution of NE-69 phenology sites in 1971.

Alaska	2 1/	New Jersey	29
Connecticut	10	New York	65
Delaware	3	North Carolina	8 2/
Illinois	7	North Dakota	5
Indiana	10	Ohio	5
Iowa	6	Oklahoma	5
Kansas	4	Pennsylvania	27
Maine	5	Rhode Island	2
Maryland	5	South Dakota	6
Massachusetts	9	Tennessee	7 2/
Michigan	7	Vermont	53
Minnesota	6	West Virginia	50
Missouri	4	Wisconsin	6
Nebraska	7	Quebec	139 3/
New Hampshire	6		
		Total	498

1/ Honeysuckles

2/ Persian lilac and honeysuckles

3/ 100: Honeysuckles only; 39: Persian lilac and honeysuckles

Hugo, Oklahoma). In the east-west direction the network extends from 67° 13'W longitude at Causap-scal, Quebec, to 103° 41'W longitude at Mitchell, Nebraska.

The density of the network is quite variable. Persian lilacs, which constitute the majority of the indicator plants, have a density in the Northeast of one site per 200 to 900 square miles and in the midwestern states of one site per 4,000 to 20,000 square miles.

RESULTS

Some of the results obtained to date are summarized below to indicate the type of information evolving from this project. Long-term data, of course, are needed before stable averages can be assured. 1971 Season

In Table 2, the dates of full bloom of Persian lilac

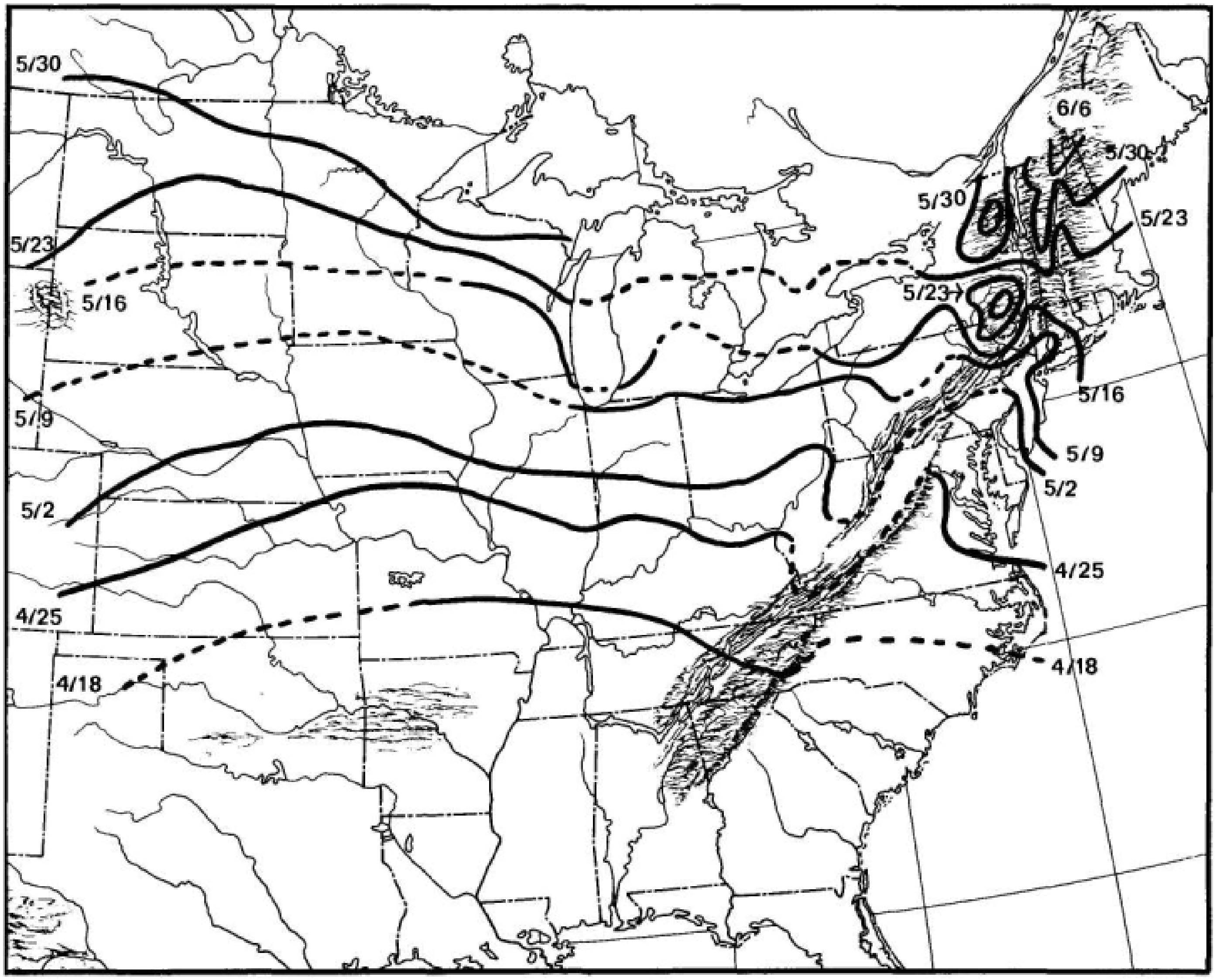

Figure 2.—Tentative average dates of first flowers of Persian lilac. Isophanes at weekly intervals.

in 1971 are compared with those of 1970 for 74 representative phenological sites in the eastern part of the Persian lilac network. The 1971 departures from 1970 and from the average of 4 or more years are noted in the table.

As in previous years, the number of days between the various phenological events varied. The average number of days, and their standard deviations, between phenological stages for the last three seasons are shown in Table 3.

Average dates of first flowers

Combining the formerly separate networks of Persian lilac in the Northeast and the North Central States made it possible to construct a tentative phenological map covering a wide geographical area. In 1970, Dr. Byron O. Blair, Purdue University, Lafayette, Indiana, coordinator of the former NC-26 network, established average dates of first flowers for a 9-year period (1962-1970) based on observations at 26 sites in 11 North Central States. These average dates were plotted; weekly isophanes are shown in Figure 2 in conjunction with those drawn in the Northeast based on records of 4 or more years.

The resulting map shows graphically the "green wave" or the northern progression of spring over a large section of the United States. Similar maps showing isophanes for other phenological events will be constructed in 1972.

Average dates of full bloom

Tentative average dates of full bloom, based on data for at least 4 or 5 years, are plotted in Figure 3. The isophanes are drawn at 5-day intervals.* These isophanes update a similar map prepared at the end of 1970 (5). The areas between isophanes show locations at which full bloom can be expected during the particular 5-day period. The multi-year averages are based on relatively short records, but later refinements are not expected to materially change the overall pattern. Since the lines are drawn for available point data values, interpolation may not produce strictly valid values elsewhere because of local influences of elevation, topography, and other factors.

Solar radiation, day length

In 1970, the number of growing degree days, base 32° F, accumulated from January 1 to the date of full bloom appeared to be lower in northern locations than farther south. Caprio (2,3) associated phenological events with solar radiation and solar-thermal unit requirements. Related to his concept is the consideration of day length. For example, the average day

Thanks are due Dr. A. B. Pack and Mr. J. A. Carr, National Weather Service, for drawing the New York and New Jersey isophanes.

Table 2.—Persian lilac phenology observations in 1971 for selected sites in the eastern United States.

Location		Date of full bloom		1971 Departure from:		No. of days between:	
City	State	1971	1970	1970 (days)	average 1/ (days)	first leaf and full bloom	first flower and end of bloom
Jackson	Tenn.	April 16	April 13	+ 3	-1.0	55	8
Springfield	Tenn.	April 21	April 20	+ 1	-0.7	36	11
Knoxville	Tenn.	April 24	April 20	+ 4	+2.7	40	11
Georgetown	Del.	May 5	May 6	- 1	+0.4	52	18
Salisbury	Md.	May 6	2/	2/	2/	28	16
Kearneysville	W. Va.	May 6	May 3	+ 3	+3.6	19(?)	13
Newark	Del.	May 10	May 11	- 1	+2.5	42	26
Wardensville	W. Va.	May 11	May 2	+ 9	+5.9	39	12
Mays Landing	N. J.	May 11	May 9	+ 2	+2.8	43	15
Morgantown	W. Va.	May 12	May 6	+ 6	+5.4	48	17
Clarksville	Md.	May 13	May 10	+ 3	2/	2/	11
Bridgeton	N. J.	May 14	May 15	- 1	+2.9	41	14
Cape May C.H.	N. J.	May 15	May 14	+ 1	-0.6	40	23
Lambertville	N. J.	May 15	May 7	+ 8	+6.2	31	12
Staten Island	N. Y.	May 15	May 11	+ 4	+6.3	42	15
Moorestown	N. J.	May 16	May 11	+ 5	+6.7	28	17
Toms River	N. J.	May 16	May 7	+ 9	+5.7	32	13
Tuckerton	N. J.	May 16	May 12	+ 4	+3.9	29	13
Canoe Brook	N. J.	May 18	May 15	+ 3	+5.8	36	33(?)
Essex Fells	N. J.	May 19	May 18	+ 1	+6.5	29	21
Setauket	N. Y.	May 19	May 16	+ 3	+1.6	26	18

Morris Plains	N. J.	May 20	May 13	+ 7	+7.2 3/	32	21
Hempstead	N. Y.	May 20	May 16	+ 4	+1.0	37	11
Oxford	Mass.	May 24	May 15	+ 9	2/	21	18
Carmel	N. Y.	May 24	May 17	+ 7	+4.1	34	18
Haddam	Conn.	May 25	May 21	+ 4	+2.0	21	15
Highland	N. Y.	May 25	May 15	+10	+5.8	36	19
Port Jervis	N. Y.	May 25	May 19	+ 6	+5.7	43	14
Freehold	N. Y.	May 29	May 19	+10	+6.9	38	20
Lewiston	N. Y.	May 29	May 22	+ 7	+4.4	41	15
Aurora	N. Y.	May 30	May 21	+ 9	+4.0	23	17
Bridgehampton	N. Y.	May 30	May 25	+ 5	+1.8	39	10
Ithaca	N. Y.	May 30	May 12	+18	+5.0	21	23
Storrs	Conn.	May 30	May 23	+ 7	+4.6	48	14
St. Albans Bay	Vt.	May 31	May 26	+ 5	-1.0	24	18
East Wareham	Mass.	May 31	May 21	+10	2/	39	12
Coventry	Conn.	May 31	May 23	+ 8	+2.6	48	14
Ballston Spa	N. Y.	May 31	May 21	+10	+5.4	32	17
Lockport	N. Y.	May 31	May 22	+ 9	+6.9 3/	42	16
Geneva	N. Y.	June 1	May 20	+12	+6.2	47	13
Rockville	Conn.	June 1	May 22	+10	+4.4	50	15
Vernon	Vt.	June 1	May 25	+ 7	+5.1	30	18
South Burlington	Vt.	June 1	May 27	+ 5	+0.6	28	13
Bellows Falls	Vt.	June 1	May 19	+13	+4.6	39	14
Valatie	N. Y.	June 1	May 22	+10	+7.4	41	15
Keene	N. H.	June 2	May 23	+10	+5.8	44	8
Union Village	Vt.	June 2	May 26	+ 7	+0.2	26	18
Reading	Mass.	June 2	May 22	+11	2/	37	12
Clinton	N. Y.	June 2	May 19	+14	+5.5 3/	42	14
Essex Jct.	Vt.	June 3	May 29	+ 5	+0.9	29	15
Walton	N. Y.	June 3	May 24	+10	+6.5	38	36(?)
Warrensburg	N. Y.	June 3	May 26	+ 8	+1.4	26	2/
Durham	N. H.	June 3	May 26	+ 8	+1.8	24	13
Dummerston	Vt.	June 3	May 22	+12	+3.8	29	15
Bennington	Vt.	June 3	May 22	+12	+5.5	41	14
Brattleboro	Vt.	June 4	May 21	+14	+8.0	47	17
Newport	Vt.	June 5	June 2	+ 3	-0.1	30	21
Woodstock	Vt.	June 5	May 26	+10	+2.8	28	13
Warsaw	N. Y.	June 5	May 25	+11	+6.7 3/	21	20
Lowville	N. Y.	June 6	May 27	+10	+4.2	25	13
Cavendish	Vt.	June 6	May 27	+10	+0.6	26	16
Randolph Center	Vt.	June 6	June 1	+ 5	+1.7	20	17
Readsboro	Vt.	June 6	May 24	+13	+4.8	24	13
Norfolk	Conn.	June 7	May 29	+ 9	+3.8	29	16
Lancaster	N. H.	June 7	May 22	+16	2/	37	24
McIndoe Falls	Vt.	June 7	May 25	+13	+1.8	27	12
Chelsea	Vt.	June 8	May 28	+11	+3.2	27	16
Oswego	N. Y.	June 8	May 28	+11	+5.6	34	12
Chazy	N. Y.	June 8	June 2	+ 6	+3.0	30	17
Danville R12	Vt.	June 9	June 3	+ 6	-0.5	29	17
Plainfield	Vt.	June 11	May 30	+12	+3.0	33	14
West Burke	Vt.	June 12	June 2	+10	+0.2	30	11
Newcomb	N. Y.	June 13	June 7	+ 6	+1.9 3/	28	15
Canaan	Vt.	June 17	frozen	2/	2/	31	12

1/ Average of 5 or more years

2/ Not available

3/ 4-year average

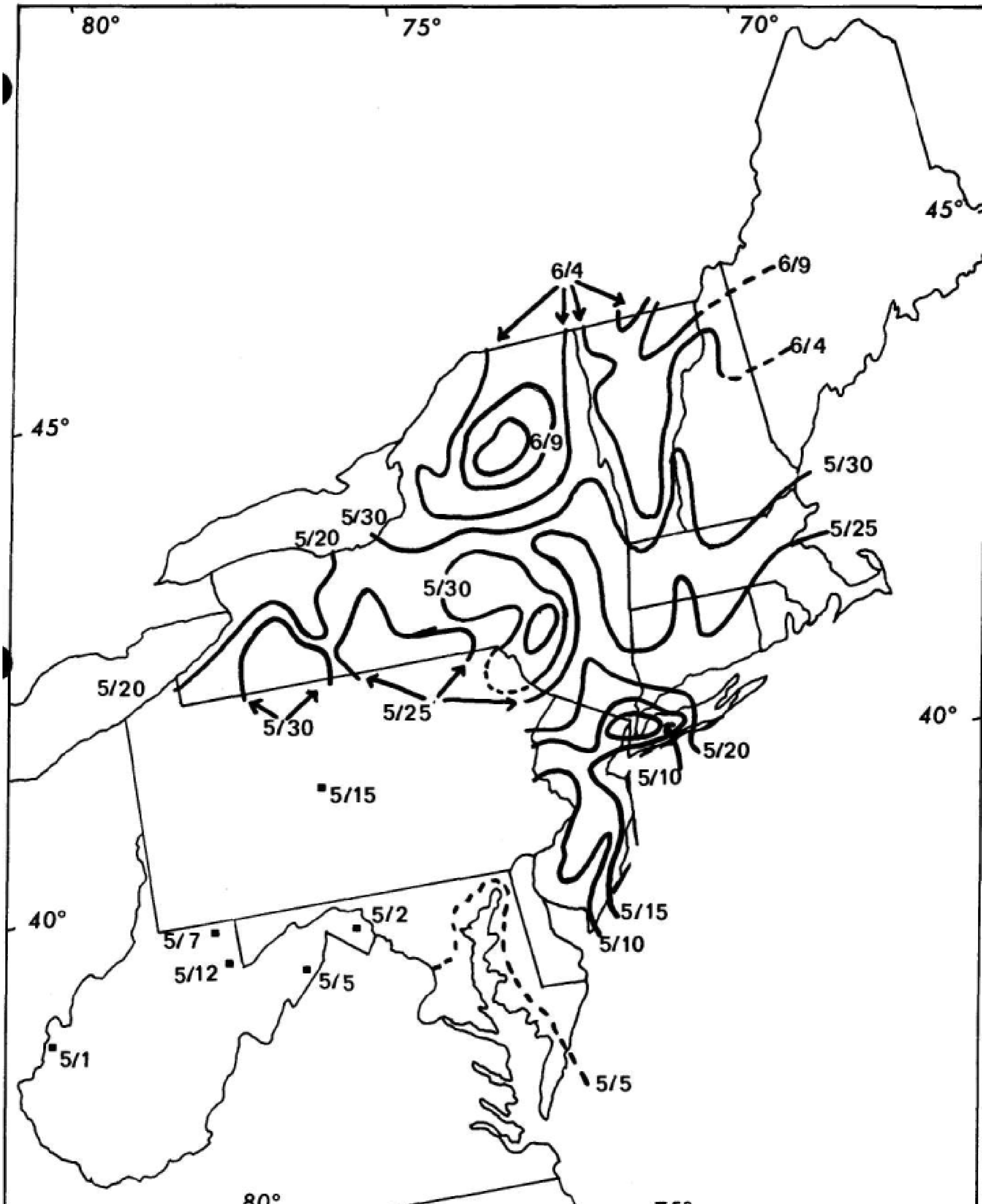

Figure 3.—Tentative average dates of full bloom of Persian lilac in the Northeast, adjusted through 1971. Isophanes drawn at 5-day intervals.

Table 3.—Average days between growth stages, 1969-1971.

Between:	Year		
	1971	1970	1969
lst leaf and full bloom	33.1 ± 8.4	31.3 ± 6.0	35.9 ± 5.1
1st flowers and full bloom	5.9 ± 2.9	5.8 ± 2.4	5.5 ± 2.7
1st flowers and end of bloom	15.3 ± 3.8	14.2 ± 3.5	14.1 ± 3.9

length during 10 days preceding full bloom of Persian lilac in Tennessee (mid-April) at approximately 35° N latitude is less than 13 hours. In West Virginia, just below 40° N latitude in early May the day length is close to 14 hours, and in Northern Vermont, approaching 45°N latitude, in mid-June it is about \blh hours. Solar radiation and day length will be studied in their relationships to phenological data of Persian lilacs collected in the East.

SUMMARY AND OUTLOOK

The phenology program of NE-69 has concentrated its efforts on collecting data used to prepare phenological maps. These maps can be used to follow the advancing "green wave" in the spring.

This is one approach to phenology, but it is not the only one. The proximity of phenological observation sites to weather stations allows for attempts to relate phenological observations to climatological parameters. This phase of the program has not yet been adequately exploited but is now possible with the acquisition of several years of observations from a number of locations.

Probably the most important use of phenology is to apply it to agricultural management—to correlate it with plantings of crops, crop development, pest control, and other cultural practices. This research approach could prove highly fruitful in the future.

Expanding the number of indicator species will greatly increase the value of phenological observations. Such an effort has already started in Indiana where a statewide network of phenological gardens has been established. It is difficult to find organizations that will adequately finance an endeavor requiring continuous observations of several plant species together with required weather observations. A limited number of phenological gardens, however, is a very desirable counterpart to the Reference Climatological Station Program of the National Oceanic and Atmospheric Administration (NOAA).

Possibly remote sensing from satellites orbiting the earth will correlate with observations from selected ground locations to give us a global view of the green wave as it moves from south to north in the spring, and of the "brown wave" that moves in the opposite direction in the fall. This information could be useful in predicting the adaptability and suitability of given areas to selected economic crops.

NE-69, using the Persian lilac as an indicator plant and based on the cooperation of hundreds of observers, shows the potential of research that does not stop at state or national boundaries but is truly interregional and even international in its application.

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