First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota

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First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota

J. Michael Callow, Harold A. Kantrud, and Kenneth F. Higgins

Abstract: We recorded flowering events for 97 species of prairie plants for 2-6 years near Woodworth, ND. Earliest and latest flower initiation dates varied by year. Temperature seemed much more important than precipitation in influencing phenology of species that bloom from late March through May, but no strong climatic effect was evident for plants that bloom later in the growing season.

Key words: Phenology, plants, North Dakota, temperature, precipitation

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flwrdate.zip () -- **First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota**

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First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota

Introduction

Knowledge of flowering (anthesis) dates or other phenological events is useful. For example, resource managers can use such information to time grazing, weed control, prescribed burning, and other land-use treatments. Botanists or teachers can also use these dates to time visits for plant collections or educational tours. Knowledge of pollination seasons is more important in the treatment of hay-fever patients. Data on plant phenology may become increasingly valuable to scientists studying changes in global climate.

Naturalists have long observed and reported sequential flowering among plants of the northern prairie grasslands. Stevens reports on first flowering along the Red River near Fargo, ND, and Moorhead, MN (Stevens 1921, 1973) and on the flowering of weeds and woody plants in North Dakota (Stevens 1956, 1972). Godfread (1976) gives general flowering periods for over 300 plants collected in Barnes and Stutsman counties, North Dakota. Phenological data for plants in northeastern (Willenbring 1971) and southeastern (Manske 1980, Seiler 1973) North Dakota and southwestern Montana (Mueggler 1972) are available. For Canadian prairies, phenological information is published for Treesbank, MB (Criddle 1927) and Swift Current, SK (Budd and Campbell 1959).

The only analysis of the effects of climatological variables on plants of the northern grasslands is that of Mueggler (1972). He found May precipitation positively correlated, but maximum temperatures of the shaded soil surface in June and July negatively correlated, with herbage production.

The major factors influencing timing of plant flowering are genetic makeup, photoperiod, and other environmental conditions, especially temperature, moisture, and nutrients (Garner 1933, Roberts 1939, McMillan 1957, Mueggler 1972, Noggle and Fritz 1976). The perennial plants dominating the mixed-grass prairie undergo a rest period during the winter, and their rest periods normally cannot be broken without exposure to low temperatures. Once this requirement is met, the plants resume activity in the spring as soon as their threshold temperatures are exceeded and provided no other adverse conditions such as insufficient day length or lack of moisture exist (Daubenmire 1959).

The purpose of this paper is to provide additional information on first flowering dates and flowering periods for upland plants on native and seeded grasslands in central North Dakota and to address the influences of temperature and precipitation on the time of flowering.

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First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota

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The purpose of this paper is to provide additional information on first flowering dates and flowering periods for upland plants on native and seeded grasslands in central North Dakota and to address the influences of temperature and precipitation on the time of flowering.

Study Area and Methods

We collected data from 1979 through 1984 on a study area near Woodworth, Stutsman County, North Dakota. This 1231-ha tract of native and seeded grasslands is on the Missouri Coteau, a physiographic region characterized by thick glacial till with knob-and-kettle topography (Bluemle 1977). The area lies in the mixed-grass prairie region of North America (Whitman and Wali 1975) at 45°08'N, 99°15'W. Elevation is about 572 m above sea level. Annual precipitation at the National Oceanic and Atmospheric Administration (NOAA) weather station nearest to the study area (Pettibone, ND) averages about 40.3 cm; the freeze-free period is about 111 days (about 22 May - 12 Sept.; North Dakota Agricultural Statistics Service 1988).

We recorded flowering stages for 97 species of native and introduced angiosperms, most of which were perennials. These stages included dates of first flowering (or emergence of inflorescences for grasses), first ten flowering individuals, full flowering aspect, flowering 95% complete, and last flowering. For all species, we recorded at least four of these five stages for at least two years; for most species we have records for four or five years. We obtained records by walking through fields of native prairie and seeded nesting cover for waterfowl throughout the study area. We visited fields at least weekly and often twice or thrice weekly during the growing season, but surveyed fields in no particular order. We gathered no data on fields with stands of seeded grasses less than two years old or on fields burned or flooded during the observation year. We considered the flowering period for each species as the number of days between the median date of the first ten flowering individuals and the median date when flowering was judged by visual estimate to be 95% complete. We regressed length of flowering period on date of first flowering. For the regression analysis we used the median date of first ten flowering individuals for the 84 species for which we had enough records to calculate flowering period. We also calculated the number of species initiating flowering earliest and latest during the six years of the study. We used a Chi-square test to determine whether these earliest blooming-date frequencies were equally distributed among years.

We assembled departures from 30-year mean temperature and precipitation for March through August, 1979-1984, from records for the weather station at Pettibone, ND (NOAA 1979, 1980, 1981, 1982, 1983, 1984). We supplemented these data with precipitation measurements from the NOAA rain gauge on the study area.

Results and Discussion

Eighty-seven percent of the earliest first-flowering records occurred in 1980 and 1981, whereas 85% of the latest first-flowering records occurred in 1979 and 1983 (Table 1). Earliest and latest first- flowering dates were not equally distributed among years ($\chi^2 = 155$, df = 5, $P < 0.001$). The regression showed there was a strong tendency among species for length of the blooming period to increase as the growing season progressed ($F_{2,80} = 8.38$, $P = 0.0005$). However, date of first flowering accounted for only about 17% of the variation in blooming period. Our analysis of similar data presented by Budd and Campbell (1959) gave almost identical results ($F_{2,107} = 7.89$, $P = 0.0009$). We suspect that one of the reasons for this increase is that many of the earliest- blooming species are small and adapted to set seed quickly before being shaded by taller plants later in the growing season. The flowering periods for plants such as dandelion (*Taraxacum officinale*, a perennial) and goatsbeard (*Tragopogon dubius*, a biennial) in the native and seeded grasslands we studied are much shorter than those measured by Budd and Campbell (1959). We attribute these differences to the lack of cultivation and heavy grazing on our study area. At least for dandelion, shading by dense vegetation seems to stop the flowering process (C. Godfread, pers. commun.).

Table 1. Flowering dates and periods for 97 species of upland and wet-meadow plants near Woodworth, North Dakota, arranged according to earliest first flowering date, 1979-1984.

Species	Flowering dates[a]					Length of flowering period (days)
	Earliest first bloom	Latest first bloom	Median date of first 10 plants with flowers	Median date of full flowering	Median date when flowering 95% complete	
Anemone patens	3/22/81	4/30/79	4/16 (5)	4/20 (6)	5/01 (5)	15
Lomatium orientale	3/30/81	5/8/79	5/02 (4)	5/06 (5)	5/16 (5)	14
Phlox hoodii	4/10/81	5/16/79	5/02 (5)	5/05 (5)	5/23 (5)	21
Taraxacum officinale	4/13/81	5/23/79	4/22 (5)	5/16 (5)	5/28 (4)	36
Potentilla concinna	4/24/80	5/20/79	5/09 (4)	5/16 (5)	5/28 (5)	19
Ranunculus rhomboideus	4/24/80	5/14/79	4/29 (4)	5/04 (4)	5/21 (4)	22
Thlaspi arvense	4/24/81	5/23/79	5/14 (4)	5/25 (4)	6/11 (3)	28
Draba nemorosa	4/25/80	5/21/79	5/04 (4)	5/10 (5)	5/20 (4)	16
Viola nuttallii	4/25/80	5/23/79	5/14 (3)	5/14 (5)	6/02 (5)	19
Oxytropis lambertii	4/26/81	5/23/79	5/05 (5)	5/17 (5)	6/04 (5)	29
Cerastium arvense	4/29/81	5/29/79	5/18 (5)	5/22 (5)	6/12 (4)	25
Astragalus crassicarpus	5/01/80	5/30/79	5/19 (4)	5/21 (6)	6/01 (4)	13
Lithospermum canescens	5/04/81	5/29/79	5/18 (5)	5/23 (6)	6/17 (6)	30
Lesquerella ludoviciana	5/04/81	5/21/79	5/11 (4)	5/16 (5)	5/29 (5)	18
Crataegus chrysocarpa	5/05/81	5/31/83	5/20 (4)	5/24 (4)	6/05 (4)	16
Hierochloe odorata	5/06/80	5/23/84	5/16 (3)	5/23 (5)	--	--
Comandra umbellata	5/09/80	6/7/79	5/26 (4)	6/05 (4)	6/26 (5)	31
Geum triflorum	5/10/83	6/6/79	5/13 (4)	5/22 (5)	6/19 (6)	37
Amelanchier alnifolia	5/10/82	5/30/79	5/11 (4)	5/17 (4)	5/28 (4)	17
Zizia aptera	5/12/80	6/1/82	5/28 (5)	6/05 (5)	7/09 (5)	42
Prunus virginiana	5/12/80	6/2/83	5/25 (5)	6/01 (5)	6/09 (5)	15
Allium textile	5/12/81	5/29/79	5/23 (5)	5/28 (4)	6/05 (2)	13
Ribes americanum	5/12/80	6/6/79	5/18 (4)	5/21 (3)	6/09/(2)	22
Viola pedatifida	5/13/81	5/31/79	5/18 (4)	5/21 (3)	--	--
Poa pratensis	5/13/81	6/11/79	5/21 (5)	6/03 (5)	--	--
Potentilla anserina	5/16/81	6/19/83	5/27 (5)	6/01 (3)	7/03 (3)	37

Castilleja sessiliflora	5/18/81	6/13/79	6/02 (4)	6/09 (3)	--	--
Elaeagnus commutata	5/19/80	6/13/79	6/02 (6)	6/04 (6)	6/19 (6)	17
Lithospermum incisum	5/20/84	5/30/79	5/23 (4)	5/28 (4)	6/11 (3)	19
Agoseris glauca	5/21/81	6/13/79	5/29 (5)	6/05 (5)	6/18 (5)	20
Sisyrinchium angustifolium	5/22/80	6/12/79	6/03 (5)	6/05 (5)	6/25 (5)	22
Vicia americana	5/23/84	6/6/79	5/31 (3)	6/04 (5)	7/01 (3)	31
Anemone canadensis	5/27/80	6/15/79	6/04 (5)	6/16 (5)	7/09 (5)	35
Bromus inernis	5/27/80	6/13/79	6/07 (6)	6/24 (6)	--	--
Penstemon albidus	5/28/82	6/13/79	5/30 (5)	6/08 (5)	6/30 (5)	31
Melilotus officinalis	5/28/80	6/25/79	6/14 (6)	6/23 (6)	7/28 (3)	44
Calylophus serrulatus	5/28/80	6/25/79	6/22 (4)	6/28 (4)	7/27 (4)	35
Tragopogon dubius	5/29/80	6/17/82	6/10 (6)	6/20 (6)	7/03 (6)	23
Silene cserei	5/29/80	6/27/79	6/15 (4)	6/21 (5)	7/02 (3)	17
Rosa woodsii	5/29/80	6/25/79	6/14 (6)	6/22 (6)	7/05 (6)	21
Rosa arkansana	5/29/80	6/26/82	6/28 (6)	6/29 (6)	7/31 (6)	33
Gaura coccinea	5/29/80	6/26/82	6/19 (5)	6/26 (5)	7/09 (3)	20
Galium boreale	5/29/80	6/21/79	6/11 (6)	6/19 (6)	7/11 (6)	30
Polygala alba	5/29/80	6/26/79	6/12 (4)	6/20 (5)	7/30 (4)	48
Koeleria pyramidata	5/29/80	6/27/79	6/11 (6)	6/19 (4)	--	--
Stipa viridula	5/30/80	6/24/79	6/15 (6)	6/24 (6)	--	--
Asclepias ovalifolia	5/30/80	6/27/79	6/20 (4)	6/26 (4)	7/31 (3)	41
Stipa comata	5/30/80	6/21/79	6/13 (5)	6/24 (5)	--	--
Gaillardia aristata	5/30/80	6/23/79	6/11 (5)	6/20 (5)	7/12 (4)	31
Medicago sativa	5/30/80	6/21/83	6/16 (6)	7/01 (6)	8/11 (4)	56
Erigeron philadelphicus	5/31/84	6/26/79	6/02 (4)	6/11 (4)	6/29 (3)	27
Psoralea esculenta	6/01/80	6/21/79	6/11 (5)	6/18 (5)	7/05 (4)	24
Campanula rotundifolia	6/04/80	6/25/79	6/21 (6)	7/01 (6)	8/01 (5)	41
Agropyron repens	6/04/80	6/19/83	6/17 (4)	6/29 (2)	--	--
Stipa spartea	6/06/80	6/25/79	6/25 (5)	7/08 (5)	--	--
Sphaeralcea coccinea	6/07/80	7/7/83	6/15 (4)	6/29 (4)	7/10 (3)	25
Apocynum cannabinum	6/08/80	7/10/79	6/30 (4)	7/07 (4)	8/10 (3)	41
Apocynum androsaemifolium	6/09/80	6/21/83	6/20 (3)	6/29 (4)	7/22 (3)	32
Achillea millefolium	6/11/80	6/25/79	6/21 (6)	6/25 (6)	8/01 (6)	41
Glycyrrhiza lepidota	6/11/80	7/9/79	7/07 (6)	7/15 (6)	7/31 (6)	24
Onosmodium molle	6/13/80	7/16/79	6/19 (4)	6/26 (5)	7/15 (3)	26
Zigadenus elegans	6/13/80	6/27/79	6/22 (4)	6/30 (5)	7/17 (5)	25
Symphoricarpos occidentalis	6/13/80	7/10/79	6/25 (6)	7/06 (6)	7/28 (6)	33
Penstemon gracilis	6/17/80	6/26/84	6/22 (4)	6/26 (5)	7/10 (3)	18
Psoralea argophylla	6/17/80	7/13/79	7/07 (6)	7/15 (6)	8/02 (6)	26
Dalea candida	6/17/80	7/8/82	7/05 (3)	7/14 (5)	8/03 (5)	29
Dalea purpurea	6/17/80	7/13/79	7/11 (5)	7/15 (5)	8/15 (4)	35
Lilium philadelphicum	6/17/80	7/3/79	6/27 (6)	7/08 (6)	7/16 (6)	19
Ratibida columnifera	6/17/80	7/13/79	7/06 (4)	7/14 (6)	8/16 (5)	41
Stachys palustris	6/18/80	7/10/79	6/30 (4)	7/11 (4)	8/09 (2)	40

Echinacea angustifolia	6/20/80	7/12/79	7/06 (6)	7/11 (6)	8/02 (6)	27
Amorpha canescens	6/23/80	8/4/79	7/17 (5)	7/24 (5)	8/12 (5)	26
Lobelia spicata	6/23/80	7/10/83	7/05 (5)	7/12 (5)	8/02 (4)	28
Rudbeckia hirta	6/23/80	7/12/79	7/08 (5)	7/15 (5)	8/15 (4)	38
Anemone cylindrica	6/23/80	7/16/79	7/02 (5)	7/07 (5)	7/26 (5)	24
Chrysopsis villosa	6/24/80	7/10/84	6/30 (5)	7/22 (5)	8/31 (4)	62
Bouteloua gracilis	6/25/80	7/18/79	7/09 (6)	7/29 (2)	--	--
Panicum virgatum	6/27/80	7/21/83	7/17 (3)	7/26 (3)	--	--
Cirsium arvense	6/30/82	7/12/83	7/08 (5)	7/19 (4)	8/10 (4)	33
Lactuca oblongifolia	7/03/84	7/7/81	7/05 (3)	7/13 (3)	8/18 (3)	44
Liatris punctata	7/07/80	7/31/82	7/26 (5)	8/05 (5)	9/02 (4)	38
Solidago missouriensis	7/07/80	7/20/79	7/15 (5)	8/01 (5)	8/27 (4)	43
Andropogon gerardii	7/07/80	8/3/79	7/18 (4)	8/06 (4)	--	--
Aster ericoides	7/07/80	8/15/79	8/11 (4)	8/24 (5)	9/07 (4)	27
Gutierrezia sarothrae	7/08/80	8/15/79	7/26 (4)	8/05 (5)	9/04 (4)	40
Solidago canadensis	7/09/81	8/3/79	7/30 (4)	8/08 (5)	9/11 (5)	43
Liatris ligulistylis	7/09/80	8/3/79	7/26 (5)	8/05 (5)	8/28 (4)	33
Cirsium flodmanii	7/10/80	8/3/83	7/19 (4)	7/26 (5)	8/28 (4)	40
Allium stellatum	7/14/80	7/25/84	7/19 (3)	7/30 (5)	8/23 (3)	35
Grindelia squarrosa	7/14/80	7/26/84	7/25 (4)	8/08 (3)	9/04 (3)	41
Helianthus rigidus	7/21/82	8/1/79	7/25 (5)	8/05 (5)	8/30 (4)	36
Helianthus maximiliani	7/22/83	8/2/81	7/25 (6)	8/09 (6)	9/01 (5)	38
Orthocarpus luteus	7/24/79	8/2/83	7/29 (2)	8/03 (5)	8/27 (3)	29
Gentiana affinis	7/25/80	8/10/81	8/08 (3)	8/09 (2)	8/17 (2)	9
Solidago rigida	8/01/82	8/3/79	8/03 (4)	8/10 (4)	9/02 (4)	30
Prenanthes racemosa	8/03/82	8/31/79	8/14 (4)	8/20 (5)	8/31 (3)	17
Gentiana andrewsii	8/16/81	8/24/83	8/19 (3)	8/23 (4)	9/13 (3)	25

[a] Figures in parentheses indicate number of years for which records were available.

[b] Length of flowering period calculated as the interval in days between median dates of the first 10 plants with flowers and flowering 95% complete.

Climatic conditions differed greatly among periods (year- month combinations) when large numbers of plants initiated flowering early versus when they initiated flowering late (Table 2). The greatest proportions of spring and early-summer plants bloomed early during March-April 1981, May 1980, and June 1980. Although departures from normal precipitation were small during these periods, the periods were warmer than the corresponding periods during the other four years of the study. Except for July-August, precipitation at Woodworth was actually slightly less during periods when we observed most early blooms than when we recorded most late blooms. The relation between within-period climatic conditions and early blooming did not hold for the mid-summer species, i.e. those for which we recorded earliest flowering during July-August. Indeed, cooler temperatures and increased precipitation characterized July-August 1980, the period when the largest number of mid-summer species bloomed early. It is likely that earliest flowering records for this period were a response to the two earlier periods in 1980 which were markedly warmer than average.

Table 2. Years with greatest numbers of earliest and latest first flowering records and their climatic variables[a].

	Period			
	Mar-Apr	**May**	**June**	**July-Aug**

Earliest blooms				
Year	1981	1980	1980	1980
Total species[b]	11	40	28	18
Percent[c]	64	62	96	56
Departure from mean temperature (°F)	+19.3	+8.1	+3.5	-3.0
Precipitation	4.37	3.68	10.82	17.68
Departure from mean precipitation (cm)	-1.0	-1.6	-0.09	+2.85
Latest blooms				
Year	1979	1979	1979	1979
Total species[b]	1	19	39	38
Percent[c]	100	89	74	61
Departure from mean temperature (°F)	-10.7	-6.7	+0.7	+1.3
Precipitation	4.78	4.01	11.33	10.57
Departure from mean precipitation (cm)	-0.25	-2.90	+0.56	+0.94

[a] Departures of temperature (°F) and precipitation (cm) and August, 1979 precipitation from NOAA weather station, Pettibone, ND; other precipitation records from NOAA gage at Woodworth, ND.

[b] Total species blooming during period.

[c] Percent of total species blooming during period (year-month combination) for which first flowering dates were earliest (under *Earliest blooms*) or latest (under *Latest blooms*) recorded.

Climatic influence on blooming dates seemed less evident during 1979, the year when most species initiated flowering late in the season. However, we note that temperatures during March-April and May of 1979 were the coldest of such periods during all five years of the study. This is in contrast to the well-above-normal temperatures during those months in years when most species bloomed early. We also observed most delayed flowering among mid- to late-summer (June or later) species in 1979. This was the only year of the study when temperature and precipitation were above normal in both June and July-August.

In summary, temperature seems much more important than precipitation in influencing phenology of prairie plants in central North Dakota. Spring flowering is probably stimulated more by warm temperatures than by heavy precipitation. A combination of warm temperatures and ample moisture in late summer seems to extend the blooming period.

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We thank A. Banks, M. Meyer, W. Barta, and other summer employees at the Woodworth Station for field assistance; T. Devries and D. Johnson for statistical analyses; and J. Austin, C. Godfread, D. Larson, G. Larson, and M. Sovada for manuscript review.

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First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota

Results and Discussion

Eighty-seven percent of the earliest first-flowering records occurred in 1980 and 1981, whereas 85% of the latest first-flowering records occurred in 1979 and 1983 (Table 1). Earliest and latest first- flowering dates were not equally distributed among years (= 155, df = 5, P < 0.001). The regression showed there was a strong tendency among species for length of the blooming period to increase as the growing season progressed ($F_{2,80}$ = 8.38, P = 0.0005). However, date of first flowering accounted for only about 17% of the variation in blooming period. Our analysis of similar data presented by Budd and Campbell (1959) gave almost identical results ($F_{2,107}$= 7.89, P = 0.0009). We suspect that one of the reasons for this increase is that many of the earliest- blooming species are small and adapted to set seed quickly before being shaded by taller plants later in the growing season. The flowering periods for plants such as dandelion (*Taraxacum officinale*, a perennial) and goatsbeard (*Tragopogon dubius*, a biennial) in the native and seeded grasslands we studied are much shorter than those measured by Budd and Campbell (1959). We attribute these differences to the lack of cultivation and heavy grazing on our study area. At least for dandelion, shading by dense vegetation seems to stop the flowering process (C. Godfread, pers. commun.).

Table 1. Flowering dates and periods for 97 species of upland and wet-meadow plants near Woodworth, North Dakota, arranged according to earliest first flowering date, 1979-1984.

Species	Flowering dates[a]					Length of flowering period (days)
	Earliest first bloom	Latest first bloom	Median date of first 10 plants with flowers	Median date of full flowering	Median date when flowering 95% complete	
Anemone patens	3/22/81	4/30/79	4/16 (5)	4/20 (6)	5/01 (5)	15
Lomatium orientale	3/30/81	5/8/79	5/02 (4)	5/06 (5)	5/16 (5)	14
Phlox hoodii	4/10/81	5/16/79	5/02 (5)	5/05 (5)	5/23 (5)	21
Taraxacum officinale	4/13/81	5/23/79	4/22 (5)	5/16 (5)	5/28 (4)	36
Potentilla concinna	4/24/80	5/20/79	5/09 (4)	5/16 (5)	5/28 (5)	19
Ranunculus rhomboideus	4/24/80	5/14/79	4/29 (4)	5/04 (4)	5/21 (4)	22
Thlaspi arvense	4/24/81	5/23/79	5/14 (4)	5/25 (4)	6/11 (3)	28
Draba nemorosa	4/25/80	5/21/79	5/04 (4)	5/10 (5)	5/20 (4)	16
Viola nuttallii	4/25/80	5/23/79	5/14 (3)	5/14 (5)	6/02 (5)	19
Oxytropis lambertii	4/26/81	5/23/79	5/05 (5)	5/17 (5)	6/04 (5)	29
Cerastium arvense	4/29/81	5/29/79	5/18 (5)	5/22 (5)	6/12 (4)	25
Astragalus crassicarpus	5/01/80	5/30/79	5/19 (4)	5/21 (6)	6/01 (4)	13
Lithospermum canescens	5/04/81	5/29/79	5/18 (5)	5/23 (6)	6/17 (6)	30
Lesquerella ludoviciana	5/04/81	5/21/79	5/11 (4)	5/16 (5)	5/29 (5)	18
Crataegus chrysocarpa	5/05/81	5/31/83	5/20 (4)	5/24 (4)	6/05 (4)	16
Hierochloe odorata	5/06/80	5/23/84	5/16 (3)	5/23 (5)	--	--
Comandra umbellata	5/09/80	6/7/79	5/26 (4)	6/05 (4)	6/26 (5)	31
Geum triflorum	5/10/83	6/6/79	5/13 (4)	5/22 (5)	6/19 (6)	37
Amelanchier alnifolia	5/10/82	5/30/79	5/11 (4)	5/17 (4)	5/28 (4)	17

Zizia aptera	5/12/80	6/1/82	5/28 (5)	6/05 (5)	7/09 (5)	42
Prunus virginiana	5/12/80	6/2/83	5/25 (5)	6/01 (5)	6/09 (5)	15
Allium textile	5/12/81	5/29/79	5/23 (5)	5/28 (4)	6/05 (2)	13
Ribes americanum	5/12/80	6/6/79	5/18 (4)	5/21 (3)	6/09/(2)	22
Viola pedatifida	5/13/81	5/31/79	5/18 (4)	5/21 (3)	--	--
Poa pratensis	5/13/81	6/11/79	5/21 (5)	6/03 (5)	--	--
Potentilla anserina	5/16/81	6/19/83	5/27 (5)	6/01 (3)	7/03 (3)	37
Castilleja sessiliflora	5/18/81	6/13/79	6/02 (4)	6/09 (3)	--	--
Elaeagnus commutata	5/19/80	6/13/79	6/02 (6)	6/04 (6)	6/19 (6)	17
Lithospermum incisum	5/20/84	5/30/79	5/23 (4)	5/28 (4)	6/11 (3)	19
Agoseris glauca	5/21/81	6/13/79	5/29 (5)	6/05 (5)	6/18 (5)	20
Sisyrinchium angustifolium	5/22/80	6/12/79	6/03 (5)	6/05 (5)	6/25 (5)	22
Vicia americana	5/23/84	6/6/79	5/31 (3)	6/04 (5)	7/01 (3)	31
Anemone canadensis	5/27/80	6/15/79	6/04 (5)	6/16 (5)	7/09 (5)	35
Bromus inernis	5/27/80	6/13/79	6/07 (6)	6/24 (6)	--	--
Penstemon albidus	5/28/82	6/13/79	5/30 (5)	6/08 (5)	6/30 (5)	31
Melilotus officinalis	5/28/80	6/25/79	6/14 (6)	6/23 (6)	7/28 (3)	44
Calylophus serrulatus	5/28/80	6/25/79	6/22 (4)	6/28 (4)	7/27 (4)	35
Tragopogon dubius	5/29/80	6/17/82	6/10 (6)	6/20 (6)	7/03 (6)	23
Silene cserei	5/29/80	6/27/79	6/15 (4)	6/21 (5)	7/02 (3)	17
Rosa woodsii	5/29/80	6/25/79	6/14 (6)	6/22 (6)	7/05 (6)	21
Rosa arkansana	5/29/80	6/26/82	6/28 (6)	6/29 (6)	7/31 (6)	33
Gaura coccinea	5/29/80	6/26/82	6/19 (5)	6/26 (5)	7/09 (3)	20
Galium boreale	5/29/80	6/21/79	6/11 (6)	6/19 (6)	7/11 (6)	30
Polygala alba	5/29/80	6/26/79	6/12 (4)	6/20 (5)	7/30 (4)	48
Koeleria pyramidata	5/29/80	6/27/79	6/11 (6)	6/19 (4)	--	--
Stipa viridula	5/30/80	6/24/79	6/15 (6)	6/24 (6)	--	--
Asclepias ovalifolia	5/30/80	6/27/79	6/20 (4)	6/26 (4)	7/31 (3)	41
Stipa comata	5/30/80	6/21/79	6/13 (5)	6/24 (5)	--	--
Gaillardia aristata	5/30/80	6/23/79	6/11 (5)	6/20 (5)	7/12 (4)	31
Medicago sativa	5/30/80	6/21/83	6/16 (6)	7/01 (6)	8/11 (4)	56
Erigeron philadelphicus	5/31/84	6/26/79	6/02 (4)	6/11 (4)	6/29 (3)	27
Psoralea esculenta	6/01/80	6/21/79	6/11 (5)	6/18 (5)	7/05 (4)	24
Campanula rotundifolia	6/04/80	6/25/79	6/21 (6)	7/01 (6)	8/01 (5)	41
Agropyron repens	6/04/80	6/19/83	6/17 (4)	6/29 (2)	--	--
Stipa spartea	6/06/80	6/25/79	6/25 (5)	7/08 (5)	--	--
Sphaeralcea coccinea	6/07/80	7/7/83	6/15 (4)	6/29 (4)	7/10 (3)	25
Apocynum cannabinum	6/08/80	7/10/79	6/30 (4)	7/07 (4)	8/10 (3)	41
Apocynum androsaemifolium	6/09/80	6/21/83	6/20 (3)	6/29 (4)	7/22 (3)	32
Achillea millefolium	6/11/80	6/25/79	6/21 (6)	6/25 (6)	8/01 (6)	41
Glycyrrhiza lepidota	6/11/80	7/9/79	7/07 (6)	7/15 (6)	7/31 (6)	24
Onosmodium molle	6/13/80	7/16/79	6/19 (4)	6/26 (5)	7/15 (3)	26
Zigadenus elegans	6/13/80	6/27/79	6/22 (4)	6/30 (5)	7/17 (5)	25
Symphoricarpos occidentalis	6/13/80	7/10/79	6/25 (6)	7/06 (6)	7/28 (6)	33

Penstemon gracilis	6/17/80	6/26/84	6/22 (4)	6/26 (5)	7/10 (3)	18
Psoralea argophylla	6/17/80	7/13/79	7/07 (6)	7/15 (6)	8/02 (6)	26
Dalea candida	6/17/80	7/8/82	7/05 (3)	7/14 (5)	8/03 (5)	29
Dalea purpurea	6/17/80	7/13/79	7/11 (5)	7/15 (5)	8/15 (4)	35
Lilium philadelphicum	6/17/80	7/3/79	6/27 (6)	7/08 (6)	7/16 (6)	19
Ratibida columnifera	6/17/80	7/13/79	7/06 (4)	7/14 (6)	8/16 (5)	41
Stachys palustris	6/18/80	7/10/79	6/30 (4)	7/11 (4)	8/09 (2)	40
Echinacea angustifolia	6/20/80	7/12/79	7/06 (6)	7/11 (6)	8/02 (6)	27
Amorpha canescens	6/23/80	8/4/79	7/17 (5)	7/24 (5)	8/12 (5)	26
Lobelia spicata	6/23/80	7/10/83	7/05 (5)	7/12 (5)	8/02 (4)	28
Rudbeckia hirta	6/23/80	7/12/79	7/08 (5)	7/15 (5)	8/15 (4)	38
Anemone cylindrica	6/23/80	7/16/79	7/02 (5)	7/07 (5)	7/26 (5)	24
Chrysopsis villosa	6/24/80	7/10/84	6/30 (5)	7/22 (5)	8/31 (4)	62
Bouteloua gracilis	6/25/80	7/18/79	7/09 (6)	7/29 (2)	--	--
Panicum virgatum	6/27/80	7/21/83	7/17 (3)	7/26 (3)	--	--
Cirsium arvense	6/30/82	7/12/83	7/08 (5)	7/19 (4)	8/10 (4)	33
Lactuca oblongifolia	7/03/84	7/7/81	7/05 (3)	7/13 (3)	8/18 (3)	44
Liatris punctata	7/07/80	7/31/82	7/26 (5)	8/05 (5)	9/02 (4)	38
Solidago missouriensis	7/07/80	7/20/79	7/15 (5)	8/01 (5)	8/27 (4)	43
Andropogon gerardii	7/07/80	8/3/79	7/18 (4)	8/06 (4)	--	--
Aster ericoides	7/07/80	8/15/79	8/11 (4)	8/24 (5)	9/07 (4)	27
Gutierrezia sarothrae	7/08/80	8/15/79	7/26 (4)	8/05 (5)	9/04 (4)	40
Solidago canadensis	7/09/81	8/3/79	7/30 (4)	8/08 (5)	9/11 (5)	43
Liatris ligulistylis	7/09/80	8/3/79	7/26 (5)	8/05 (5)	8/28 (4)	33
Cirsium flodmanii	7/10/80	8/3/83	7/19 (4)	7/26 (5)	8/28 (4)	40
Allium stellatum	7/14/80	7/25/84	7/19 (3)	7/30 (5)	8/23 (3)	35
Grindelia squarrosa	7/14/80	7/26/84	7/25 (4)	8/08 (3)	9/04 (3)	41
Helianthus rigidus	7/21/82	8/1/79	7/25 (5)	8/05 (5)	8/30 (4)	36
Helianthus maximiliani	7/22/83	8/2/81	7/25 (6)	8/09 (6)	9/01 (5)	38
Orthocarpus luteus	7/24/79	8/2/83	7/29 (2)	8/03 (5)	8/27 (3)	29
Gentiana affinis	7/25/80	8/10/81	8/08 (3)	8/09 (2)	8/17 (2)	9
Solidago rigida	8/01/82	8/3/79	8/03 (4)	8/10 (4)	9/02 (4)	30
Prenanthes racemosa	8/03/82	8/31/79	8/14 (4)	8/20 (5)	8/31 (3)	17
Gentiana andrewsii	8/16/81	8/24/83	8/19 (3)	8/23 (4)	9/13 (3)	25

[a] Figures in parentheses indicate number of years for which records were available.

[b] Length of flowering period calculated as the interval in days between median dates of the first 10 plants with flowers and flowering 95% complete.

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August 1980, the period when the largest number of mid-summer species bloomed early. It is likely that earliest flowering records for this period were a response to the two earlier periods in 1980 which were markedly warmer than average.

Table 2. Years with greatest numbers of earliest and latest first flowering records and their climatic variables[a].

	Period			
	Mar-Apr	**May**	**June**	**July-Aug**
Earliest blooms				
Year	1981	1980	1980	1980
Total species[b]	11	40	28	18
Percent[c]	64	62	96	56
Departure from mean temperature (°F)	+19.3	+8.1	+3.5	-3.0
Precipitation	4.37	3.68	10.82	17.68
Departure from mean precipitation (cm)	-1.0	-1.6	-0.09	+2.85
Latest blooms				
Year	1979	1979	1979	1979
Total species[b]	1	19	39	38
Percent[c]	100	89	74	61
Departure from mean temperature (°F)	-10.7	-6.7	+0.7	+1.3
Precipitation	4.78	4.01	11.33	10.57
Departure from mean precipitation (cm)	-0.25	-2.90	+0.56	+0.94

[a] Departures of temperature (°F) and precipitation (cm) and August, 1979 precipitation from NOAA weather station, Pettibone, ND; other precipitation records from NOAA gage at Woodworth, ND.

[b] Total species blooming during period.

[c] Percent of total species blooming during period (year-month combination) for which first flowering dates were earliest (under *Earliest blooms*) or latest (under *Latest blooms*) recorded.

Climatic influence on blooming dates seemed less evident during 1979, the year when most species initiated flowering late in the season. However, we note that temperatures during March-April and May of 1979 were the coldest of such periods during all five years of the study. This is in contrast to the well-above-normal temperatures during those months in years when most species bloomed early. We also observed most delayed flowering among mid- to late-summer (June or later) species in 1979. This was the only year of the study when temperature and precipitation were above normal in both June and July-August.

In summary, temperature seems much more important than precipitation in influencing phenology of prairie plants in central North Dakota. Spring flowering is probably stimulated more by warm temperatures than by heavy precipitation. A combination of warm temperatures and ample moisture in late summer seems to extend the blooming period.

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First Flowering Dates and Flowering Periods of Prairie Plants at Woodworth, North Dakota

Study Area and Methods

We collected data from 1979 through 1984 on a study area near Woodworth, Stutsman County, North Dakota. This 1231-ha tract of native and seeded grasslands is on the Missouri Coteau, a physiographic region characterized by thick glacial till with knob-and-kettle topography (Bluemle 1977). The area lies in the mixed-grass prairie region of North America (Whitman and Wali 1975) at 45°08'N, 99°15'W. Elevation is about 572 m above sea level. Annual precipitation at the National Oceanic and Atmospheric Administration (NOAA) weather station nearest to the study area (Pettibone, ND) averages about 40.3 cm; the freeze-free period is about 111 days (about 22 May - 12 Sept.; North Dakota Agricultural Statistics Service 1988).

We recorded flowering stages for 97 species of native and introduced angiosperms, most of which were perennials. These stages included dates of first flowering (or emergence of inflorescences for grasses), first ten flowering individuals, full flowering aspect, flowering 95% complete, and last flowering. For all species, we recorded at least four of these five stages for at least two years; for most species we have records for four or five years. We obtained records by walking through fields of native prairie and seeded nesting cover for waterfowl throughout the study area. We visited fields at least weekly and often twice or thrice weekly during the growing season, but surveyed fields in no particular order. We gathered no data on fields with stands of seeded grasses less than two years old or on fields burned or flooded during the observation year. We considered the flowering period for each species as the number of days between the median date of the first ten flowering individuals and the median date when flowering was judged by visual estimate to be 95% complete. We regressed length of flowering period on date of first flowering. For the regression analysis we used the median date of first ten flowering individuals for the 84 species for which we had enough records to calculate flowering period. We also calculated the number of species initiating flowering earliest and latest during the six years of the study. We used a Chi-square test to determine whether these earliest blooming-date frequencies were equally distributed among years.

We assembled departures from 30-year mean temperature and precipitation for March through August, 1979-1984, from records for the weather station at Pettibone, ND (NOAA 1979, 1980, 1981, 1982, 1983, 1984). We supplemented these data with precipitation measurements from the NOAA rain gauge on the study area.

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