

# Ecophysiology of Seed Germination and Flowering in Common Broomweed, *Amphiachyris dracunculoides* (DC) Nutt.

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## Abstract

Common broomweed (*Amphiachyris dracunculoides* (DC.) Nutt.) behaves both as a winter and as a summer annual. Seeds germinate in either autumn or spring, and the life cycle is completed the following autumn. Seeds were nondormant at maturity, and 48 to 94% of them germinated in light at daily thermoperiods of 15/6, 20/10, 25/15, 30/15 and 35/20°C, but 42% or less germinated in darkness at these temperatures. Thus, a high percentage of the seeds dispersed in early autumn germinate within a few days in warm soil if soil water is not limiting. With late autumn dispersal, however, germination of a high percentage of the seeds is delayed until spring. Vernalization was not required for flowering, and both vernalized and nonvernalized plants flowered under long and short photoperiods. However, plants from vernalized seeds required fewer days to flower under both photoperiods than did plants from nonvernalized controls. Additionally, plants vernalized in the seed and/or seedling stages did not form a rosette prior to shoot elongation, whereas plants not vernalized in the seed or seedling stages formed a rosette.

Common broomweed (*Amphiachyris dracunculoides* (DC.) Nutt., *Gutierrezia dracunculoides* (DC.) S.F. Blake, *Xanthocephalum dracunculoides* (DC.) Shinnery) is an annual weedy forb of the family Compositae. Its natural range extends from western Missouri and Kansas thru Oklahoma and Texas to eastern New Mexico and into Mexico (Jones and Fuller 1955), but it is adventive east of the Mississippi River (Harper 1944, Solbrig 1960, Jones and Fuller 1955), where it has been collected in several states (Lane 1979).

Heavy infestations of common broomweed can become a serious problem on rangeland where the grass cover has been reduced by drought or overgrazing (Scifres et al. 1971). The invasion of this unpalatable weed into overgrazed rangeland in Kansas (Hetzer and McGregor 1951, Tomanek and Albertson 1957), Oklahoma (Bruner 1926, Smith 1940, Kelting 1954, Sims and Dwyer 1965, Hutchinson et al. 1968) and Texas (Dyksterhuis 1946, 1948; Launchbaugh 1955) is well documented.

Common broomweed can behave both as a winter and as a summer annual. That is, seeds germinate in both autumn and spring, and plants from both germination seasons set seeds and die the following autumn (Scifres et al. 1970, Scifres et al. 1971). Flowering begins in late July and continues into October. Seeds mature from late September through October, and the seed dispersal period may last for at least 2 months. Seeds that fall off the plants in early autumn germinate soon after dispersal, and an overwintering rosette is formed. Bolting (i.e., elongation of the flowering shoot from the rosette) occurs the following spring and summer. Seeds that are dispersed in late autumn do not germinate until the following spring, and plants from these seeds do not form a rosette. Instead, elongation of the flowering shoot begins at or shortly after

germination and continues until early summer.

Factors controlling the timing of germination and flowering were investigated to better understand the ecological life cycle of common broomweed. Consideration was given to effects of (1) time of seed dispersal on germination phenology, (2) various alternating temperature regimes on germination in light and in darkness, (3) vernalization temperature regimes on germination in light and in darkness, (3) vernalization of seed, seed and seedling, seedling or rosette stages on subsequent plant development, and (4) photoperiod on flowering.

## Methods

### Germination Greenhouse

Achenes (hereafter called seeds) were collected from plants of common broomweed growing in Rutherford County, Tenn., on 7 October 1978. Three days later, 3 replications of 300 seeds each were planted on soil in small flats in a non-temperature-controlled greenhouse (i.e., no heating or air-conditioning and windows open all year). Temperatures in this greenhouse were recorded continuously with a thermograph. On the same day, several thousand dry seeds of the 7 October collection were placed in a glass storage jar that had numerous holes in its lid; the jar was placed inside a weatherhouse in the greenhouse. Some of the seeds were removed from the jar on 15 November 1978, and 3 replications of 300 seeds each were planted on soils in small flats in the greenhouse.

The soil in all 6 flats was watered daily to field capacity, except on days during winter when the soil was frozen, and then water was withheld. The flats were examined at about 7-day intervals, and germinated seeds were counted and removed. Seeds were considered to be germinated when the radicle emerged from the seed coat. The study was terminated on 13 May 1979.

### Laboratory

Seeds were collected on 7 October 1978, and 3 days later germination tests were initiated. These tests were performed in temperature- and light-controlled incubators in light (14-hr daily photoperiod) and in continuous darkness at alternating (12/12 hr) temperature regimes that approximated the mean daily maximum and minimum monthly air temperature in central Tennessee during the growing season (U.S.D.C. 1965): September and June, 30/15; October and April, 20/10; November and March, 15/6; May, 25/15; July and August, 35/20°C. Daily photoperiod extended from 1 hr before to 1 hr after the daily high temperature period for seeds incubated in light. The light source was 20-W, cool-white fluorescent tubes, and light intensity at seed level was ca.  $30\mu\text{EM}^{-2}\text{Sec}^{-1}$  (400-700 nm). Seeds were placed in 5.5 cm petri dishes on clean quartz sand moistened with distilled water. Three replications of 50 seeds each were used for each treatment. Dishes were wrapped with plastic film and those containing seeds to be incubated in darkness were wrapped with two layers of aluminum foil. In the light, seeds were examined at 5-day intervals for 30 days, and each time germinated seeds were counted and removed. Seeds incubated in darkness were examined only at the end of 30 days.

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## Flowering

### Vernalization

Seeds of common broomweed were collected on 19 September 1975, and 1 week later several hundred of them were planted on moist soil in flats in the non-temperature-controlled greenhouse. On 13 October 1975, seedlings were potted individually in 10-cm-diameter pots. Fifteen plants were moved to a heated greenhouse, where day temperatures ranged from 20 to 30°C and night temperatures from 15 to 20°C, on 13 October, 1 November, and 1 December 1975 and on 1 January, 1 February, and 1 March 1976. An additional set of 15 plants was retained in the non-temperature-controlled greenhouse. All plants were exposed to natural photoperiods and were watered as needed to keep them moist. The number of hours that the various groups of plants were exposed to temperatures between 0.5 and 10°C (vernalization temperatures) was calculated from the thermograph records. The number of plants in each group with ray flowers of at least one head in full bloom was determined on 18 April, 4 May, 8 June, and 19 August 1976.

Seeds of common broomweed were collected on 9 October 1980 and planted on soil at various times in 1980 and 1981 in the non-temperature-controlled and heated greenhouses and manipulated so that the seed, seed plus seedling, seedling, or rosette stage of the life cycle was given a vernalization treatment. Control plants received no vernalization. All seeds were germinated on soil, and 15 seedlings for each treatment and the control were potted individually in 10-cm-diameter pots. Plants that were vernalized in the rosette stage were started from seeds in late October, and all others were started from seeds in early March. Plants were exposed to natural photoperiods and watered daily. The number of hours that seeds and/or plants were exposed to temperatures between 0.5 and 10°C was calculated from thermograph records. All plants were in the non-temperature-controlled greenhouse from 1 May 1981 until the experiment was terminated on 31 August 1981. The number of flowering plants was recorded at about 1-week intervals.

### Effects of Spring Planting Time on Subsequent Flowering

Seeds were collected on 6 October 1979 and stored in a closed glass jar in the laboratory until used. Seeds were planted on moist soil in the heated greenhouse on 2 March, 12 and 29 April, and 22 May 1980. For each planting, 15 seedlings were potted individually in 10-cm-diameter pots, and on 1 June all plants were moved to the non-temperature-controlled greenhouse where they remained until they either flowered or died. Plants were watered daily, and the number of flowering plants was recorded at about 1-week intervals.

### Photoperiod

Studies on the effects of photoperiod on rosette formation and flowering were conducted in 2 growth chambers: one set on a "short day" and the other on a "light break (long day)" photoperiod regime. Light intensity at plant level was about 110  $\mu\text{EM}^{-2}\text{Sec}^{-1}$  (400-700 nm) of cool-white fluorescent light. Seeds and plants in the short-day chamber received a 10-hr light period each day, and those in the long-day chamber received an 8-hr light period plus 2 hr of light in the middle of the dark period. The 2 chambers were set on a 12/12-hr daily thermoperiod of 25/15°C. In the short-day chamber the high-temperature period extended from 1 hr before the beginning of the light period to 1 hr after it ended, while in the long-day chamber the high-temperature period extended from 2 hr before the beginning of the light period to 2 hr after it ended. Thus, in the long-day chamber the light break was given at the lower temperature of the thermoperiod.

Seeds used in these studies were collected on 6 October 1979. Plants from freshly matured, laboratory-stored, and vernalized seeds were grown from seeds under both photoperiods. Seeds were germinated on moist soil under both photoperiods for each group of plants, and then 15 seedlings were transplanted to individual pots. Freshly matured seeds were planted on soil in both chambers on 9 October 1979, and laboratory-stored seeds were planted on 15 February 1980. Seeds receiving the vernalization treatment were

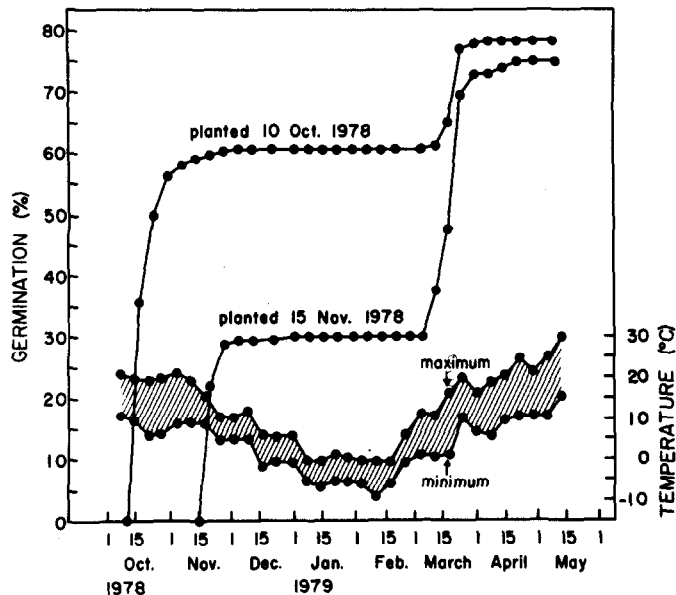


Fig. 1. Cumulative germination percentages of common broomweed seeds planted on soil in the non-temperature-controlled greenhouse on 10 October and 15 November 1978. Lines represent germination curves and hatched area represents mean weekly maximum and minimum temperatures in the greenhouse.

placed on moist soil in the non-temperature-controlled greenhouse from 30 December 1979 until 15 February 1980; they received 433 hours of temperatures between 0.5 and 10°C. All plants were watered daily, and observations on rosette formation and flowering were made at about 7-day intervals until the last plant in each set had flowered.

## Results

### Germination Greenhouse

Germination of both sets of seeds planted in the non-temperature-controlled greenhouse peaked in autumn with a second peak in spring (Fig. 1). Seeds planted on 10 October germinated to 61% in autumn, and an additional 18% germinated in spring. Those planted on 15 November germinated to 30% in autumn, and an additional 45% germinated in spring. Seeds began to germinate soon after they were placed on moist soil, regardless of planting date, and within 3 weeks most of the autumn germination had taken place.

### Laboratory

Freshly matured seeds were nondormant, but they required light to germinate to high percentages. Whereas seeds incubated in darkness germinated to 24, 31, 39, 42 and 24% at 15/6, 20/10, 25/15, 30/15, and 35/20°C, respectively, seeds incubated in light germinated to 53 to 94% at all temperatures, except at 15/6°C, where they germinated to 48% (Fig. 2). Optimum temperatures (as based on rates and final percentages of germination) were 30/15 and 25/15°C.

### Flowering Vernalization

Plants moved to the heated greenhouse on 13 October, 1 November, 1 December, 1 January, 3 February, and 1 March received 0, 134, 430, 836, 1,127, and 1,360 hr of vernalization respectively, while in the rosette stage. Plants remaining in the non-temperature-controlled greenhouse received 1,732 hr of vernalization. All plants in both greenhouses flowered, showing that vernalization is not required for flowering. On 8 June 1976 all plants in the heated greenhouse had started flowering, but none of those in the non-temperature-controlled greenhouse had started. One-hundred percent flowering did not occur in the latter green-

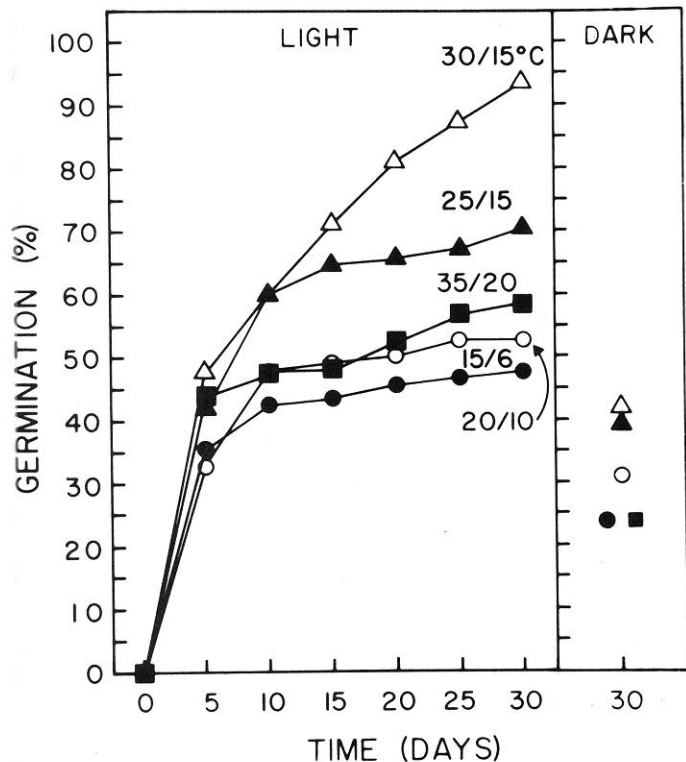


Fig. 2. Germination of freshly matured common broomweed seeds incubated in light or dark at 5 daily thermoperiods. Germination in darkness was determined only at the end of the 30-day incubation period.

house until 19 August.

The number of hours of vernalization received by the various stages in the life cycle were: seed, 654; seed plus seedling, 1,151; seedling, 497; rosette, 2,088. Plants that received no vernalization formed rosettes; those vernalized in the seed, seed plus seedling, or seedling stages did not form rosettes. By mid May 1981 shoot growth (bolting) had begun for all plants except the controls (no vernalization); the controls were still in the rosette stage. Plants that had been vernalized in the rosette stage were 30 to 40 cm tall, and the rosette leaves were dead (Fig. 3A). Although plants differed greatly in height in mid May, all plants in all treatments flowered during August 1981. However, the plants in the controls were 10 to 15 cm shorter than those receiving vernalization (Fig. 3B).

#### Effects of Spring Planting Time on Subsequent Flowering

All of the plants from seeds planted on 2 March, 12 and 29 April, and 22 May 1980 in the heated greenhouse (and thus receiving no vernalization treatment) formed rosettes. All of the plants from seeds planted on 2 March and 12 April flowered, while 93 and 67% of those from seeds planted on 29 April and 22 May, respectively, flowered. The number of days from planting date until the first plant in each set flowered was 165, 135, 125, and 86, respectively. All plants from seeds planted on 2 March and 12 April had started to flower by the end of August. However, for plants from seeds planted on 29 April and 22 May, 1 and 5 plants, respectively, had not flowered on 31 December. These 6 plants died during winter without flowering; they apparently were killed by low temperatures.

#### Photoperiod

Plants from freshly harvested and laboratory-stored seeds formed rosettes, but those from vernalized seeds did not. Rosette formation from nonvernalized seeds vs. nonrosette formation from vernalized seeds is depicted in Fig. 3A. Second plant from left is from a vernalized seed, and plant on far right is from a nonvernalized seed. Both plants are the same age. All plants in the 3 treatments flowered under both photoperiods (Fig. 4); however,

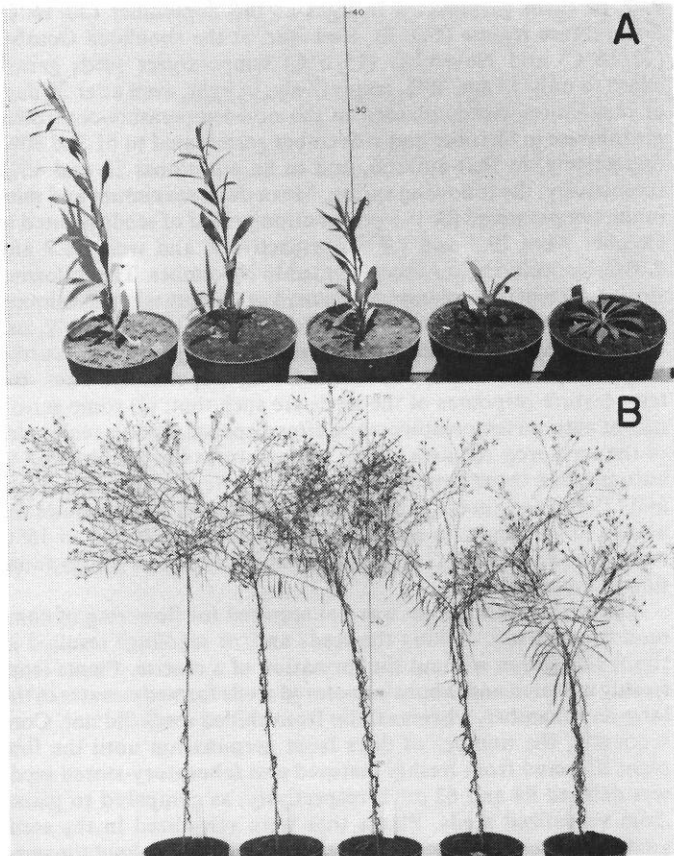


Fig. 3. From left to right, plants of common broomweed that were vernalized in the rosette, seed, seed plus seedling and seedling stages and a plant receiving no vernalization. A: 17 May 1981; B: same plants 8 September 1981.

the time varied from seed germination until the first plant in a treatment flowered, depending on pretreatment of the seeds and the photoperiod. The number of days until the first plant flowered for plants from vernalized, laboratory-stored, and freshly matured seeds exposed to long days was 147, 210, and 241, respectively, and for those exposed to short days the number of days to flowering was 168, 245, and 256, respectively. Not only did plants begin to flower sooner under long days, but the last plant to flower in each set did so sooner under long days than under short days (Fig. 4).

#### Discussion

Seeds of common broomweed were nondormant at maturity, as

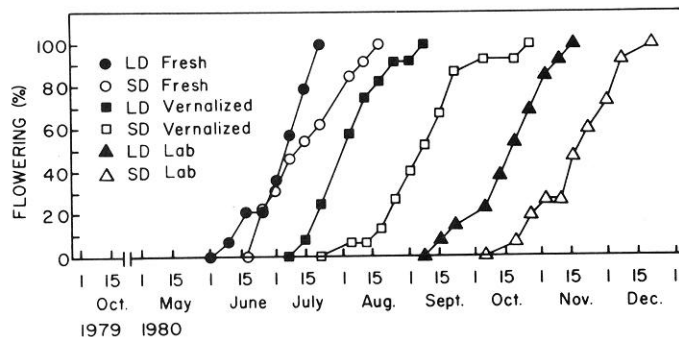


Fig. 4. Cumulative percent flowering of common broomweed plants grown from freshly-matured, laboratory-stored (lab) and vernalized seeds under long (LD) and short (SD) days in growth chambers. Fresh seeds were planted in growth chambers on 9 October 1979 and laboratory-stored and vernalized seeds on 15 February 1980. Seeds in all treatments germinated within a few days after planting.

94% of them germinated in light at the September (30/15°C) temperature regime (Fig. 2). However, at the simulated October (20/10°C) and November (15/6°C) temperatures seeds germinated to only 53 and 48%, respectively, in light, even after 30 days of incubation. Seeds planted in the non-temperature-controlled greenhouse in October and November germinated to 61 and 30%, respectively, in that autumn, and to an additional 18 and 45%, respectively, the following spring. Mean daily maximum and minimum temperatures for the germination period of seeds planted in October were 19.3 and 7.8°C, respectively, and were 11.7 and 5.0°C, respectively, for those planted in November. The following spring seeds in both plantings began to germinate when maximum and minimum temperatures were 11.6 and 1.0°C, respectively, and most of the spring germination for seeds in both plantings occurred when temperatures were 15.3 and 4.7°C, respectively. Thus, the temperature responses of the seeds are such that: (1) some germinate at autumn temperatures soon after dispersal, but the remainder of the seed crop requires higher temperatures for germination in autumn than those that occur in the field after they are dispersed, and (2) during winter many of the ungerminated seeds acquire the ability to germinate in spring at daily temperatures (10 to 15°C maximum and 1 to 5°C minimum) that were too low for germination in autumn.

Although vernalization was not required for flowering of common broomweed, chilling the seeds and/or seedlings resulted in shoot elongation without the formation of a rosette. Plants from freshly matured and laboratory-stored seeds formed rosettes in the long-day chamber, whereas those from chilled seeds did not. Consequently, the number of days from germination until the first plant flowered from freshly matured and laboratory-stored seeds was delayed 94 and 63 days, respectively, as compared to plants from vernalized seeds. Plants that were vernalized in the seed, seedling, or rosette stage of the life cycle flowered at about the same time in the greenhouse. However, plants receiving no vernalization bolted later and at maturity were 10 to 15 cm shorter than those that were vernalized during some stage of the life cycle (Fig. 3B). Thus, in the field the low temperatures to which seeds of common broomweed are subjected during winter (1) lower the temperature requirement for germination, and as a result seeds germinate in early spring when soil moisture is optimal for seedling establishment and (2) cause plants from spring-germinating seeds to reach maturity at about the same time as those from autumn-germinating seeds.

Since plants from seeds that germinate in autumn as well as in spring flower and produce seeds during the first growing season, a good control program for this species requires that the plants from both germination seasons be destroyed. Thus, the best time to

apply control measures for common broomweed would be after the spring germination season is completed, when both sets of plants could be killed with a single treatment (Scifres et al. 1971).

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