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A CONTRIBUTION TO THE ECOLOGICAL LIFE CYCLE OF ASTRAGALUS TENNESSEENSIS

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ABSTRACT

Age at first flowering and induction of flowering were investigated in *Astragalus tennesseensis* Gray, a near-endemic to cedar glades of central Tennessee and northern Alabama. Plants potentially can flower when they are 1 yr. old; however, in the field they may be 4 yr or older before flowering. Plants have an absolute vernalization requirement, and 0% flowering was obtained in those receiving 0 to 539 h of exposure to chilling temperatures (0.5 to 10 C). Only 27% of the plants that received 734 h of chilling flowered, but 87 to 100% of those exposed to 1,043 to 1,928 h of chilling flowered.

INTRODUCTION

Astragalus tennesseensis Gray (Leguminosae) is one of 25 or so herbaceous plant taxa that are endemic or near-endemic to cedar (limestone) glades of the southeastern United States. This species is a near-endemic and is on the Smithsonian Institution's 1978 list of recommended threatened plant species of the United States (Ayensu and DeFilipps, 1978). *Astragalus tennesseensis* has a bicentric distribution; one center is in north-central Illinois—western Indiana, and the other is in middle Tennessee—northern Alabama (Baskin *et al.*, 1972). The species was believed to be extinct in Illinois (Baskin *et al.*, 1972), until recently, when Dr. Robert F. Betz of Northeastern Illinois University found a population surviving in a virgin or near-virgin gravel terrace prairie in Tazewell County, Illinois (Betz, 1976a). It is thought to be extinct in Indiana (Betz, 1976b).

The ecological life cycle of *A. tennesseensis* previously has been described (Baskin & Quarterman, 1969; Baskin *et al.*, 1972); however, except for some observations on flowering phenology and pollination ecology, nothing is known about the flowering stage of the life cycle. Thus, the purposes of this study were to determine the (1) age at which flowering occurs and (2) environmental requirements for induction of flowering.

PROCEDURES AND RESULTS

Age at First Flowering

Five hundred seeds of *A. tennesseensis* were sown in three 1 x 0.5 m quadrats in a cedar glade north of Lavergne, Tennessee on 14 June 1970. No *A. tennesseensis* plants were growing on this glade, but the habitat in which the seeds were sown appeared to be nearly identical to some of the habitats on other glades where populations of this species are established. Between 14 June 1970 and 17 September 1976, when the study was terminated, only 100 seedlings appeared in the quadrats; 45 in 1971, 14 in 1972, 20 in 1973, 14 in 1974, 4 in 1975 and 3 in 1976. Ninety-nine of these seedlings germinated in the spring, and the other one germinated in autumn. When the study was terminated on 17 September 1976, 23, 6, 2, 9, 4, 1 and 1 plants from each respective year were still alive.

During the period of observation, only 14 plants flowered; 11 from seeds that germinated in 1971, 1 from 1972, 1 from 1973 and 1 from 1974. One of the plants flowered at age 1 yr, one at age 2 yr, ten at age 3 yr and two at age 4 yr. One of the plants from seeds that germinated in 1972 did not flower in 1976 although it was 4 yr old. None of the nine plants of the 1973 cohort that were still alive in 1976 flowered at age 3 yr. Since the study was terminated in September 1976, the fate of these plants is unknown.

Some of the plants that flowered one year did not flower in the succeeding year, and some did.

Vernalization and Flowering

Plants of *A. tennesseensis* kept for 2 yr in a heated greenhouse in Lexington, Kentucky did not flower nor produce flower buds. From these preliminary results, we speculated that plants required vernalization (low temperature promotion of flowering) before they would flower. Thus, an experiment was conducted to compare flowering of nonvernalized plants with that of plants which were vernalized for various lengths of time.

Seeds of *A. tennesseensis* were planted in petri dishes (Baskin & Quarterman, 1969) in April 1977, and one seedling was planted in each of 165 15-cm-diameter plastic pots filled with soil. A'l plants were grown in a nonheated greenhouse (no heating or air-conditioning and windows open all year) until 17 September 1977. On this date, 15 plants were transferred to a greenhouse that was heated during winter (heated control), but the others were kept in the nonheated greenhouse until a later date. On 1 November and 1 and 15 December 1977 and on 1 and 19 January, 1 and 15 February and 1 and 15 March 1978, fifteen plants were transferred to the heated greenhouse; the remaining 15 plants were kept in the nonheated greenhouse (nonheated control). Plants were watered daily, except when the soil was frozen in the nonheated greenhouse in winter, and checked once each week for flowers. All plants transferred to the heated greenhouse on the various dates and the nonheated control were kept in their respective greenhouses until 7 May 1979, at which time the experiment was terminated. In both greenhouses, plants were exposed to natural photoperiods. In the heated greenhouse, temperatures ranged mostly from 20 to 30 C during the day and from 15 to 20 C at night. From thermograph recordings in the nonheated greenhouse, we calculated the number of hours that the various groups of plants were exposed to temperatures between 0.5 and 10 C. According to Leopold (1964), the optimum vernalization temperatures of most plant species are 0 to 5 C, but effective temperatures range from a few degrees below 0 to 10 C.

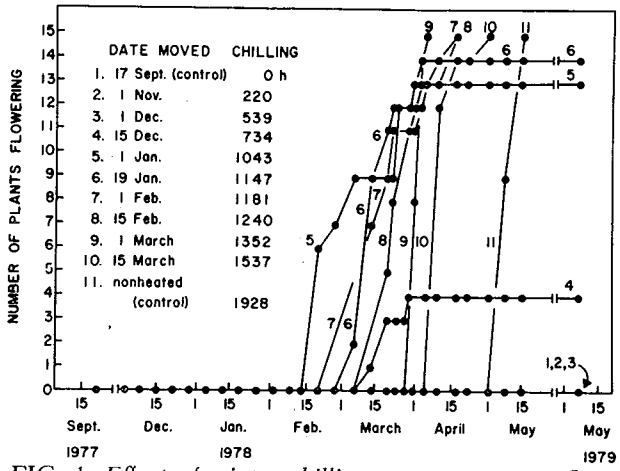

FIG. 1. *Effect of winter chilling temperatures on flowering of* Astragalus tennesseensis.

None of the plants moved to the heated greenhouse on or before 1 December and receiving from 0 to 539 h of vernalization temperatures flowered (Fig. 1). Four of the plants moved on 15 December (734 h of chilling), 13 of those moved on 1 January (1,043 h) and 14 of those moved on 19 January (1,147 h) flowered during the spring of 1978. All of the plants moved on, or after, 1 February (1,181 to 1,537 h), as well as the nonheated control (1,928) flowered in the spring of 1978.

In the heated greenhouse, none of the plants that failed to flower in the spring of 1978 flowered in the spring of 1979, and plants that did flower in the spring of 1978 failed to flower in 1979. However, some of the plants kept in the nonheated greenhouse (nonheated contro') flowered again in the spring of 1979.

Discussion

Our results clearly show that plants of *A. tennesseensis* have an absolute vernalization requirement for flowering. Plants of *A. tennesseensis* potentially can flower at the beginning of their second growing season, at age 1 yr. Thus, when grown in well-watered soil in the greenhouse and exposed to a sufficient number of hours of vernalization temperatures, 100% of them flowered when they were 1 yr old. However, of the 14 plants that we followed from germination to flowering in the field, only one flowered at age 1 yr and 10 of the 14 flowered at age 3 yr. We hypothesize (no data) that plants of *A. tennesseensis* must grow to a certain minimum size before they can be vernalized and that due to environmental stresses in the field they need more than one growing season to reach this critical minimum size. Thus, plants flowering at age 3 yr needed two growing seasons and those flowering at age 4 yr needed three growing seasons to become large enough to be vernalized. The one plant in the study that did not flower at age 4 yr obviously needed more than three growing seasons to reach a sufficient size for vernalization. The frequency and intensity of soil moisture stress in the various microhabitats during summer probably play a significant role in the amount of growth made by *A. tennesseensis* in a growing season and consequently on the age at first flowering. As is true for other perennials (Hillman, 1969), once plants of *A. tennesseensis* reach vernalization size they must be vernalized each year in order to flower. In nature, this vernalization requirement is fulfilled during winter.

The fact that many plants flowered under natural daylengths in the heated greenhouse in February and March, up to 10 weeks before any plants flowered in the nonheated greenhouse, indicates that flowering in nature is not controlled by photoperiod and that the low temperatures of late winter and early spring delay the onset of flowering. Thus, in the field the vernalization requirement of plants is fulfilled by early to mid winter but flowering is delayed by low temperatures until mid April to early May.

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