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SOME ASPECTS OF THE AUTECOLOGY OF *BUPLEURUM ROTUNDIFOLIUM* IN TENNESSEE CEDAR GLADES

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Abstract

Bupleurum rotundifolium is a native Eurasian winter annual that grows in disturbed habitats in various parts of the United States. In this study certain aspects of its autecology in the middle Tennessee cedar glades were investigated; particular emphasis was placed on the seed stage of the life cycle. Its ecological life cycle is as follows. Seeds germinate in autumn, plants overwinter in the vegetative (rosette) stage, flowering occurs during spring, and seeds are mature by early July. Seeds are not dispersed at maturity but remain attached to the erect, dead plants for about two months, until September. Most of the seeds are innately dormant at maturity, but durng the two month period on the dead parent plant they after-ripen. Thus, when the seeds are shed in autumn, they are capable of germinating to high percentages at normal field temperatures and do so when soil moisture is nonlimiting.

In comparison to many other species of winter annuals, *B. rotundifolium* grows to be much taller and completes its life cycle later in the year. These two aspects of its biology may help to explain why plants of this species do not occur in habitats that are regularly mowed or plowed during spring and summer.

Introduction

Bupleurum rotundifolium L. (Umbelliferae) is an annual plant native to Europe and western Asia that has been introduced into the United States where it ranges from New Hampshire and southern New York to southern Indiana, Missouri and South Dakota south to North Carolina, Tennessee, Alabama and Arkansas and southwestward to Arizona (Small, 1933; Fernald, 1950; Gleason and Cronquist, 1963). Radford, Ahles and Bell (1968) indicate that the species is rare in North Carolina, and their herbarium records show it as occurring only in two counties in the Piedmont Region. In his description of its distribution, Small (1933) says that it occurs in various provinces north of the Coastal Plain. In the Central Basin of Tennessee *B. rotundifolium* frequently occurs in cedar glades (Baskin, Quarterman and Caudle, 1968). The purposes of the present investigation are to describe some aspects of the autecology of this species in cedar glades of central Tennessee and to carry out germination experiments on the seed stage of the life cycle. This is a part of a broader investigation of the phenology and germination ecology of weedy and nonweedy winter annuals in Tennessee and Kentucky.

Cedar Glade Habitat and Plant Associates

Plants of *B. rotundifolium* usually occur in disturbed habitats (Small, 1933; Fernald, 1950; Gleason and Cronquist, 1963), and in the cedar glades they grow along roadsides and in areas that have been used for pastures. On glades developed on the thin-bedded Lebanon limestone, *B. rotundifolium* grows in shallow soil (2 to 10 cm deep) that has accumulated among the rock fragments. It sometimes is relatively more abundant in piles of rock fragments and soil along shoulders of unpaved roads through cedar glades. These piles of rocks and soil have accumulated due to annual grading or smoothing of the roads. On glades developed on thick-bedded limestone, *B. rotundifolium* grows in soil that ranges from 5 to 15 cm deep.

The plant associates of *B. rotundifolium* in the cedar glades include: *Allium vineale, Ambrosia artemisiifolia, Andropogon virginicus, Arenaria patula* Michx. var. *patula, Bromus* sp., *Carduus nutans, Chaerophyllum procumbens, C. tainturieri, Chrysanthemum leucanthemum, Croton monanthogynus, Daucus carota, Erigeron strigosus, Euphorbia dentata, E. obtusata, Galium parisiense, Geranium carolinianum, Grindelia lanceolata, Gutierrezia dracunculoides, Onosmodium molle, Opuntia compressa* (Salis.) Macbr., *Panicum capillare, Panicum* spp., *Petalostemon gattingeri* Heller, *Plantago virginica, Rosa carolina, Rudbeckia triloba, Ruellia humilis, Satureja calamintha, Scutellaria parvula, Senecio smallii, Sporobolus vaginiflorus, Verbena canadensis* and *V. simplex*. (Unless authorities are given nomenclature follows Fernald (1950).

Ecological Life Cycle

Seed Stage

Field observations. Seeds of *B. rotundifolium* are mature by early July, but they remain attached to the dead, erect plants until September or October. Seeds on a particular plant are not all dispersed at the same time but are gradually shed over a period of several weeks. After dispersal, seeds germinate within a few days if the soil is moist. Although germination occurs mostly in September and October, a few new seedlings have been found in December and late February.

Laboratory studies. Seeds of *B. rotundifolium* were collected on 19 July 1971 and 19 September 1971 from plants growing in a cedar glade in Davidson County, Tennessee, east of Nashville, and in each case laboratory germination tests were started two days after the seeds were collected. Seeds were placed to germinate on moist sand in Petri dishes, and three replications of fifty seeds each were used for each treatment. Seeds from each collection date were placed to germinate in light (14-hr photoperiod) and continuous darkness at five constant (5, 10, 15, 20 and 25 C) and four alternating (15/6, 20/10, 30/15 and 35/20 C) temperature regimes. At the alternating temperatures, the high and low temperatures were maintained for 12 hours each day, and the photoperiod was 14 hours. The light period began one hour before the beginning of the high temperature period and ended one hour after the beginning of the low temperature period. The light source was twenty watt "cool white" fluorescent tubes, and the light intensity at seed level was approximately 2,100 lux. Petri dishes containing seeds that were tested for germination in constant darkness were wrapped with Saran wrap to retard loss of water and then with aluminum foil to provide darkness. Petri dishes containing seeds that were germinated at the 14-hr photoperiod also were wrapped with Saran wrap. In all treatments the seeds were examined every tens days to thirty days and germinated seeds counted and removed. Radicle emergence was the criterion for germination. Germination of seeds tested in constant darkness was checked in a darkened room with the aid of a green safe light. The green safe light consisted of a green fluorescent tube wrapped with a dark green sheet of "Cinemoid" No. 24 (Kliegl Bros., Long Island City, New York). The peak intensity of the green light as determined using an ISCO Model SR Spectroradiometer was at 550 mμ, and essentially all of the energy impinging on the seeds was between 500 and 600 mμ. There was no energy above 600 mμ. Light in the spectral region of 500-600 mμ is relatively inactive in promoting photomorphogenic and photochemical processes in plants (Withrow, 1959). The green safe light that we used did not stimulate germination in the light-requiring seeds of bitterweed (*Helenium amarum* (Raf.) H. Rock) (Baskin and Baskin, 1973).

Most of the seeds collected in July were innately dormant as evidenced by the fact that only a low percentage of germination occurred even at the most optimal conditions (5, 10 and 15/6 C in darkness (See Table 1). At all temperatures where germination occurred, a higher percentage of seeds germinated in darkness than in light. During the two month interval from 19 July to 19 September, the seeds underwent physiological changes (after-ripening) on the dead, parent plants in the field. Seeds collected on 19 September germinated to a much higher percentage than those collected in July. Some germination of the seeds collected in September occurred at all temperatures in light and darkness, but at all of the temperatures except 30/15 C seeds germinated to a higher percentage in darkness than in light. At 30/15 C the seeds germinated to 78.7 and 70.7% in light and darkness, respectively. At 5, 10 and 15/6 C, which appear to be near-optimal temperatures for germination, germination was considerably higher in darkness than in light. A thermoperiod of 20/10 C also appears to be close to optimal for germination in darkness; September-collected seeds were not tested for germination at 20/10 C in light. At these temperatures, except 5 C, where a relatively high percentage of the September-collected seeds germinated, germination was almost complete ten days after the start of the experiment. (See Table 11.

TABLE 1: *Percentage germination (mean ± S.E.) of Bupleurum rotundifolium seeds**

Days After Initiation of Experiment	Germination Temperatures (°C)								
	5	10	15	20	25	15/6	20/10	30/15	35/20
JULY 14-hr Photoperiod									
10	0.0	0.0	3.3 ± 2.4	0.0	0.0	0.0	3.3 ± 0.7	0.0	0.0
20	0.0	6.7 ± 3.7	4.0 ± 2.0	0.0	0.0	7.3 ± 0.7	3.3 ± 0.7	0.0	0.0
30	0.7 ± 0.7	6.7 ± 3.7	4.0 ± 2.0	0.0	0.0	7.3 ± 0.7	5.3 ± 1.3	0.0	0.0
Darkness									
10	0.0	0.0	8.7 ± 1.8	0.0	0.0	0.0	4.7 ± 0.7	0.0	0.0
20	0.0	25.3 ± 3.7	9.3 ± 1.8	0.0	0.0	24.7 ± 2.7	6.7 ± 0.7	0.0	0.0
30	28.7 ± 6.6	28.7 ± 3.5	9.3 ± 1.8	0.0	0.0	26.0 ± 2.3	7.3 ± 1.3	0.0	0.0
SEPTEMBER 14-hr Photoperiod									
10	0.0	42.7 ± 8.1	14.7 ± 5.8	2.0 ± 2.0	0.0	46.7 ± 4.4	-	67.3 ± 2.4	0.0
20	4.0 ± 2.0	44.0 ± 8.7	15.3 ± 5.2	2.0 ± 2.0	0.0	50.0 ± 4.2	-	78.0 ± 1.2	0.7 ± 0.7
30	12.7 ± 6.4	44.0 ± 8.7	15.3 ± 5.2	2.0 ± 2.0	0.7 ± 0.7	50.7 ± 4.4	-	78.7 ± 0.7	0.7 ± 0.7
Darkness									
10	0.0	74.7 ± 3.7	29.3 ±13.4	4.0 ± 2.3	0.0	80.7 ± 1.8	56.0 ± 3.1	56.0 ±13.9	6.0 ± 1.2
20	2.7 ± 1.8	74.7 ± 3.7	38.7 ±10.5	10.7 ± 2.9	0.7 ± 0.7	81.3 ± 1.3	60.7 ± 4.1	70.7 ± 8.2	6.7 ± 1.3
30	74.7 ± 1.2	75.3 ± 3.5	44.7 ± 8.8	12.0 ± 2.0	1.3 ± 0.7	81.3 ± 1.3	61.3 ± 4.1	70.7 ± 8.2	7.3 ± 1.8

**Seeds collected from plants in the field on 19 July 1971 and 19 September 1971 and placed to germinate in light (14-hr photoperiod) and constant darkness as a function of temperatures.*

Growth Cycle

In autumn after germination in September and October, each plant produces a rosette or semi-rosette that is five to ten cm tall and has four to ten leaves(See Figure 1). Very little, if any, growth occurs during winter, but with the arrival of warm weather in spring growth is resumed. By mid-May vegetative growth is almost complete, and the plants are 1.5 to 3.5 cm tall and have from ten to twenty-five leaves.

Flower buds are initiated in April. In 1970, plants were collected from the field every two weeks from February until the last of April and the shoot apices were examined for flower buds under a dissecting microscope. No flower buds were found on plants collected on any date through 11 April, but small flower buds were present on plants collected 26 April. Anthesis begins in mid-May or slightly thereafter, and flowering continues until about the third week in June with the peak of flowering occurring in early June.

Although the plants overwinter in the vegetative state and flower the next spring, low, winter temperatures are not a prerequisite for flowering. On 15 September 1971 one seedling of *B. rotundifolium* in the cotyledon stage was planted in each of fifteen 10-cm clay pots filled with greenhouse potting soil and placed in the heated room of the Botany Greenhouse at the University of Kentucky where they remained until early summer of 1972. The plants grew normally, and by 6 March 1972 one of them had visible (to naked eye) flower buds. On 19 March two of the plants were flowering. On 3 April nine plants had visible flower buds and five were flowering; by 5 June all fifteen were flowering. Thirteen of the plants produced seeds, apparently without cross pollination.

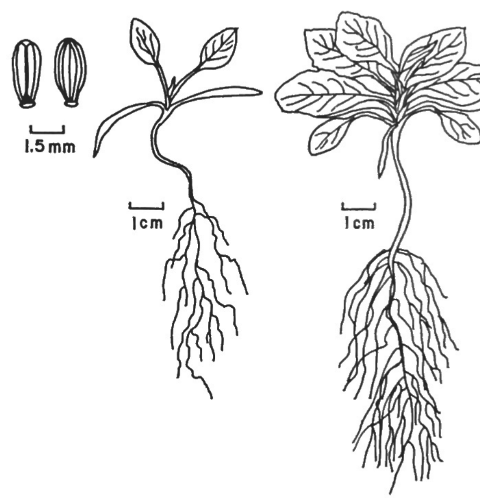

FIG. 1. From left to right: seed (bottom and top view), seedling and winter rosette of *B. rotundifolium*. Seedling and winter rosette were drawn from plants collected from the field in October and February, respectively. (Drawings by J. Sumner, Jr.)

DISCUSSION

The life cycle of *B. rotundifolium* in the cedar glades of central Tennessee and perhaps throughout its range is that of a winter annual. In central Tennessee seeds germinate in autumn, plants overwinter in the rosette stage, flowering occurs during spring and the seeds are mature by early summer. The life cycle of *B. rotundifolium* is similar to that of *Chaerophyllum procumbens* (Baskin and Baskin, pers. obs.), another introduced member of the Umbelliferae, except that flowering and seed set in *C. procumbens* occur a few weeks later. The life cycles of both of these species are different from those of many other weedy winter annuals common in Tennessee and Kentucky (*e.g.*. *Holosteum umbellatum, Stellaria media, Draba verna* and *Veronica arvensis*). In all of these latter species germination occurs in autumn, and the life cycle is completed in early to mid-spring. However, in *B. rotundifolium* and *C. procumbens*, the life cycle is not completed until early summer, several weeks after the other species have shed their seeds and died. A second difference is that the seeds of *B. rotundifolium* and *C. procumbens* are retained on the dead, erect plants until autumn; whereas, in the other species mentioned seeds are shed as the fruits mature in spring.

Plants of a number of the early-maturing winter annuals commonly grow in fields and lawns and along roadsides. They produce ripe seeds before the plowing or mowing season begins and/or they are quite short and the entire plant or some of the lower branches (*e.g. Stellaria media*) escape the mower and produce seeds later. However, since mature plants of *B. rotundifolium* may be 4-6 dm tall (Small, 1933) and since the plants do not mature until summer, plants of this species are not adapted for survival in habitats that are regularly mowed or plowed in spring.

Although most of the seeds are innately dormant at the time of maturity in July, they after-ripen on the dead, parent plant during the summer. However, attachment to the dead, parent plant during the natural, summer after-ripening period is not a requirement for after-ripening. Seeds collected from plants in July and stored dry in the laboratory (25 ± 2 C) during summer germinated to about the same percentages in September under the same temperature and light conditions as seeds collected from plants in the field in September (Baskin and Baskin, unpub.).

Results from the present study indicate that a high percentage of the seeds are capable of germinating at the 30/15, 20/10 and 15/6 C temperature regimes characteristic of autumn (See Table 1). In middle Tennessee the average daily maximum and minimum monthly air temperature of September, October and November, respectively, are 30 C and 16 C, and 23 C and 12 C and 15 C and 6 C (USDC, 1965). Thus, even though the seeds are not dispersed until September, there is a two to three month period during which the