COMPLETE OR PARTIAL INHIBITION OF FLOWERING IN CERTAIN PLANTS WHEN DAYS ARE TOO SHORT OR TOO LONG

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INTRODUCTION

On the basis of their flowering behavior as related to or dependent upon length of day, it has long been recognized that plants may be grouped into three classes—the long-day plants, the short-day plants, and indeterminate plants, i.e., those insensitive to length of day. The long-day plants are induced to flower or flower more quickly as the days are lengthened and the short-day plants as the days are shortened; the indeterminate plants have been so called because their usual flowering appears to be little related to any particular length of day in the natural terrestrial arrangement.

Typical long-day, short-day, and indeterminate plants have been found in abundance. Further studies of the behavior of different plants in relation to length of day have shown that still other plants exist that flower within a definite range of length of day, producing flowers less readily or becoming strictly vegetative when the days are either sufficiently shortened on the one hand or sufficiently lengthened on the other. Since the flowering behavior of these plants in relation to length of day is so distinctive, they have been termed "intermediate" to distinguish them from the long-day, the short-day, and the indeterminate plants.

Relatively few plants showing intermediate flowering behavior have been found. Climbing hempweed (Mikania scandens (L.) Willd.) appears to be a typical example of this class, and several other wild plants, including the native wild bean (Phaseolus polystachyus (L.) BSP.) and the wild boneset (Eupatorium torreyanum Short.), likewise show more or less definite tendencies toward the same behavior. A variety of tropical sugarcane (28 N. G. 292) of the species Saccharum spontaneum L. gives evidence of having the sharpest and narrowest flowering range of any plant yet found in this group.

METHODS

In the tests where the entire plant was subjected to the treatment, constant daily light periods of 10, 12, 12½, 13, 13½, 14, 14½, 16, and 18 hours were used. The behavior of the plants in response to the full length of day is taken as the normal seasonal behavior. In those tests with light periods shorter than 16 hours, i.e., from 10 to 14½ hours, inclusive, the plants were kept in large well-ventilated lightproof houses to exclude daylight. The containers with the plants remained upon movable trucks running on tracks and were moved into the daylight on fixed schedules each morning and evening to secure the proper

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(775)
daylight periods. In all tests involving light periods shorter than the maximum length of the summer day in the latitude of Washington, which is about 15 hours, the light source was natural daylight. However, in those tests requiring 16 and 18 hours of light, respectively, each day, it was necessary to make use of artificial light from sunset. This supplemental light in each test was obtained from four 200-watt incandescent bulbs with reflectors kept at a distance of 1 foot above the plants. In all tests the plants were grown in large galvanized-iron buckets of 14-quart capacity.

EXPERIMENTAL RESULTS

CLIMBING HEMPeWeed

Climbing hempweed (*Mikania scandens*) is a perennial usually found in low-ground thickets and is distinctive in being the only species of climbing composite in the Washington region. The slender herbaceous stems die to the ground each autumn, leaving matted rootstocks from which new and vigorous shoots arise each year as soon as spring opens. The flowers also produce seed in abundance, and these tiny propagules, furnished with a hairy pappus, are readily carried away by the winds to establish new plants elsewhere in damp thickets.

Studies were made both with seedlings and with root divisions from a single large rootstock, and the behavior of the plants from these two sources will be presented.

Behavior of Seedlings

Seed of *Mikania scandens* was sown October 5, 1936, in a flat that was kept out of doors until December 7, 1936. The flat was then brought into a cool greenhouse ranging in temperature from 50° to 55° F. Germination took place January 1, 1937, and the small seedlings were pricked off into thumb pots March 3, 1937. Young, vigorous plants having an average height of about 3 inches were transferred to buckets, two in each container, May 18, 1937. On this date the tests in which only natural daylight was used began, while the tests of 16 and 18 hours, requiring supplemental artificial light, began April 22. The flowering behavior for the various constant daily light periods is shown in table 1.

<p>| Table 1.—Flowering behavior of seedlings of <em>Mikania scandens</em> exposed to various constant daily light periods |
|------------------|-------------|-------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Daily light period (hours)</th>
<th>Date of budding</th>
<th>Date of blooming</th>
<th>Height of stem</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>June 18</td>
<td>July 9</td>
<td>4</td>
<td>Inches</td>
</tr>
<tr>
<td>12</td>
<td>June 5</td>
<td>June 28</td>
<td>50</td>
<td>Very few flowers.</td>
</tr>
<tr>
<td>12½</td>
<td>June 10</td>
<td>...do...</td>
<td>50</td>
<td>Few flowers and flowering soon ceased.</td>
</tr>
<tr>
<td>13</td>
<td>June 9</td>
<td>...do...</td>
<td>50</td>
<td>Many flowers.</td>
</tr>
<tr>
<td>13½</td>
<td>...do...</td>
<td>...do...</td>
<td>50</td>
<td>Do.</td>
</tr>
<tr>
<td>14</td>
<td>June 11</td>
<td>June 26</td>
<td>50</td>
<td>Do.</td>
</tr>
<tr>
<td>14½</td>
<td>June 8</td>
<td>June 28</td>
<td>50</td>
<td>Do.</td>
</tr>
<tr>
<td>16</td>
<td>Aug. 19</td>
<td>Sept. 18</td>
<td>50</td>
<td>1 or 2 flower clusters only.</td>
</tr>
<tr>
<td>18</td>
<td>June 22</td>
<td>Aug. 10</td>
<td>50</td>
<td>Many flowers.</td>
</tr>
<tr>
<td>Full day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Plants failed to bud at this day length.
Behavior of Rootstock Divisions

Divisions from a single rootstock of Mikania scandens were potted in 3-inch pots in the cool greenhouse October 26, 1936. Shoots were starting January 21, 1937. These divisions were transferred to buckets, and the tests began May 18, 1937, when the plants were about 30 inches in height. The results are given in table 2.

**Table 2.**—Flowering behavior of rootstock divisions of Mikania scandens exposed to various constant daily light periods

<table>
<thead>
<tr>
<th>Daily light period (hours)</th>
<th>Date of budding</th>
<th>Date of blooming</th>
<th>Height of stem</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>June 30</td>
<td>July 24</td>
<td>50</td>
<td>Four flower clusters only.</td>
</tr>
<tr>
<td>12</td>
<td>June 7</td>
<td>July 6</td>
<td>50</td>
<td>Few flowers.</td>
</tr>
<tr>
<td>12 1/2</td>
<td>June 11</td>
<td>July 2</td>
<td>50</td>
<td>Do.</td>
</tr>
<tr>
<td>13</td>
<td>June 8</td>
<td>June 28</td>
<td>50</td>
<td>Sparse flowering.</td>
</tr>
<tr>
<td>13 1/2</td>
<td>June 7</td>
<td>June 25</td>
<td>50</td>
<td>Do.</td>
</tr>
<tr>
<td>14</td>
<td>June 12</td>
<td>June 28</td>
<td>50</td>
<td>Good flowering.</td>
</tr>
<tr>
<td>14 1/2</td>
<td>June 7</td>
<td>do</td>
<td>50</td>
<td>Do.</td>
</tr>
<tr>
<td>16</td>
<td>June 28</td>
<td>June 28</td>
<td>50</td>
<td>Good flowering.</td>
</tr>
<tr>
<td>Full day</td>
<td>June 21</td>
<td>July 5</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

1 Plants failed to bud at this day length.

The plants derived from rootstock divisions produced very few flowers on lengths of day of 10, 12, and 12 1/2 hours. Flowering soon ceased, and the plants maintained a purely vegetative condition but were less inclined to become scrambling twiner than those that experienced longer light periods.

Localization Tests

Rootstock cuttings of one plant of Mikania scandens were made and placed in 3-inch pots October 26, 1936, in the cool greenhouse. These were starting growth January 21, 1937. In April the main stem was cut back to a node within a few inches of the ground in order to stimulate new branches from this node. The plants were transferred to buckets, and the tests began May 29 (fig. 1).

The cases used in these tests were so constructed that a branch conducted inside the case from the plant in the bucket placed just outside was completely excluded from light when the sides of the case were fastened in position. The inside branch was given 10 hours of light each day, i. e., from 6 a. m. to 4 p. m., while an opposite branch from the same node was exposed to the full length of day. Two tests were made. In one the bucket was placed inside the case, with one branch remaining inside and an opposite branch conducted outside; in the other the bucket was placed outside the case, with one branch remaining outside and an opposite branch conducted inside the case.

In the test with the bucket inside the case, the length of the inside branch was 15 inches and that of the outside branch 16 inches, when the test began. The inside branch, given 10 hours of daylight each day, produced buds June 17 and open flowers July 12 at a length of 40 inches. A single flower cluster appeared, and no further flowering took place, the branch otherwise remaining in a vegetative condition all summer. The stem exposed to the full length of day produced buds June 15 and open flowers July 8. This branch was very floriferous throughout the summer.
FIGURE 1.—Climbing hempweed (Mikania scandens) in localization tests begun May 29. Portions of the plants inside the case received 10 hours of daylight each day, those outside experienced the full day. A, plant with rooted portion outside under the full length of day, and one branch inside. The outside branch showed visible buds June 17 and flowered July 8, the flowers appearing in great abundance. The inside branch never budded visibly. B, Plant with rooted portion inside the case, and one branch outside under the full length of day. The inside branch produced one flower cluster only, July 12, then ceased. The outside branch produced buds June 15 and open flowers July 8; very floriferous throughout summer. These plants were grown from divided crowns. Photographed August 13.
In the test with the bucket outside the case, the length of the outside branch was 24 inches and that of the inside branch 13 inches, when the test began. The inside stem, experiencing a 10-hour day, never budded; the outside stem, receiving full daylight, showed buds June 17 and open flowers July 8, at 50 inches.

In both localization tests, the branch receiving only 10 hours of daylight either failed to flower entirely or produced a single cluster of flowers only, showing that this length of day is very unfavorable to flowering.

**WILD KIDNEY BEAN**

The wild kidney bean (*Phaseolus polystachyus*), a native woodland plant, is the only representative of the genus in the Washington region. It is a scrambling twiner in the woodlands and copes which it frequents, and it flowers in July and August. The stems are herbaceous and die back to the perennial crowns each autumn. This interesting bean is a casual constituent of the flora in some situations of the upper Piedmont, as on the slopes of Bull Run Mountain and Big Cobbler, but its occurrence is usually restricted and only a careful canvass of the woodland undergrowth where it occurs will reveal its presence.

**Behavior as Affected by Short Winter Days**

The wild bean is very adversely affected by short days of 12½ hours or less. During the autumn of 1936 several hundred plants were grown in the greenhouse from seed that was sown October 4 and germinated October 26. These seedlings were transferred to 6-inch pots November 2, when about 3 inches tall. The young plants soon ceased to grow following the exhaustion of the reserves in the cotyledons.

The foliage on these plants consisted of a pair of simple opposite leaves above the cotyledons, succeeded by a small compound leaf with the usual three leaflets. These leaves were small, thick, crinkled, dark green in color, and never had the appearance of the thin healthy foliage of the summertime. Plants were grown in both cool (50° to 55° F.) and warm (75° to 80°) temperatures, but in neither condition did they show anything but the dwarfed and sickly growth described.

Although the plants are vigorous climbers in response to long summer days, the winter-grown plants gave no hint of elongating stems or twining habit. The plants soon passed into a state of dormancy, followed by loss of foliage, thickening of the stems, and finally death in many instances. It was obvious that the short winter days almost entirely inhibited growth in these plants, which in summertime are accustomed to become much-branched high-climbing vines.

Weak light from a 200-watt mazda bulb with reflector was supplied to a number of these plants from sunset till midnight throughout the winter. The plants quickly responded, becoming leafy twiners, but there was no indication of flowering throughout the winter, perhaps because the light periods, near 16 hours or more in length, were too long. It was evident that a very slight dosage of weak electric light at the end of the natural day sufficed to give the unhealthy winter plants a new lease on life so far as growth and twining were concerned.

**Behavior in Response to Different Light Periods in Summertime**

Seed of the wild bean were sown March 23, 1937. These germinated April 8 and were transferred to 3-inch pots April 23, and to buckets
May 17, with two plants in each; two buckets were included in each test. At this time the average height of the plants was 2½ to 3 inches. Two series of tests were run, one beginning May 17 and another June 4, but the results were similar. The following results with the different constant light periods were secured in the tests of June 4.

10 hours: None budded, and no twining stems were produced; height 4 inches.
12 hours: One blossom July 12 on one plant; no twining stems; height 4 inches.
12½ hours: One plant flowered July 27 and one August 11; two did not flower; slight twining; height 3 to 4 inches.
13 hours: Three plants flowered sparsely, July 16, July 24, and August 6 respectively; one never flowered; a few short runners produced; height 7 to 16 inches.
13½ hours: Three plants flowered June 23, two July 19, one July 21; runners short, the plants tending to remain bushy; height 22 to 36 inches.
14 hours: Two plants flowered July 8 and one July 27; twining habit strongly developed and plants very floriferous; height 30 to 40 inches.
14½ hours: Two plants flowered July 7 and two July 10; strong twining habit and very floriferous; height 35 to 48 inches.
Full day: Plants flowered August 15; strong twining habit and very floriferous; height 40 to 64 inches.
16 hours: Flowered August 16; strong twining habit, but sparse flowering; height 50 inches.
18 hours: Flowered October 1 at 50 inches; strong twining habit, but only a few closed flowers.

Localization Tests

Seed of the wild bean were sown March 23, and germination was evident April 8. The tiny plants were transferred to 3-inch pots April 23, and to buckets June 4. The tests began June 9, the bucket being kept inside the case (fig. 2). These plants were made to produce lateral branches by cutting back the main stem in April. When the tests began, the inside stem, receiving 10 hours of daylight each day, i.e., from 6 a.m. to 4 p.m., was 5 inches in height, and the outside stem, experiencing the full day, was 1 inch in height.

The inside stem remained very short, producing small, dark-green leafage, as in wintertime, and never budded. This portion of the plant was only 6 inches high on August 18.

The outside branch, receiving full daylight, produced buds July 21, and flowers August 2, at 60 inches. The plant was very floriferous until autumn.

Boneset

Boneset (Eupatorium torreyanum) is a native perennial composite of the Washington region, the herbaceous stems dying back to the rootstock each autumn. A clump was divided October 1, 1936, and the divisions were transplanted into buckets to remain out of doors throughout the winter. The various tests with these began March 29, 1937. The results were as follows:

10 hours: No buds formed; 14 sterile leafy stems, the tallest 25 inches; stems very lax, tending to bend over.
12 hours: 11 stems, none flowering; height 28 inches; stems weak, lax, arching toward the ground.
12½ hours: 9 stems, one flowering August 4 at 40 inches; stems very lax, arching.
13 hours: 13 stems, all flowering July 7 at 30 inches; stems very lax, arching.
13½ hours: Many stems, all flowering July 10 at 36 inches; stems more stiff, upright, but less erect than the controls.
14 hours: Many stems, all flowering July 27 at 35 inches; stems less erect than controls.
14½ hours: Many stems, all flowering August 4 at 33 inches; stems strictly erect.
Full day: Many stems, all flowering August 18 at 38 inches, with broad corymbose heads and erect stems.
FIGURE 2.—Wild kidney bean (*Phaseolus polystachyus*) (*B*) in localization tests begun June 9. Inside portion in bucket received 10 hours of daylight each day, i.e., from 6 a.m. to 4 p.m. The branch inside grew but little beyond the original height, 5 inches, at the time the tests began, and finally died in late summer. The branch conducted outside, which received the full day, grew with great vigor, buds being visible on July 21 and open flowers on August 2. This branch was very floriferous, as shown by the pods developed. Photographed August 31. (The plant shown in *A* had no connection with the investigation reported here.)
Regulation and timely control of flowering is a matter of great importance in the breeding of sugarcane. Many varieties have shown tendencies to be very irregular in their flowering habits. In order to obtain a better knowledge of the relationship of flowering of some of the sugarcanes to length of day, the Division of Sugar Plant Investigations of the Bureau of Plant Industry arranged tests with a number of their varieties, making use of the large lightproof houses and equipment of the Division of Tobacco and Plant Nutrition. Table 3 shows the growth and flowering behavior of the variety 28 N. G. 292, a form of the species *Saccharum spontaneum* found growing wild in New Guinea by E. W. Brandes, of the Division of Sugar Plant Investigations.

Stalk cuttings of this variety were made in October 1936 and were transferred first to 4-inch and then to 6-inch pots and finally to buckets. The tests were begun about May 1.

### Table 3.—Average length and number of stalks produced by the variety of sugarcane 28 N. G. 292 (*Saccharum spontaneum*) in response to different light periods

<table>
<thead>
<tr>
<th>Daily light period (hours)</th>
<th>Average length of stalk</th>
<th>Average stalks</th>
<th>Daily light period (hours)</th>
<th>Average length of stalk</th>
<th>Average stalks</th>
<th>Daily light period (hours)</th>
<th>Average length of stalk</th>
<th>Average stalks</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>36.0</td>
<td>14.7</td>
<td>14</td>
<td>45.2</td>
<td>10.6</td>
<td>16</td>
<td>37.5</td>
<td>12.0</td>
</tr>
<tr>
<td>12</td>
<td>26.0</td>
<td>13.4</td>
<td>Full day</td>
<td>30.7</td>
<td>8.3</td>
<td>18</td>
<td>41.5</td>
<td>12.0</td>
</tr>
<tr>
<td>15</td>
<td>41.7</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Flower buds present.

An examination of the stalks revealed the presence of young, developing flowers in response to the 13-hour day only. From the number of stalks shown it would appear that the shorter lengths of day, represented by 10 hours and 12 hours of light each day, favored a more active vegetative condition than the 13- or 14-hour day. It would appear that the additional light from sunset has had little effect upon the behavior of the plants.

It is evident that this sugarcane has shown a very striking behavior, which places it in the intermediate class. This behavior is especially interesting since it shows an exceedingly narrow range of flowering, lying somewhere between 12 and 14 hours.

### DISCUSSION

It is obvious that *Mikania scandens* finds conditions most favorable for flowering when the days are neither too short nor too long, or within a range of 12 or 12½ hours to 15 or 16 hours (figs. 3 and 4).

On the basis of its length-of-day behavior, the prediction could have been made that the northern limits of its range would be found somewhere within the latitudes of New England. As a matter of fact its range actually extends from southern Maine to Florida and Texas. It is probable that interactions between lowered temperatures, short summers, and the unfavorable influence of very long days help to define the northern limits of distribution of this plant. Length

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1 This work was under the immediate supervision of George B. Sartoris, of the Division of Sugar Plant Investigations, who has very kindly submitted the data for table 3.
of day alone, as it approaches the critical near 16 hours, retards the appearance of flowers about 5 weeks, and it is obvious that further delay can be expected where much cooler and shorter summers prevail.

The summative effects of these factors must make successful flowering and seed production before frost a hazardous event for the species near its northern limits.

On the basis of its length-of-day behavior with respect to the lower limits of flowering, its southern distribution should depend entirely
upon length of day, for unfavorable low temperature is not a factor and the summer season is greatly extended toward the Tropics. All evidence at hand indicates that in its present genetic state the species is not adapted to the shortened days of a tropical habitat, since flowering becomes sparse and uncertain when the days are shortened much below 12 to 12\textfrac{1}{2} hours.

The behavior of the plants grown from seed has been somewhat different from plants derived from old, established crowns. The former did not appear to be affected by the shortened days until a constant length of day between 12\textfrac{1}{2} and 12 hours was reached; the latter when the length of day had fallen somewhere between 13\textfrac{1}{2} and 13 hours.

![Figure 4](image_url)

**FIGURE 4.**—Climbing hempweed (*Mikania scandens*). General growth behavior of plants with the various periods of natural daylight indicated on the buckets. C received the full daylight, serving as a control. Plants receiving 10 hours of daylight daily flowered July 24, producing only four flower clusters. The 12-hour plants, flowering July 6, the 12\textfrac{1}{2}-hour plants, flowering July 2, and the 13-hour plants, flowering June 28, all flowered sparsely, indicating unfavorable conditions. Copious flowering was shown when the plants received 13\textfrac{1}{2}, 14, and 14\textfrac{1}{2} hours of light each day; flowering taking place June 25 for the 13\textfrac{1}{2}-hour plants and June 28 for the 14- and 14\textfrac{1}{2}-hour plants. The plants (C) receiving the full day flowered July 14, with copious flowering into September. These plants were grown from crown divisions.

The seedlings, likewise, have shown a greater tendency to flower on the higher lengths of day, since there was slight flowering in response to 16 hours of light, whereas the plants developed from rootstocks showed no tendency to flower on the 16-hour light period.

Until a careful analysis of the genetic behavior of the species throughout its range has been determined with respect to its responses to length of day, one cannot, of course, be sure that plants near the northern limits of distribution are identical in their day-length responses with those found in Florida or elsewhere in its range.

The wild kidney bean (*Phaseolus polystachyus*), like *Mikania scandens*, flowers best with an intermediate range of day lengths. Days that are too short or too long are very unfavorable to flowering and may even inhibit it entirely. The normal twining habit of the wild bean is entirely dependent upon length of day. The plants show little or no inclination toward the production of elongate branches or
the twining habit until a length of day between $13\frac{1}{2}$ and 14 hours is experienced, and until the twining habit vigorously asserts itself few flowers are produced.

Vigorous flowering is not strictly correlated with the twining habit, however, since an excessively long day again tends to inhibit flowering, in comparison with the full length of day, as shown by the daily light periods of 16 and 18 hours.

On lengths of day shorter than $12\frac{1}{2}$ hours the plants were of the dwarfed sterile winter type, with rather thick, dark-green rugose leaves and short stems (figs. 5 and 6). They barely survived the summer, and were virtually in a state of vegetative dormancy for many months. On those shorter lengths of day near the lower critical length of day for flowering, i.e., $12\frac{1}{2}$ hours, an interesting response asserted itself, characterized by the production of exceptionally large flowers and pods. It is evident that under these extreme conditions leading to an almost complete suppression of twining branches, the few flowers and pods produced were assured a superabundance of available reserve material, since none of it was diverted to the support of rapidly elongating stems.

The natural distribution of the wild kidney bean from Connecticut to Florida is in agreement with its day-length responses and limitations as revealed in the tests. Its inability to flower on the shorter lengths of day and its sparse and delayed flowering when the days are considerably lengthened would preclude a successful invasion into tropical latitudes on the one hand or a far northern distribution on the other, if it is assumed that the genetic constitution is like that which the tests
revealed. The plant probably finds its best adaptation near the middle ground of its range, rather than at the critical extremes where conditions are always more hazardous for any species.

The most striking features of the behavior of *Eupatorium torreyanum* are the development of sterile stems on lengths of day of 12½ hours or less and the development of very weak, lax, or arching stems until the longest light periods have been reached. The shortest day lengths have strictly inhibited flowering. The 12½-hour day, which appears to be near the critical length for the initiation of flowering as the days are lengthened, greatly delayed flowering as compared with the most favorable day lengths of 13 to 13½ hours (fig. 7). It is obvious that at the higher lengths of day, near 14 hours, flowering is again very noticeably delayed. From the data at hand it would appear that this boneset is not adapted to the extremely long days of northern latitudes nor to the extremely short days of tropical regions, and its natural distribution conforms with these limitations of its day-length behavior, ranging as it does from Pennsylvania to Florida and Texas.

**INTERMEDIATE BEHAVIOR AND THE ADAPTATION OF PLANTS**

The permanent colonization of plants, whether natural or through human agency, depends upon the inherent adaptive powers of the
species. Since length of day has been shown to be a very potent factor in the control of flowering, it is obvious that the length-of-day responses play a very important part in permanent colonization in any region. The position of the critical length of day for flowering and its sharpness or narrowness may very definitely determine in what latitudes a plant will survive and produce seed before frost. Short-day plants are adapted to distribution in lower latitudes, while long-day plants require the long summer days of higher latitudes. Just how far north short-day plants can succeed depends upon how far into the long-day region the critical length of day is extended, and just how far south long-day plants will spread depends upon how far down toward the shorter days the critical length of day is situated.

![Figure 7](image)

 Unlike the long-day and the short-day groups, plants of intermediate habit have their limitations determined by two critical points, a maximum in the direction of long days and a minimum in the direction of short days. If the minimum in the direction of the short days is near 13 hours, as in the case of the wild kidney bean, it is evident that the plant cannot flower in latitudes much below 20°, where the longest days of the year scarcely reach this critical length of day.

*Eupatorium torreyanum* would not flower in the Tropics in latitudes much below 10°, since the minimum critical length of day for this plant is near 12½ hours. On the basis of their length-of-day requirements, *Mikania scandens*, *Phaseolus polystachyus*, and *Eupatorium torreyanum* are not fitted to flower and to reproduce seed near the Equator, where the length of day approaches a constant of about 12 hours throughout the year.
The sugarcane variety 28 N. G. 292 has shown a definite flowering impulse in response to a daily light duration of 13 hours, and a vegetative condition with 12 and 14 hours. It is possible, however, that a length of day approaching 12½ hours and one somewhat longer than 13 hours would also have been favorable to flowering. On this basis this variety can be expected to flower almost on the Equator or at least in tropical latitudes ranging from 4° to 5° up to 20° or more, and this appears to be its normal behavior. This sugarcane has flowered at Guayama, Puerto Rico, practically on the eighteenth parallel, November 9. When this sugarcane is grown in Louisiana near the latitude of 30° N., flowering becomes irregular and may not take place until December. This behavior would indicate that this cane does not find length-of-day conditions very favorable to flowering much outside the Tropics, the northern and southern boundaries of which are 23½° from the Equator. If this behavior is an inherent condition of this variety, as indicated by the very narrow flowering range in the tests, flowering could not be expected in northern latitudes.

In the narrow responses of this cane one sees a highly specialized length-of-day behavior that has not previously been encountered. The very narrow restriction of its flowering responses, however, fits it admirably for naturalization in the Tropics alone, where it has been found at home.

In the case of the sugarcane it must be emphasized that the results presented were secured from a single test. It is thought, however, that the finality of the results of this test indicates the behavior of the variety under the conditions.

The wild kidney bean, *Mikania scandens*, and *Eupatorium torreyanum* are well adapted to middle latitudes lying roughly between 25° and 45°. The north and south range of such intermediate plants depends upon the upper and lower limits of their day-length responses. If these are far apart the range of the plants will be wide; if they are close together the range, as in the case of the sugarcane 28 N. G. 292, will be restricted. In the case of this cane, the capacity to flower lies somewhere within a range in length of day of only 2 hours, and the low upper limit at which flowering fails keeps the plant within the Tropics. While such plants have not yet been found, it is possible that intermediate plants quite as narrow in their length-of-day requirements for flowering will be found to exist in far northern latitudes. Such plants, like those in the long-day class, flowering in response only to very long days, could adapt themselves only to far northern latitudes. On this basis it is possible that some plants require continuous light for their best development.

**SUMMARY**

A number of plants of intermediate behavior have been found. They constitute a group of plants whose flowering is favored by lengths of day neither too short nor too long. On either side of this optimum range, flowering may cease entirely or be delayed or less profuse.

Mikanior scandens flowers very poorly in response to lengths of day that are 12 hours long or less, and flowering has practically ceased when the days have been lengthened to 16 hours or more.

*Phaseolus polystachyus* is near its flowering limit when the days are reduced to 12½ hours, and flowering is again checked or delayed when the days have been lengthened to 16 hours or more.

*Eupatorium torreyanum* ceases to flower when the length of day has been reduced to about 12½ hours or less. Experiments indicate that the plants flower most readily with 13 to 14 hours of daylight, and show a delay in flowering when the daylight periods exceed these values.

The wild New Guinea sugarcane 28 N. G. 292 of the species *Saccharum spontaneum* L. has shown the narrowest flowering response of any plant yet studied. Tests with daily light periods ranging, at 1-hour intervals, from 10 to 14 hours, and with the full length of day, at Washington, D. C., revealed that flower buds were formed only when the plants were afforded 13 hours of light each day. The flowering range for this species, therefore, lies somewhere between 12 and 14 hours of daylight.