unit leaf rates are higher during the earlier stages of plant ontogeny (Fig. 2). Since plant spacing did not significantly affect unit leaf rate (Fig. 2), it could be argued that cultivars that set fruit early might be able to more efficiently use their leaf canopy to photosynthesize and support fruit growth. Therefore, if gynoecious genotypes have sufficient leaf area at fruit-set to produce and partition the necessary assimilate to facilitate the growth of at least one fruit per plant, increased yields should be achieved by increasing plant density. A reduction in between-row spacing from 71 to 36 cm would appear to be the better strategy for enhancing plant density than a reduction in within-row spacing, due to its relatively lesser effect on shoot growth rate (Table 3) and the significantly higher canopy leaf area indexes (LAI) produced (Table 6). As long as biomass partitioning between vegetative and fruit tissues is not altered markedly by attempting to enhance LAI through increased plant densities, the higher LAI should be considered beneficial, since unit leaf rate was not found to be significantly compromised (Fig. 2).

The lack of consistent pickling cucumber yield enhancement due to increased plant density among reported studies (Cantliffe and Phatak, 1975; O’Sullivan, 1980; Tan et al., 1983) suggests, however, that other factors also might influence unit leaf rate and biomass partitioning within the plant. These factors might include genotype and environmental conditions, such as water (O’Sullivan, 1980; Tan et al., 1983) and/or mineral nutrient (Cantliffe, 1977) availability. Certainly, any environmental factor that reduces net assimilation rates or leads to greater partitioning of assimilates into vegetative growth (e.g., stem and petiole tissue), rather than into reproductive growth, would not be conducive to achieving increased yields at high plant densities. In addition, any pickling cucumber cultivar in which the plant’s source limitation for fruit production is accentuated markedly by a particular environmental stress associated with high plant densities would be expected to be quite sensitive to neighboring plant interactions. Under such conditions, maximum fruit yields by once-over harvest should theoretically be achieved at somewhat lower plant populations.

**Photoperiodic Control of Flowering of *Salvia leucantha***

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*(Additional index words: velvet sage, Mexican bush sage, light drift, irradiance)*

**Abstract.** Plants of *Salvia leucantha* were subjected to 8, 10, 12, or 14 hr of light under controlled environmental conditions. *Salvia leucantha* is a short-day plant with a critical photoperiod of 12 hr for macrobud development, but 10 hr for subsequent flower development. About 14 photoperiodic cycles are necessary for flower initiation, but at least 42 cycles are required for normal anthesis and raceme elongation. Apices that had initiated under < 6 weeks of short days failed to develop when placed under long days. Flower initiation did not occur when night break lighting of 1.3 μmol·s⁻¹·m⁻² was provided by incandescent lamps.

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**Literature Cited**


on flowering. Early work with old cultivars suggested that they were quantitative short-day plants (SDP) (Cathey and Piringer, 1961; Withrow and Biebel, 1936). Later studies showed that flowering of ‘Fireball’, a more recent cultivar, was delayed by 2 hr of night break lighting during the 16-hr dark periods (Furuta, 1954). ‘St Johnsfire’, however, was described as a long-day plant (LDP) (Crawford, 1961; Gaspar, 1963) or as day-neutral (DNP) (Weiler, 1972; Weiler and Lai, 1973). Similar variation in flowering response due to photoperiod has been shown among other cultivars, some being classified as SDP, some LDP, and others DNP (Weiler, 1972; Weiler and Lai, 1973; Zimmer and Saefteld, 1980). Struckmeyer (1941) found that flower primordia were present after 9 short days in SD cultivars, but further development was inhibited if placed under noninductive conditions. Additional SD were necessary for flower development. Other work on LD–SD effects on flower initiation and subsequent development concluded that photoperiodically responsive cultivars of \textit{S. splendens} need continuous photoperiodic induction for both flower induction and development of the racemes (Crawford, 1961; Zimmer and Junker, 1985).

The object of this research was to determine the photoperiodic requirements for flower induction and development of \textit{S. leucantha}.

Materials and Methods

\textbf{Effect of photoperiod on flowering (Expt. 1).} Forty terminal cuttings were rooted under intermittent mist in June and potted 2 weeks later in a commercial soilless medium (Fafard #3, Anderson, S.C.) in 10-cm pots (containing \textasciitilde550 ml of medium). Pots were placed in a glass greenhouse at 17 \textpm 2C \pm 2C day/night temperatures with a natural photoperiod of \textasciitilde14 hr. Plants were grown for 2 weeks, at which time terminals were pinched to two nodes. Ten plants were randomly placed in environmental control chambers with 8-, 10-, 12-, or 14-hr photoperiods 20 \textpm 2C and with an irradiance of 150 \textmu mol s\textsuperscript{-1} m\textsuperscript{-2}. Cool-white fluorescent lamps provided 130 \textmu mol s\textsuperscript{-1} m\textsuperscript{-2} and 60-W incandescent lamps the remainder. Plants were irrigated with tap water containing 200 ppm N using 15N-9.9P-12.7K until water drained from the pots. Tap water was used only every fourth watering to reduce soluble salt accumulation. Time to macrobud and first anthesis were recorded as defined by the appearance of at least two white corollas on the racemes. Plant height, including inflorescence, was measured and plants were harvested at soil level for dry weight determination at time of anthesis. Number of nodes to macrobud was also determined. The experiment was terminated 80 days after the beginning of SD. Trend analysis was accomplished among treatment means.

\textbf{Effect of photoperiodic cycles on flower development (Expt. 2).} Plants were propagated as described in Expt. 1—fifty-six were transplanted to 10-cm pots 3 weeks later and placed in a glass greenhouse where night temperatures were 15 \pm 4C and day temperature fluctuated with ambient, but were never \textless 18C. All plants were placed under black cloth from 1700 HR until 0900 HR and received LD conditions from 2300 to 0200 HR by overhead incandescent lamps (60 W) beneath the drawn cloth. The lamps provided 5 \pm 1 \textmu mol s\textsuperscript{-1} m\textsuperscript{-2} irradiance and raised air temperature by 1 to 2C. Plants were pinched to two nodes 1 week later. Seven plants in SD were removed after 1, 2, 3, 4, 5, or 6 weeks and when flower calyces began to show color \textasciitilde9 weeks) and immediately were placed in LD. The remainder stayed under SD until anthesis. A black screen was positioned between LD and SD plants to eliminate light drift. The experiment was terminated 80 days after the beginning of SD. The design was completely randomized and trend analysis was used for dose response.

\textbf{Effect of light drift on flowering (Expt. 3).} Forty-five plants, propagated and grown as described in Expt. 1, were placed along the length of a 4-m-long bench, at one end of which was a 40-W incandescent lamp. Plants were grown on 40-cm centers and 15 rows (three plants per row) were used. The light was applied from 2300 to 0200 HR. Irradiance level due to the incandescent light for each plant was recorded using a LI-COR quantum sensor (model LI-1000). Days to macrobud, anthesis, height, and dry weight for each plant were recorded. The experiment was terminated 80 days after treatment began. Trend analysis was used for dose response.

\textbf{Results and Discussion}

\textbf{Expt. 1.} Short days are necessary for flower initiation and development of \textit{S. leucantha} (Table 1). Photoperiods of 12 hr or less resulted in flower initiation, as shown by macrobud development; however, a critical photoperiod of 10 hr was necessary for normal flower development and anthesis (Table 1, Fig. 1). Flower buds initiated under the 12-hr photoperiod ceased to grow and vegetative lateral shoots developed from the internode immediately below the terminal. There was no difference in node number or dry weight among plants that reached macrobud stage. No flower buds were visible after 80 days on plants grown under 14-hr photoperiods (Table 1), suggesting that \textit{S. leucantha} may be a qualitative SDP. However, if plants had been allowed

\begin{table}[h]
\centering
\caption{Effect of photoperiod on flowering of \textit{Salvia leucantha}}
\begin{tabular}{|c|c|c|c|c|c|}
\hline
\textbf{Photoperiod (hr)} & \textbf{To macrobud} & \textbf{To flower} & \textbf{Dry wt (g)} \\
\hline
8 & 42.2 & 57.2 & 6.6 \\
10 & 44.2 & 60.5 & 6.9 \\
12 & 48.3 & 70.1 & 6.8 \\
14 & 52.4 & 70.2 & 9.4 \\
\hline
\textbf{Trend analysis} & & & \\
L & * & * & * \\
Q & NS & NS & NS \\
\hline
\end{tabular}
\begin{flushleft}
*Time from beginning of photoperiod treatment. \\
Event did not occur within 80 days after beginning treatments. \\
NS.* Not significant or significant at $P = 0.05$, respectively.
\end{flushleft}
\end{table}

Fig. 1. Effect of photoperiod on flowering of \textit{Salvia leucantha}. Eight-, 12-, and 14-hr photoperiod (left to right). Buds formed under 12 hr did not develop to anthesis.
to grow indefinitely, flower initiation may have occurred eventually, as with *Chrysanthemum morifolium* (Cockshull, 1976).

**Exp. 2.** Flower buds were formed on plants that received 2 or more weeks of SD treatment; however, at least 6 weeks of SD were necessary for anthesis (Table 2). Raceme development of plants that received <6 weeks of SD was arrested and eventually aborted when plants were transferred to LD conditions (Fig. 2). At 6 weeks, however, 57% of the plants developed normal inflorescences. As long as short days were applied, racemes continued to develop normally. If short days were continued until calyx appeared (~9 weeks), 100% of the plants reached anthesis. Although average raceme length of 6-week SD plants was shorter than 9-week SD plants (Table 2), those that developed normally (57%) were the same length.

These data indicate that the process of flower initiation and flower development are under different photoperiodic control. The maximum daylength at which flower development proceeds is less than that at which flower initiation occurs (Table 2). This is similar to *S. splendens* (Gaspar, 1963; Struckmeyer, 1941) and chrysanthemum (Furuta, 1954; Schwabe, 1951; Seeley and Weise, 1965). With *S. leucantha*, calyces must show color before normal flower development proceeds uninterrupted in all plants. Machin and Scopes (1978) and Kofranek (1980) recommend similar treatment for commercial production of chrysanthemum. The arrested racemes of velvet sage are analogous to "crown buds" of chrysanthemum; i.e., they are formed in the same manner as normal flower buds but their development is arrested by the environmental conditions under which they are growing (Cathey, 1957; Chan, 1950; Schwabe, 1951). Node number was similar for plants given 4 weeks or more of SD, but flower buds were formed later on higher nodes when <4 weeks of SD were provided (Table 2).

**Exp. 3.** Light drift inhibited flower development. Unidirectional irradiance >0.3 μmol·s⁻¹·m⁻² for 4 hr inhibited flower initiation and 0.7 inhibited anthesis (Table 3). No macrobud was formed at irradiances >1.3 μmol·s⁻¹·m⁻². Plants that reached macrobud stage were similarly high, but dry weight was greater for plants that remained vegetative (Table 3). We have shown *S. leucantha* to be a SDP with different critical photoperiods for flower initiation and subsequent development. Six weeks of SD are necessary for anthesis, but SD until calyx color develops ensures 100% development. Flowering is totally inhibited at night break irradiances >1.3 μmol·s⁻¹·m⁻².

---

Table 2. Effect of photoperiodic cycles on flowering of *Salvia leucantha*.

<table>
<thead>
<tr>
<th>Short days (weeks)</th>
<th>Interval (days)</th>
<th>No. of raceme nodes</th>
<th>Length of raceme (mm)</th>
<th>Flowering plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>^z</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>8.2</td>
<td>7.3</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>7.3</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>36</td>
<td>6.3</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>6.2</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>34</td>
<td>63</td>
<td>207</td>
<td>57</td>
</tr>
<tr>
<td>9</td>
<td>33</td>
<td>60</td>
<td>286</td>
<td>100</td>
</tr>
</tbody>
</table>

Trend analysis: L * * Q NS * NS

^z Event did not occur within 80 days from beginning of short days.
NS-Not significant or significant at *P* = 0.05, respectively. Does not include 0 or 1-week SD treatments.

Table 3. Effect of light drift on flowering of *Salvia leucantha*.

<table>
<thead>
<tr>
<th>Irradiance (μmol·s⁻¹·m⁻²)</th>
<th>Interval (days)*</th>
<th>Dry wt (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>32</td>
<td>47</td>
</tr>
<tr>
<td>0.1</td>
<td>32</td>
<td>53</td>
</tr>
<tr>
<td>0.2</td>
<td>32</td>
<td>52</td>
</tr>
<tr>
<td>0.3</td>
<td>32</td>
<td>51</td>
</tr>
<tr>
<td>0.5</td>
<td>38</td>
<td>54</td>
</tr>
<tr>
<td>2.3</td>
<td>43</td>
<td>62</td>
</tr>
<tr>
<td>4.5</td>
<td>39</td>
<td>60</td>
</tr>
<tr>
<td>6.1</td>
<td>38</td>
<td>54</td>
</tr>
</tbody>
</table>
| Event did not take place within 80 days from beginning of light treatment.
*Significant at *P* = 0.05. Statistics do not include 6.1, 4.5, or 2.3 μmol·s⁻¹·m⁻² irradiance treatments, except for dry weight, which includes all.

---

Fig. 2. Arrested raceme development due to transfer from SD to LD. Three, 4, 5, and 9 weeks SD.
Fruit and Seed Development of Seven Jojoba Clones over Two Seasons

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Additional index words. Simmondsia chinensis, seed filling, new crops, arid adapted plant, industrial crops

Abstract. Fruit and seed development of seven jojoba [Simmondsia chinensis (Link) C. Schneid.] clones were monitored over two seasons. Pollination occurred in late February and early March. However, most of the seed dry matter and wax accumulated after 15 June in both years. Fruit weight rapidly increased during May, followed by a leveling off in June and a 70% drop in weight in July as fruit matured and water was lost. While all seven clones exhibited similar fruit and seed developmental patterns, there were large differences between clones in the actual values observed over the two seasons. Differences in final seed weight between clones were due to differences in both rate and length of time of filling.

Liquid wax accounts for ~50% of the total dry weight of jojoba seed. However, studies of the pattern of wax and dry matter accumulation during jojoba seed development under cultivated field conditions have not been reported. Studies on development of jojoba seed have been limited to a single plant in one season (Benzioni, 1978), 15 plants in a native stand over one season (Yermanos, 1975a, 1975b) and greenhouse-grown plants (Dunstone, 1985; Dunstone et al., 1985; Dunstone et al., 1984; Wardlaw and Dunstone, 1984). Here we describe fruit and seed developmental patterns and wax and dry matter accumulation of several jojoba clones growing under cultivated field conditions near Bakersfield, Calif.

Materials and Methods

Jojoba plants propagated by cuttings were planted in Summer 1979 in a field ~32 km south of Bakersfield, Calif. Plants were planted 1.5 m apart within rows, with 3.7 m between rows. About 360 mm of irrigation water were applied annually to supplement ~140 mm of rainfall received in this area. In May 1982, three adjacent plants of each of seven clones located in different parts of the field were selected for study. Eight fruit were harvested from each of these plants at ~2-week intervals during the fruit-filling season. The following fruit and seed characteristics were measured: fruit length, width, and fresh weight (measured after removal of sepals) and seed length and fresh weight. The study was repeated in 1983 with 10 fruits harvested

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