

Growth and Reproduction of Annual Sowthistle (*Sonchus asper* L.) in Response to Environmental Light

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Abstract

Sowthistle (*Sonchus asper* L.) is believed to be a highly resource demanding species that spreads mainly by seeds. In this study, the effect of light availability on plant size and seed production was investigated. Sowthistle plants showed high phenotypic plasticity in their height, number of leaves, leaf length and number of branches per plant in relation to light availability. Seed mass production per plant ranged from >3.5 g in the control to less than 0.2 g in the 50% light availability treatment. It was concluded that changing the canopy architecture of crops can suppress growth and seed production in this plant. The results of this research can be used to develop models in crop-weed competition.

Keywords: Neutral shade; Seed mass; Annual weed

Introduction

Annual sowthistle (*Sonchus asper* L.) is a broad leaf weed from the Asteraceae. It is a common weed among many crops [1]. The ability to germinate at any time of the year, compete well for resources and interfere with crop harvest are the most important features of this weed. One of the resources that has a critical effect on plant growth and development is light availability [2] which is measured by both light quantity and quality [3]. Light is especially important in crop-weed competition studies where enough water and nutrients are provided [4,5].

Plants with more access to light will be better able to forage for nutrients than the plants with less access to light [6]. In sustainable agriculture, manipulating the amount of light availability is one of the methods for controlling weeds [7]. It can be achieved through the selection of the appropriate crop cultivars, seeding time, and crop density.

Under the crop canopy both light intensity and red:far red ratios (R:FR ratios) decrease, resulting in decrease in the number of branches and seeds of the weeds. This consequently leads to the reduction of the weeds' seed banks in the long term [8]. For example, McLachlan et al. [4] showed that the amount of light availability changes the leaf initiation rate, the leaf expansion rate, and the final height of redroot pigweed (*Amaranthus retroflexus* L.). Velvetleaf (*Abutilon theophrasti* Medicus.) plant height, leaf number, number of branches, dry weight and seed dormancy were also decreased by decreasing the light availability [9]. Reduced light levels also decreased the leaf initiation rate, the area of rosette leaves and the leaf expansion rate of *Arabidopsis thaliana* L. [10]. In other words, plants needed more time to reach their maximum size.

Despite the widespread importance of annual sowthistle, there is little information available on its requirements for resources such as light, water and nutrients, especially between seedling establishment and seed setting. Since sowthistle is a rosette weed, it was hypothesized that manipulating the light availability could be a promising way for suppressing its growth and development. Thus, the aim of this study was to quantify the effects of light availability on sowthistle growth and reproduction capacity.

Materials and Methods

Plant material

Sowthistle is a rosette plant that its leaves show phenological variations depending on their positions on the stem. Sowthistle has two different forms of leaf. Rosette leaves close to cauline leaves grow on the upper part of the stem. The length of the stem internodes associated with cauline leaves increases dramatically after the appearance of the first flower buds. Plants can grow to 1.0 m or more in height [1].

Seeds of sowthistle were collected from plants growing in the Mallard roadside, near Karaj, Alborz, Iran, during several months and kept in a dry and cool place until used in the experiment. The experiment was conducted in a glasshouse during 2011. The average temperature was 26 ± 3 and 16 ± 2 C for day and night time, respectively. Seeds were sown directly in the pots with the size of 20 cm in diameter and 17 cm in height. Light textured soil with neutral pH was used. The soil was watered to the field capacity with tap water and no fertilizers were used.

Shade treatment

The treatment period began after the appearance of the first true leaf of the sowthistle seedlings. The experiment consisted of a full-sun treatment (control) and two neutral shade treatments. Plants were randomly assigned to positions on five glasshouse benches, and arranged with sufficient distance among individuals to prevent competition for light. In the neutral shade experiment, plants were placed under vertically adjustable frames covered with black neutral-density shade cloth (Hummert International, Earth City, MO USA) that reduced photosynthetically active radiation (PAR) by c. 70 and 50% (Red:Far Red=1.03). Pots were regularly rotated (every week) to minimize the variation in their growth.

Data collection

Leaf number and the time of bolting in sowthistle plants were noted daily. Plant development expressed in terms of phyllochron [11], which is the period of time or the number of degree-days in thermal time between the appearance of one leaf and the appearance of the next. The average phyllochron for sowthistle was obtained by totalling the thermal time taken from the appearance of the first true leaf to the bolting stage and dividing it by the number of leaves produced.

The height of the sowthistle plants was measured (after bolting) every 10 days using a ruler. At the time of harvest, leaves were scanned in a leaf area meter (LI-3100; Li-Cor, Lincoln, NE, USA). The number of capitula and lateral branches were counted on each plant. Five capitula from each sowthistle plant were randomly chosen and their seeds counted. As other seed heads matured they were collected in separate packets and later weighed. Also, the internode lengths in each fully grown sowthistle plant were measured. Finally, 90 days after starting the experiment, the above ground parts of the sowthistle plants were harvested, dried at 70°C for 72 hours and then weighed.

Statistical Analysis

The data on leaf appearance rate and height over thermal time (growing degree-days, GDD), as affected by the different light availability regimes, were analysed using a general linear model. The number of branches, number of capitula, and the amount of biomass were tested with a one-way ANOVA using Minitab 14.0 [12]. Differences between averages were tested by a LSD test for a significance level of $P < 0.05$.

Results

Sowthistle plants grown under the two lower light availability (50 and 70% light availability) had significantly ($P < 0.05$) slower development times (Figure 1 and Table 1) than those grown in full sun light (100% light availability). However, the total number of leaves on the main stem of sowthistle plant at the end of experiment was not affected by the amount of light availability (Figure 1). They all produced 23 ± 2 leaves on the main stem. Sowthistle plants grown under 50, 70, and 100% light availability needed about 1090, 940, and 640 GDDs respectively to bolt (Table 1). Phyllochron (Table 1 and Figure 2) was negatively correlated with the amount of light available for growth.

The final leaf area produced in the different treatments was not significantly different (Table 1). The height of sowthistle plants over time was significantly affected by light availability ($P < 0.05$, Figure 3). The final length of internodes in basal nodes of the plants grown under

the 50% light availability regimes was slightly longer than those grown under full light (Figure 4).

Measured parameters	Light availability			P-value
	50%	70%	100%	
Phyllochron (growing degree days)	48.4 ± 1	41.4 ± 0.4	28.4 ± 0.5	<0.05
Bolting (growing degree days)	1,090 ± 10	940 ± 5	640 ± 24	<0.05
Total leaf area (cm ² plant ⁻¹)	1437 ± 66	1,434 ± 26	1,425 ± 21	>0.05 ^{ns}
Total canopy plant biomass (g plant ⁻¹)	9.52 ± 0.7	15.2 ± 1.56	31.6 ± 1.8	<0.05

Table 1: Parameter means and standard errors (±SE) recorded from sowthistle plants growing under different levels of light availability (%).

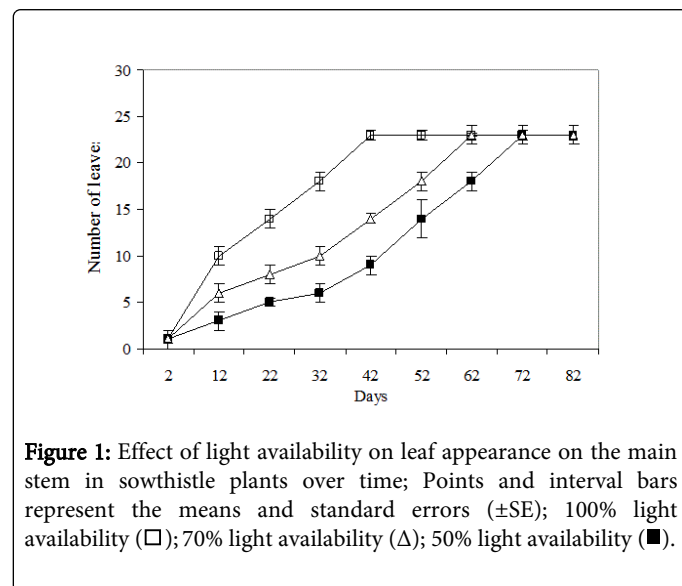


Figure 1: Effect of light availability on leaf appearance on the main stem in sowthistle plants over time; Points and interval bars represent the means and standard errors (±SE); 100% light availability (□); 70% light availability (Δ); 50% light availability (■).

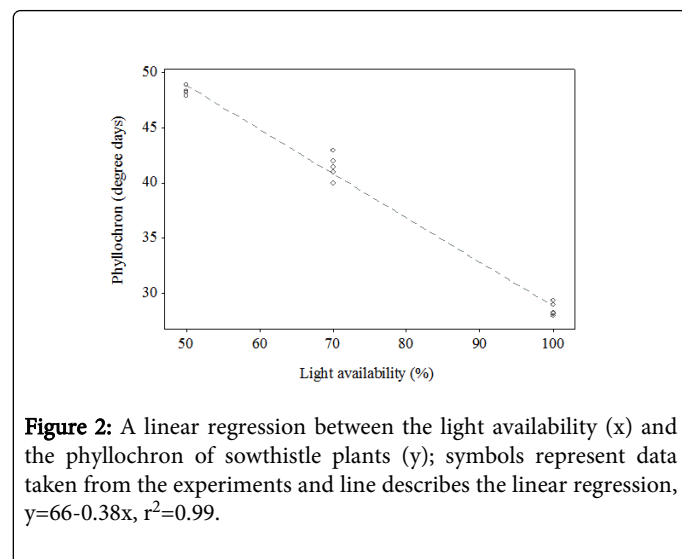


Figure 2: A linear regression between the light availability (x) and the phyllochron of sowthistle plants (y); symbols represent data taken from the experiments and line describes the linear regression, $y = 66 - 0.38x$, $r^2 = 0.99$.

No noticeable differences were found in the lengths of internodes above node 11 (cauline nodes) in sowthistle plants grown under the different treatments (Figure 4). Sowthistle plant canopy biomass was decreased by 69 and 51% when the light availability used for growth was 50 and 70%, respectively (Table 1).

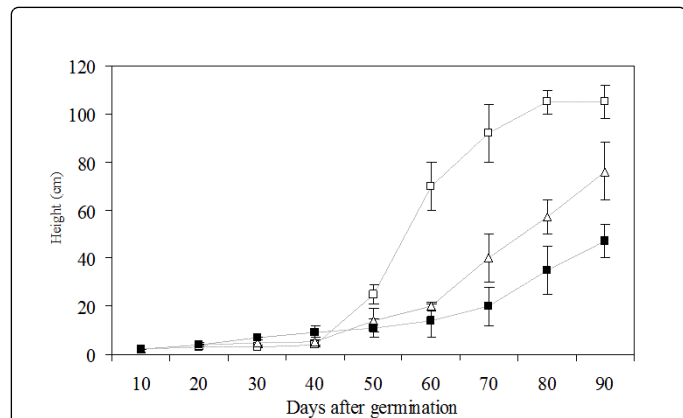


Figure 3: Effect of light availability on height (cm) of sowthistle over time; symbols showing the mean of height over time; vertical bars are standard errors (\pm SE); lines depict the trend of growth; 100% light availability (\square); 70% light availability (Δ); 50% light availability (\blacksquare).

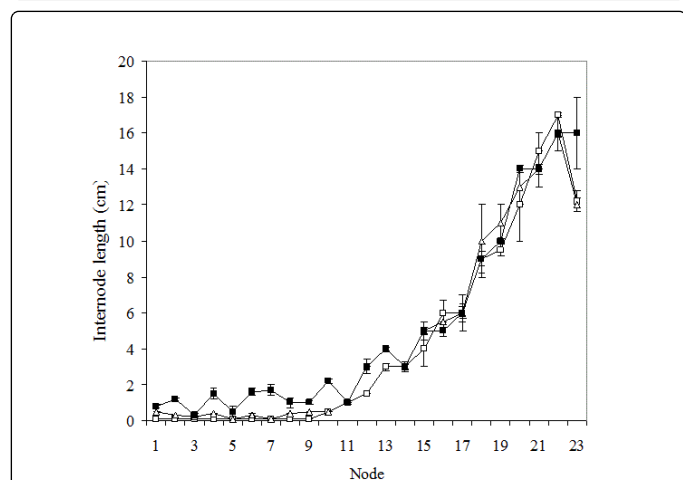


Figure 4: Effect of light availability on internode length (cm) in mature sowthistle plants; Symbols and interval bars represent means and standard errors (\pm SE), respectively. 100% light availability (\square); 70% light availability (Δ); 50% light availability (\blacksquare).

The number of branches (Figure 5) and capitula (Figure 6) were also significantly ($P < 0.05$) reduced by reduced light availability (Table 2). Not only the number of capitula but also the number of seeds produced per capitulum was significantly ($P < 0.05$) decreased by the reduced light availability (Figure 7). Consequently the total mass of seeds per plant (Figure 8) was significantly reduced by the reduced light availability as well.

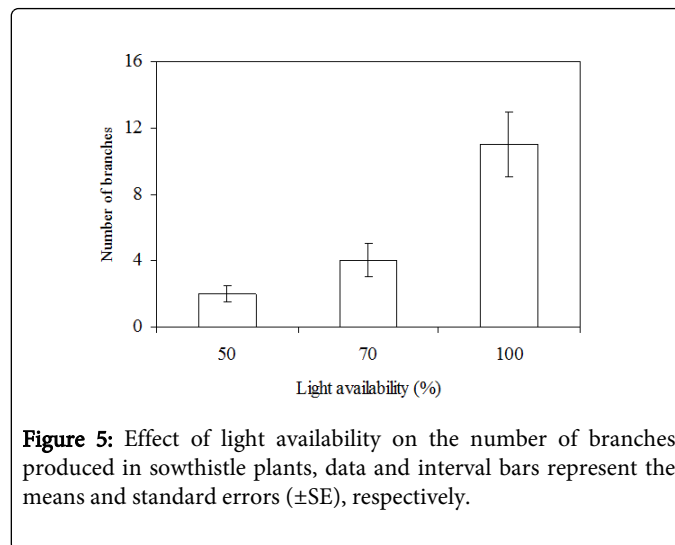


Figure 5: Effect of light availability on the number of branches produced in sowthistle plants, data and interval bars represent the means and standard errors (\pm SE), respectively.

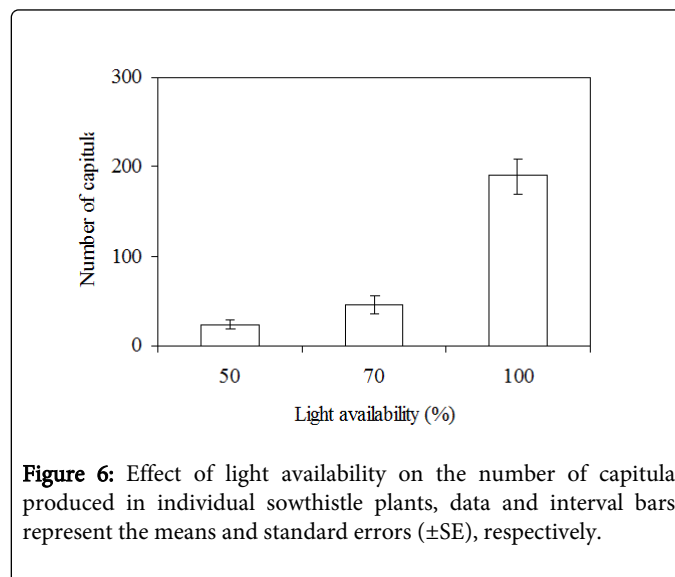


Figure 6: Effect of light availability on the number of capitula produced in individual sowthistle plants, data and interval bars represent the means and standard errors (\pm SE), respectively.

Measured parameters	Model	Source variance	of SS	d.f	F	P
Stem Height	GLM	*GDD ? Light	34,842	10	350	<0.05
Branch no plant ⁻¹	ANOV A	Light	934	2	539	<0.05
Capitulum no plant ⁻¹	ANOV A	Light	208,043	2	536	<0.05
Seed no capitulum ⁻¹	ANOV A	Light	12,636	2	218	<0.05
Seed mass plant ⁻¹	ANOV A	Light	26.9	2	1,361	<0.05

Table 2: General Linear Model (GLM) and ANOVA of the effects of light availability on sowthistle plant morphogenesis parameters; *GDD: growing degree days.

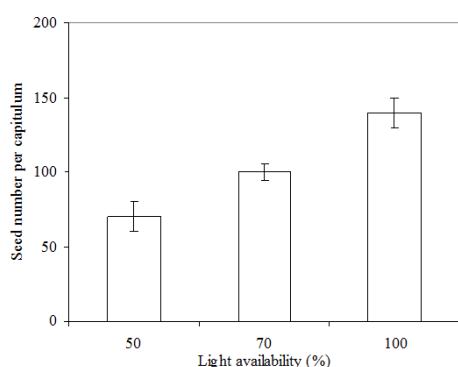


Figure 7: Influence of light availability on the mean seed number per capitulum, data are means of the number of seeds averaged from five randomly selected capitula per plant and interval bars are standard errors (\pm SE).

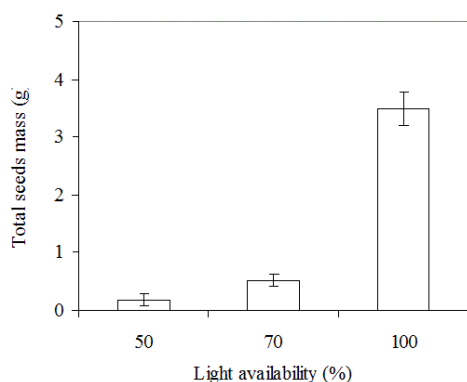


Figure 8: Influence of light availability on the mean of seed mass per sowthistle, data are means of the total seed mass (after 1280 growing degree-days) per plant and the interval bars are standard errors (\pm SE).

Discussion

Different responses to environmental light have been documented in many plants [13]. In the current experiment, while the final number of leaves on the main stem of the sowthistle were the same in all the treatments, the rate of leaf appearance was slowed by the reduced light environment. Gonzales and Gianoli [14] found similar results in a *Convolvulus* species. On the basis of reports in the literature [15], in plants under reduced light intensity conditions the time to flowering was delayed while the number of nodes in the main stem did not change. In the case of sowthistle plant, a decrease in light availability delayed the bolting time.

When sowthistle plants were subjected to lower light availabilities (50 and 70%) they took longer to reach their maximum height. Also, the number of branches, capitula, seed per capitulum and seed mass were all reduced significantly when the level of light was reduced. For example, when the amount of light availability was reduced to 50 and 70% of the full sun light the number of branches were decreased by

about 83 and 58%, respectively. These findings are consistent with those of Smith and Whitlam [2], who have shown that when light availability is decreased, branching is also decreased. Rajacan et al., [16] reported that the number of branches produced by pigweed plants was more greatly affected by light intensity than by the R:FR ratios.

The biomass of sowthistle plants was significantly reduced as light availability was reduced. A similar response to light has been shown by Gibson et al., [17] in *Ammannia coccinea* L. and by Brainard et al., [18] working on *Amaranthus powellii* L. This is in contrast with the findings of a study by Shrestha and Fidelibus [19] who reported that the light availability over the range included in the experiment did not affect the final biomass production in *Solanum nigrum* L. plants.

The reduction in sowthistle plant seed production under reduced light availability could be the result of a decrease in the resources allocated to the reproduction of those plants. Similar decreases in the total mass of seeds produced under reduced light availability has been reported for *Abutilon theophrasti* L. [20], *Amaranthus powellii* L. [18], and *Solanum nigrum* L. [19]. Bello et al. [9] showed that *Abutilon theophrasti* L. plants grown under neutral shade could decrease their growth and seed production by as much as 94% as compared to those grown in full light. Such reductions in seed return have a long term perspective for plant population dynamics and IWM [8]. The results of this experiment can be used in developing models to explore the effect of manipulating light availability in crop production [21].

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