Effect of Shade on Velvetleaf (*Abutilon theophrasti*) Growth, Seed Production, and Dormancy[1]

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Abstract. Growth, seed production, and dormancy of velvetleaf in response to shading were evaluated in the field. Velvetleaf plant height, leaf number, number of branches, and plant dry weight decreased linearly with increasing shade. No differences were observed for plant height, number of leaves, or branches/plant when plants were shaded 30% or not shaded throughout the growing season. However, the 76% shade treatment reduced velvetleaf height (1984 only), leaf number, stem branches, and plant dry weight. These reductions were greater in 1984 than 1985 except for plant dry weight that decreased by 88% each year. The number of capsules and the number of seeds/plant decreased linearly with increasing shade levels, while the seed weight increased with increasing shade level. Shading also decreased seed dormancy. These results demonstrate that shade suppresses velvetleaf growth and seed production, and shortens the dormancy of seeds that are produced by these plants. **Nomenclature:** Velvetleaf, *Abutilon theophrasti* Medicus #[3] ABUTH.
Additional index words. Intraspecific competition, seed dormancy, seed production, ABUTH.

INTRODUCTION

The importance of velvetleaf in the agroecosystem of the midwestern states has been attributed, in part, to the aggressive growth habit and the production of large numbers of seeds that can germinate throughout the season when conditions are suitable. Velvetleaf reaches maximum growth 10 wk after emergence (3) and produces mature seeds within 20 d after pollination (24). A single plant is capable of producing 17 000 seeds (23). Buried seeds have retained viability for 20 to 50 yr (13, 21) because of a thick, hard seed coat that is impermeable to water (4, 5). These characteristics make velvetleaf control a long-lasting problem in field crops.

It has been estimated that velvetleaf could cause a $1 billion soybean [*Glycine max* (L.) Merr.] loss because of the competitive ability of velvetleaf to reduce soybean growth and yield (19). Stoller and Woolley concluded that most, if not all the interference from velvetleaf infestations in soybean could be attributed to light competition (20). The total number of nodes on soybean branches has been shown to be inversely proportional to the duration of shade when plants were artificially shaded (1). Studies with weed species grown under light-limiting conditions have demonstrated reduced growth, development, and seed production (3, 12, 16, 17). It has also been shown that greater corn population densities reduced foxtail (*Setaria* spp.) growth and seed production (14) and that a velvetleaf population as low as 2.4 to 4.7 plant/m^2 reduced soybean branch node production (6, 7). However, no research has demonstrated the effect of shade on velvetleaf growth and seed production and only a few have reported effects of soybean interference on velvetleaf growth and yield (6, 10, 15). Such evidence would provide a framework and incentive for future research utilizing the soybean canopy to suppress velvetleaf and other annual weeds in soybean production. The objectives of this research were to investigate the effect of artificial shading (simulating those found under a soybean canopy) and intraspecific competition on the growth, seed production, and dormancy of velvetleaf.

MATERIALS AND METHODS

Experiments were conducted in 1984 and 1985 at Ames, IA on a Webster clay loam (Typic Haplaquolls) soil with 4.9% organic matter and a 7.95 pH. Alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide] was applied preemergence at 2.3 kg ai/ha each year for annual grass weed control. The experimental design was a split-

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 1508 West University Ave., Champaign, IL 61821-3133.

split-plot with three replications arranged in a randomized complete block. The main plots were the three velvetleaf population densities, the subplots were the three levels of shade, and the sub-subplots were the weekly measurements. Velvetleaf population densities were established by thinning the natural infestation to 6, 8, and 14 plants/30.5 m^2 for low, medium, and high population densities, respectively. These population densities were equivalent to 6500, 8600, and 15 100 plants/ha.

Shading was achieved by covering 3.05 by 3.05 by 2.44-m wooden structures with a black lumite polypropylene fabric[4]. Shade structures were constructed when velvetleaf seedlings were 3 wk old. An integrating quantum sensor[5] at solar noon on a clear day was used to measure PPFD under each shade canopy. Full sunlight (0% shade) had a maximum measurement of 1700 $\mu mol/m^2/s$ PPFD. The percentage irradiance reduction in PPFD provided by the shade cloth was 30% and 76%.

Plant height and the number of leaves, main stem branches, and seed capsules were recorded weekly until harvest, from five and four randomly selected plants in 1984 and 1985, respectively. At harvest, accumulated shoot dry matter, excluding the seed capsules and the weight of 100 seeds were measured. The estimated total number of seeds per plant was determined by randomly sampling 10 intact capsules.

Germination percentages were determined before and after breaking dormancy so that the seed dormancy percentage within each treatment could be calculated. Seed dormancy was broken by immersing the seeds in boiling water for 1 minute (11). Germination of 50 seeds placed on two moist germination papers[6] in 27.5 by 16.9 by 4.4 cm clear styrene boxes[7] was evaluated for 6 d at 30 C. Percentage seed dormancy was calculated by:

$$\% \text{ dormancy} = \frac{(A - B) \times 100}{50}$$

where: A = number of germinated seeds after breaking dormancy, B = number of germinated seeds without breaking dormancy, 50 = number of seeds per treatment. Germination was defined as the growth stage when the radicle had penetrated the seed coat and was approximately 2 to 3 mm long.

Analysis of variance was used to determine significance of velvetleaf population density, shade, and the interactions on a weekly basis for the two-year experiment. Treatment differences were compared using the LSD test ($P < 0.05$) where appropriate.

RESULTS AND DISCUSSION

Rainfall was more evenly distributed in 1985 than in 1984 (Table 1), resulting in more velvetleaf biomass accumulation in 1985.

Vegetative parameters. The height of shaded velvetleaf plants did not differ from those in full sunlight until 3 wk after the shade levels were established (data not shown). Only the 76% shade level reduced velvetleaf height at harvest with a 35% and 18% reduction in 1984 and 1985, respectively (Table 2). Several researchers proposed that increasing shade will increase plant height until photosynthate production limits growth (2, 9, 16). The lack of velvetleaf height differences between full sunlight and 30% shade suggests that the threshold for a photomorphogenetic response in velvetleaf was not reached by the 30% shading. Velvetleaf population levels of 6500, 8600, and 15 100 plants/ha did not affect velvetleaf height (data not shown). Previous research (6), which reported that 24 000 to 47 000 velvetleaf plants/ha were required to reduce soybean branching, may suggest that these population levels were too low for intraspecific competition to increase plant heights.

Velvetleaf populations did not affect leaf number. Leaf number increased until 9 wk after emergence when leaf senescence started (Figure 1). Velvetleaf populations and shade treatments also did not affect the onset of leaf senescence. However, the leaf drop rate was greater for

Table 1. Seasonal rainfall distribution for the 1984 and 1985 growing seasons, Ames, IA.

	Amount of rainfall		
Month	1984	1985	30 year ave.
		cm	
May	17.53	3.61	4.37
June	27.10	6.24	5.11
July	9.22	5.30	3.45
August	0.18	15.70	3.89
September	11.71	9.68	3.21
Total	65.74	40.53	20.03

[4]Lumite Chicopee Manufacturing, A. H. Hummert and Co., St. Louis, MO 63103.
[5]Licor Model LI-188B. Licor Ltd., Lincoln, NE 68504.
[6]Anchor Paper Co., Box 3648, St. Paul, MN 55165.
[7]Flambeau Productions Corp., Butler Ave., Middlefield, OH 44062.

Table 2. Effect of shade on vegetative growth parameters of velvetleaf.[a]

Shade level	Plant height		Leaf number		Branch number		Dry weight	
	1984	1985	1984	1985	1984	1985	1984	1985
%	cm		no./plant				g/plant	
0	88	96	54	43	18	11	125	527
30	84	93	45	32	17	9	108	275
76	57	78	6	13	7	5	12	65
LSD (0.05)	15	17	5	10	3	2	20	140

[a]Data are pooled means of three replications of three velvetleaf population densities.

plants grown under 0% or 30% shade than plants in 76% shade (data not shown). The average leaf number under 30% shade was reduced 17% and 26%, while 76% shading resulted in a 89% and 70% reduction, in 1984 and 1985, respectively (Table 2). Several researchers suggest that the redistribution of nutrients from mature leaves to meet the sink demand of seed formation and seed filling may be one of the causes of leaf senescence in mesocarpic plants (8, 18, 22).

Plants grown under 76% shade produced less than 8 branches/plant; approximately half the number produced by plants grown under 0% and 30% shade levels (Table 2). The 76% shade level also delayed branch formation by 1 wk although the rate of branch formation was not affected by shading (data not shown). Plants grown in full sunlight produced 57% more branches in 1985 than in 1984. This could be attributed to various environmental differences including the uniform rainfall distribution throughout the 1985 growing season.

The plant dry weight foliar portions, excluding capsules, decreased with increasing shade levels (Table 2). These effects are similar to those reported by researchers using other plant species (2, 9). Plant dry weight in both years was reduced approximately 90% by the 76% shade level in comparison to unshaded plants (Table 2). In 1985, the 30% shade level also reduced the plant dry weight.

Reproductive parameters. Shading did not delay the time of flower initiation or capsule formation, but capsule number decreased as the shade level increased (Table 3). Capsule number was decreased by 90% with 76% shade and 63% with 30% shade compared to full sun. In 1984, seed capsule number also decreased with increasing population levels (data not shown).

Increasing shade reduced seed production (Table 3). Seed production for velvetleaf grown under 76% shade level was reduced by 94% and 88% in 1984 and 1985, respectively. The decrease in the number of seeds per plant with increasing shade levels was directly proportional to the number of pods produced per plant, not the average number of seeds per pod (data not shown), and were similar to those reported by Eaton et al. (7). Seed production was approximately 45% less in 1985 than in 1984.

In 1984, plants grown under 76% shade produced seeds that weighed 16% more than seeds from plants grown in full sunlight (Table 3). August coincides with the time of seed filling which in 1984, was dry with less than 1 cm total rainfall, compared with 15.7 cm in August 1985. Plants growing in full sun in 1984 also produced 16 times more seed than velvetleaf grown under 76% shade. To-

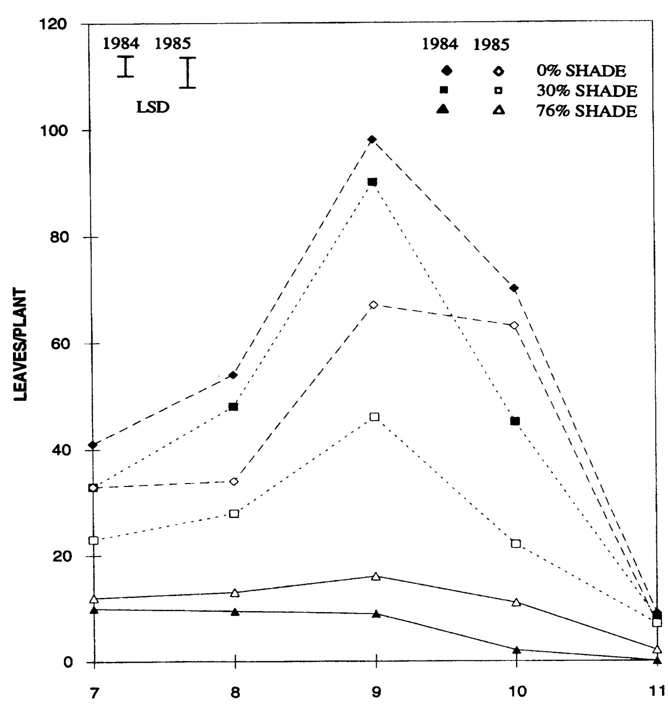

Figure 1. Effect of shade and time on leaf number averaged over all velevetleaf population densities.

Table 3. Effect of shade on reproduction parameters and seed dormancy of velvetleaf.[a]

Shade level	Seed capsules		Seed yield		Seed weight		Seed dormancy	
	1984	1985	1984	1985	1984	1985	1984	1985
%	no./plant				mg		%	
0	250	121	8,000	4,900	80	94	77	78
30	165	70	6,200	2,602	88	98	63	65
76	20	15	500	605	92	100	62	64
LSD (0.05)	35	34	2,408	1,450	11	14	13	12

[a]Data are pooled means of three replications of three velvetleaf population densities.

gether, this would explain the 17% lighter seeds in 1984 than 1985.

Shaded plants produced seed that broke dormancy sooner than seeds produced from plants grown in full sunlight (Table 3). Plants grown in full sunlight produced seeds that were approximately 20% less likely to germinate when subjected to optimal environmental conditions for germination in comparison with shaded plants. This occurred both years suggesting that rainfall during seed filling does not influence seed dormancy. However, it is unclear whether the decrease in seed dormancy when plants were shaded resulted from less seeds with a hard seed coat or if some other dormancy mechanism was responsible.

The results of this investigation demonstrate that increasing shade levels reduces growth and development, seed production, and dormancy of velvetleaf. Shade treatments reduced velvetleaf plant height (1984 only), leaf number, number of branches per plant, and plant dry weight. The decrease in these parameters reduced the number of seed capsules as well as seed yield per plant. This suggests that by utilizing crop production management strategies which enhance early crop canopy development and ground coverage, and provide adequate shade, one can suppress velvetleaf growth and seed production, and shorten the dormancy of seeds that are produced by the plants that emerge late in the season.

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