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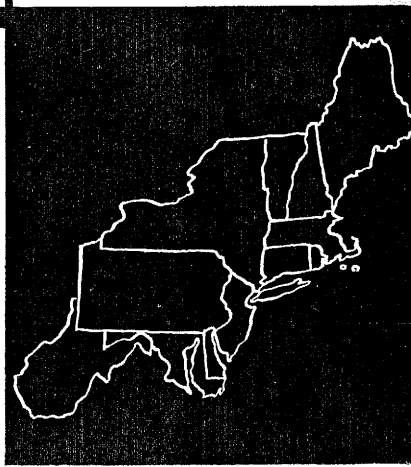
LIFE HISTORY STUDIES AS RELATED TO WEED CONTROL IN THE NORTHEAST

6—Large and Small Crabgrass



NORTHEAST REGIONAL PUBLICATION

STORRS
AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE AND
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THE UNIVERSITY OF CONNECTICUT

This bulletin is one of a series that pertains to life history studies of weeds that are important in the Northeastern states.

This series of bulletins is being published by the Northeast Regional Weed Control Technical Committee (NE-42).

Bulletins previously published pertain to the following weeds: nutgrass (Rhode Island Agr. Expt. Sta. Bul. 364. 1962), quackgrass (Rhode Island Agr. Expt. Sta. Bul. 365. 1962), horse nettle (Rhode Island Agr. Expt. Sta. Bul. 368. 1962), yellow foxtail and giant foxtail (Rhode Island Agr. Expt. Sta. Bul. 369. 1963) and barnyardgrass (Delaware Agr. Expt. Sta. Bul. 368. 1968)

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TABLE OF CONTENTS

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LIFE HISTORY STUDIES AS RELATED TO WEED CONTROL IN THE NORTHEAST

6—Large and Small Crabgrass

INTRODUCTION

Large crabgrass, *Digitaria sanguinalis* (L.) Scop., and small crabgrass, *Digitaria ischaemum* (Schreb) Muhl., are among the most cosmopolitan of the warm season annual weeds. Both species are found in temperate regions of North America, Europe, and South America (Henrard as cited by King and Kramer (7). Large crabgrass is found in the entire latitudinal range of the United States while small crabgrass is found principally in the more northerly areas.

Crabgrass is commonly found in intertilled crops, in new seedings of forage crops, and in turf grass. In the Northeast crabgrass has increased in prevalence due to poor control obtained in corn fields sprayed with atrazine. Since most other annual weed species are controlled, crabgrass is moving into the ecological gap created.

Crabgrass is recognized in many areas to be the most serious of the lawn weeds. Selective control of crabgrass in turf from herbicides has become a standard practice. Reinfestation commonly occurs because of the prolific seed production; thus, yearly use of herbicides is required.

This bulletin presents the results of a study of crabgrass carried out by the Storrs (Conn.) Agricultural Experiment Station. The Maryland and New Hampshire agricultural experiment stations cooperated.

DISTINGUISHING CHARACTERISTICS

The genus *Digitaria* is characterized by one-flowered spikelets, solitary or in two or three in two rows, on one side of a continuous narrow or winged rachis, forming simple racemes. The individual spikelets are one flowered. Of the five species of *Digitaria* listed by Fernald (3), the two most common are

D. ischaemum (Schreb) Muhl. and *D. sanguinalis* (L.) Scop. These species are commonly called small or smooth crabgrass and large or hairy crabgrass, respectively. The average height of *D. ischaemum* is 1 to 16 inches while *D. sanguinalis* is 12 to 48 inches. In *D. ischaemum* the single outer glume of the 1½–2 mm–long spikelet is the same length as the sterile and fertile lemma. The 3–3½ mm–long spikelet of *D. sanguinalis* has a single outer glume only half the length of the sterile and fertile lemma. There is a distinct difference between species in the color of the fertile lemma. The fertile lemma is gray on *D. sanguinalis* and black on *D. ischaemum.*

The various parts of the spikelets of small and large crabgrass are shown in Figure 1.

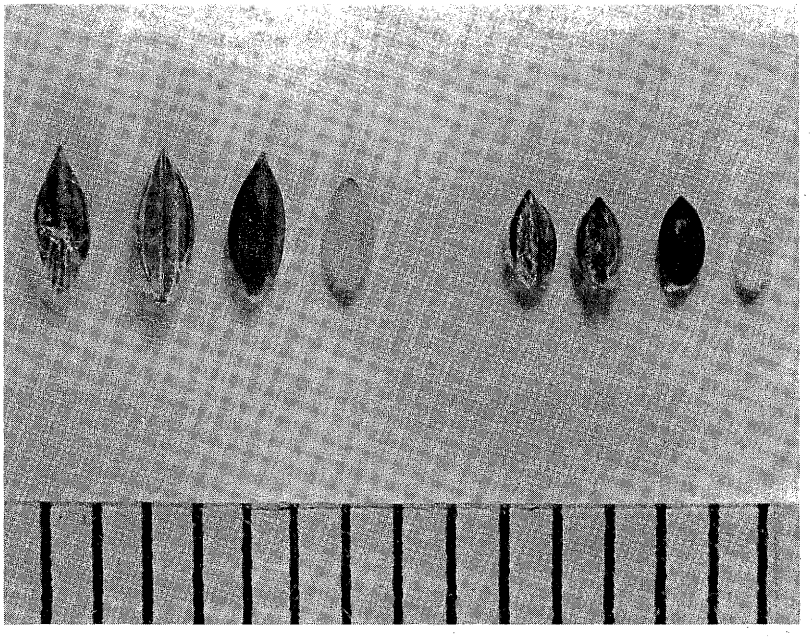

Figure 1. Spikelet characteristics of large and small crabgrass. Left group–large crabgrass; Right group–small crabgrass. Left–intact spikelet showing outer glumes; left center–infertile lemma; right center; flowering lemma; right–caryopsis. Scale is in mm.

MORPHOLOGICAL DEVELOPMENT

The morphological development of crabgrass was studied by Peters (9) at Storrs in the field and in growth chambers.

Vegetative development

Procedure Crabgrass plants volunteering on plots at the Agronomy Research Farm at Storrs were individually marked in the 1962 season and measurements were periodically made, over an 11-week period, of tiller number and time of flowering. A circular area of at least 1 foot in diameter was provided for each plant by removing adjacent plants as needed. Two populations were marked—an early population germinating in May and a late population germinating about one month later.

A spaced plant nursery was established in 1963 by seeding in the field. After emergence, plants of both species were spaced in rows 6 inches and 36 inches apart. Periodic measurements were made of the number of tillers and lateral spread of 16 plants.

Results and Discussion The morphological distinction between the two crabgrass species is apparent soon after emergence. Large crabgrass is a darker

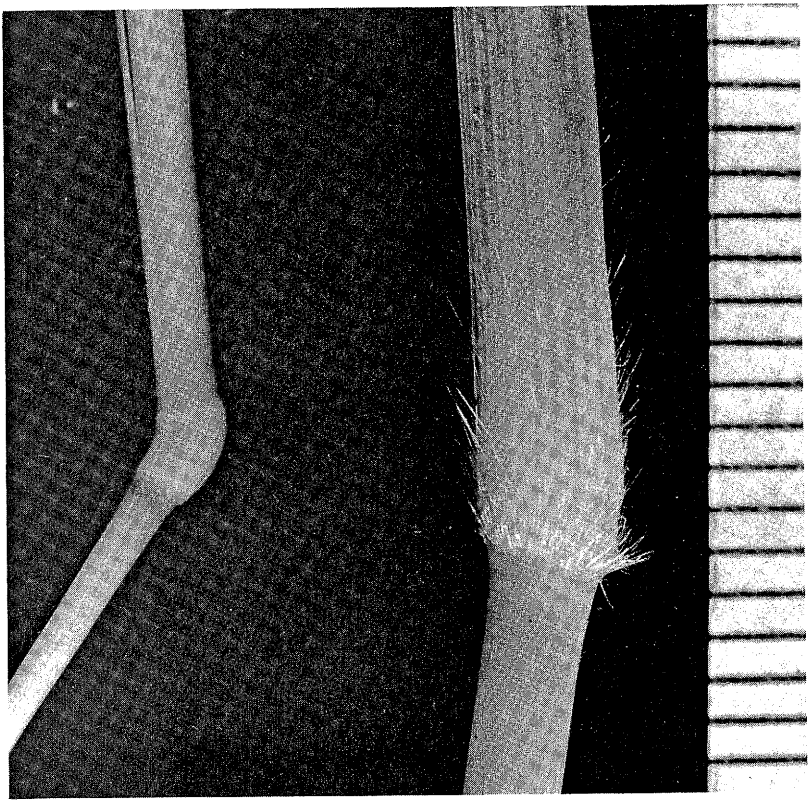

Figure 2. Sheath characteristics of crabgrass. Left, glabrous sheath of small crabgrass; right, pubescent sheath of large crabgrass.

green in color and has a broader seedling leaf (4 mm) compared to small crabgrass (2 mm).

Most large crabgrass plants display pubescence on the sheath (Figure 2) but this trait is consistently absent in small crabgrass. Pubescence is not consistently found on large crabgrass, however, except at the collar area. Figure 3 shows a large crabgrass plant which is entirely lacking pubescence except at the collar, contrasted with the completely glabrous small crabgrass.

Because of the degree of variability found in *D. sanguinalis*, the common names hairy and smooth crabgrass, sometimes ascribed to *D. sanguinalis* and *D. ischaemum*, respectively, is one of dubious distinction. The names large and small crabgrass for *D. sanguinalis* and *D. ischaemum*, respectively, has validity because if both species are grown in comparable environments the former has consistently larger stems, leaves, inflorescences and seeds as shown by Figures 2, 3, 4 and 5. Large crabgrass is further distinguished from small crabgrass by a more upright habit of growth as shown in Figure 6.

Figure 3. Collar characteristics of crabgrass. Left, pubescence on large crabgrass; right, glabrous collar of smooth crabgrass.

TABLE 1. Tiller formation and blooming of crabgrass as influenced by time of field germination, expressed in number of tillers per plant.

Time of Germ.	Date of Measurement								
	6/17	7/18	7/20	7/27	8/3	8/12	8/19	8/27	9/10
					Large Crabgrass				
Early (May)	3	29	64	111*	168	298	327	431	519
Late (June)			6	11	20	48*	81	144	333
					Small Crabgrass				
Early (May)	3	31	70	111	118*	361	406	430	460
Late (June)			3	7	16	42	74	136*	279

*First bloom

After the fourth leaf stage of either species is reached, further increase in size is principally by means of tillering. Multiple tillering best describes the growth habit of crabgrass (Figure 7). Tiller counts recorded periodically during the growing season are given in Tables 1 and 2. The rate of tiller formation followed a sigmoid curve. There were no marked overall differences between the two species in the number of tillers produced. The

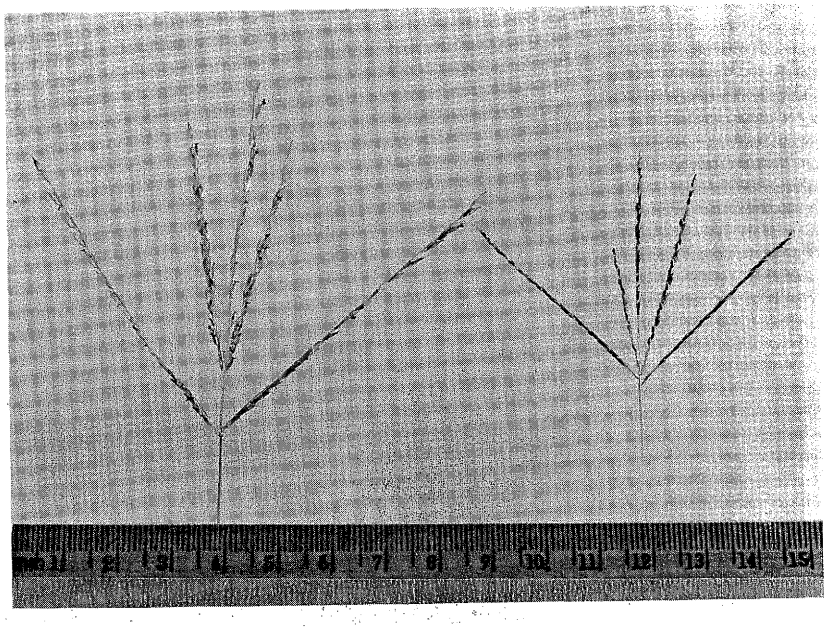

Figure 4. Inflorescences of crabgrass. Left, large crabgrass; right, small crabgrass. Scale is in mm.

larger size of individual plants of large crabgrass was related more to the longer internodes and leaf blades than to differences in total number of tillers.

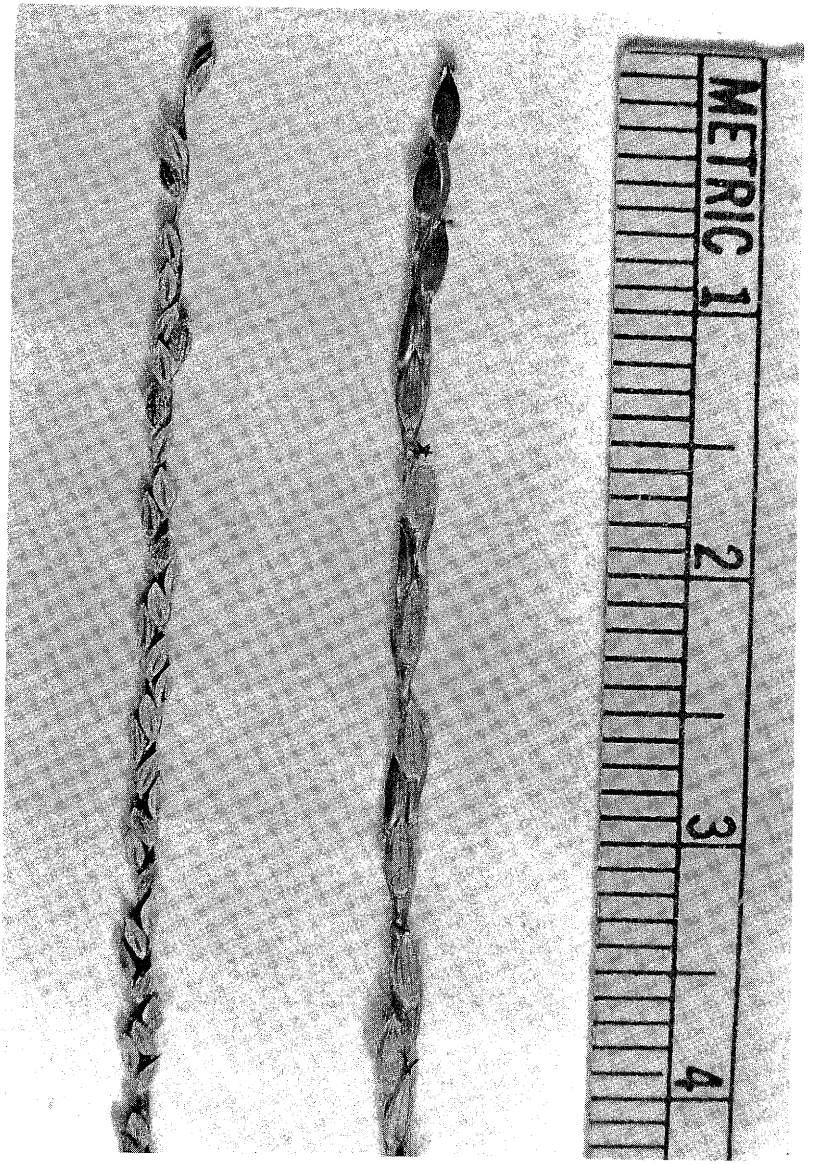

Figure 5. Single rachis of crabgrass. Left, small crabgrass; right, large crabgrass. Scale is in mm.

TABLE 2. Number of tillers produced by spaced crabgrass plants. Seeded May 27.

Spacing	Date of Measurement						
	6/24	7/1	7/15	7/29	8/13	8/29	9/5
				Large Crabgrass			
6 inches	3	8	24	60	60	60	60
36 inches	3	8	36	168	396	635	688
				Small Crabgrass			
6 inches	2	7	33	172	198	227	
36 inches	2	7	38	222	455	791	791

As shown by Table 1, the rate of formation as well as number of tillers formed was greater on the early (May) than in the late germinating plants (June). Numerous field observations of plants germinating in late summer disclosed that only a few score tillers were formed compared to the several hundred produced by spring germinating plants. It was also noted as the season progressed that newly-formed tillers had progressively shorter internodes. The data indicates that tiller formation is conditioned by photoperiod with the most rapid rate of formation occurring during the long days of late spring. Growth is severely restricted in the shortening days of late summer even under favorable temperature and moisture conditions.

Spacing between plants had a marked influence on tiller number. As shown in Table 2, after large crabgrass had reached an average of 60 tillers per plant at the 6 inch spacing, no further increase occurred. Small crabgrass was less restricted by the close spacing, but both the rate of increase and the total number of tillers was markedly less with the 6 inch spacing as compared to the 36 inch spacing.

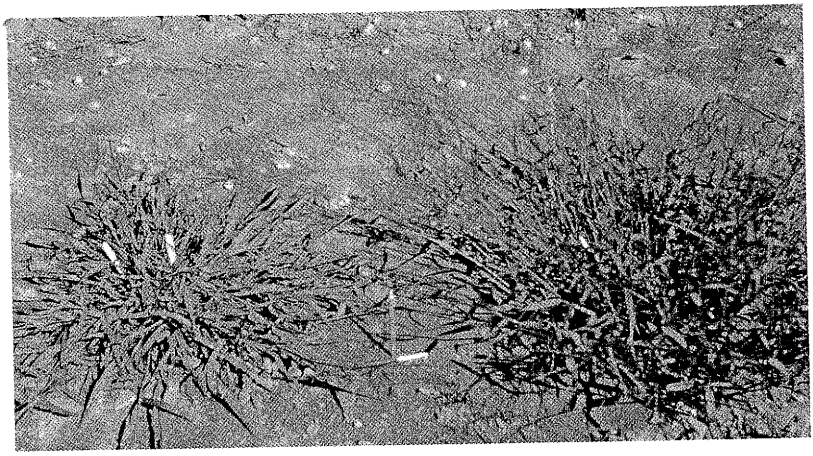

Figure 6. Growth habit of small and large crabgrass; left and right, respectively.

TABLE 3. Lateral spread as measured by diameter in inches of spaced crabgrass plants. Seeded May 27.

Spacing	Date of Measurement				
	6/24	7/1	7/15	7/29	8/13
			Large Crabgrass		
6 inches	3	8	34	40	42
36 inches	3	7	23	70	76
			Small Crabgrass		
6 inches	2	7	17	33	39
36 inches	2	6	15	47	56

Another measure of development, the lateral spread or sprawl of individual plants, was also influenced by spacing. As shown by Table 3, there

Figure 7. Multiple tillering pattern of large crabgrass.

was overlapping of plants but the diameter of the plants at the 36 inch spacing was half again as great as the plants spaced 6 inches apart.

The data clearly show that initial stand has little influence on the ultimate ground cover of crabgrass realized. The sprawling habit combined with the prolific tillering capacity of both crabgrass species may result in a complete ground cover from only two or three surviving plants per square yard.

Effect of Temperatures on Crabgrass Development

Procedure Large crabgrass was grown in a growth chamber for 8 weeks at two photoperiods; 10 hours and 18 hours of light. The temperature was 80°F during the light period and 70°F during the dark period.

Results and Discussion As shown in Figure 8, the long photoperiod fostered vegetative growth. The short photoperiod which promoted flowering severely restricted further vegetative growth.

Figure 8. Effect of photoperiod on development of large crabgrass. Left, 10-hour light period; right, 18-hour light period. The temperature was 80°F during the light period and 70°F during the dark period.

Effect of Shading

Procedure Varying degrees of shading were obtained in the field and in growth chambers by using frames covered with saran cloth of differing size mesh which reduced light intensity 30% or 63%, respectively.

Results and Discussion When established plants in the field were shaded on July 18, vegetative growth in the shade was paler and spindlier than in plants without shade but there was no reduction in total dry matter due to shading nor was seed formation significantly altered.

In the growth chamber experiment, however, where the maximum light intensity was only 3000 foot candles, there was a marked reduction in dry matter reduction when plants were shaded.

TABLE 4. Effect of shading on dry weight of crabgrass grown in a growth chamber.

Species	No shade gm. dry wt.[1]	30% shade gm. dry wt.[1]	60% shade gm. dry wt.[1]
Large crabgrass	9.1	6.9	1.0
Small crabgrass	7.3	3.3	0.5

[1] Mean of 3 pots

As indicated in Table 4 there was a dry matter reduction at 30% and 60% shading of 25% and 90%, respectively, for large crabgrass and 60% and 94%, respectively, for small crabgrass. Small crabgrass was the more sensitive of the two species, which may be a factor in the lesser incidence of this species in cornfields.

The variation in results between the field and the growth chamber can be related to the marginal light intensities in the growth chamber.

Light can obviously be a factor in the growth of crabgrass in cornfields as shown by the much ranker grass growth on the field margins compared to growth away from the edges. In fact, once a canopy of corn closes over the ground, crabgrass growth becomes very restricted. Closer row spacing and higher corn plant populations are cultural practices which will reduce competition from crabgrass by hastening the time when the canopy shades the ground.

Stem Rooting

Procedure To determine the importance of stem rooting in perpetuating large crabgrass under field conditions, established crabgrass plants were partially covered with soil in the field and stem cuttings were sprigged into vermiculite in cups in the greenhouse.

Results and Discussion If intact tillers in the field were partially covered, adventitious roots formed at the nodes with rooting most frequently occurring at the basal node. If the tillers were completely covered with soil, many emerged at the tips and continued to develop normally. Other culms, when buried, decayed, especially if covered with moist soil.

If stem cuttings were placed in moist vermiculite, with or without removal of the growing point, rooting occurred readily at the nodes. Most of the cuttings with the growing point removed readily regenerated from lateral buds. Rooting occurred most readily at the basal node but other nodes sometimes rooted as well.

The readiness with which large crabgrass rooted at the nodes when the culms are covered explains why cultivation is frequently ineffective in controlling crabgrass in cornfields.

Effect of Seed Origin on Development

Procedure Seed of both crabgrass species obtained from Maryland were planted on June 24 at Storrs in a spaced nursery along with seed collected at Storrs.

Results and Discussion Heading and seed formation was later in the season for both species of crabgrass obtained from Maryland than in the Connecticut derived biotypes. Heading of large crabgrass occurred on August 14 for the Connecticut biotype and on September 3 for the Maryland biotype. Small crabgrass from Connecticut headed on September 3 while the Maryland biotype headed on September 13.

The delayed flowering of the Maryland biotype can be associated with the seasonal delay in the onset of shorter days required to induce flowering in the more southerly latitude of Maryland. This, plus the greater frost resistance of the plants grown from Connecticut seed, indicates a geographical adaptation.

Flower Formation and Seed Production

Procedure Periodic observations of volunteer and seeded crabgrass stands in the field at Storrs were recorded. The influence of photoperiod was studied under controlled light conditions in a growth chamber.

Results and Discussion The number of inflorescences produced by crabgrass plants was directly related to the number of tillers formed since the trend is for each tiller to produce a single digitate raceme.

Once blooming started, 40 to 50 days after a mid-May germination, seed heads continued to appear as tillers formed up to the time of frost.

Flower formation started approximately one week sooner in large crabgrass than in small crabgrass on plants germinating in May.

As shown in Table 1, plants which did not start growing until June started to bloom while much younger than the plants starting in May. The late germinating plants, of both species, started growth one month later than the early germinating plants. There was only a 2-week delay in time of flowering of large crabgrass and a 3-week delay of flowering in small crabgrass. One could readily observe plants in the field which germinated in August which started to flower when only a few inches in size.

Short-day photoperiodic control of floral initiation is clearly indicated by the above observations. The influence of photoperiod was confirmed by growing crabgrass plants in controlled environment growth chambers. As shown in Figure 8, the plants grown in 18 hours of light and 6 hours of dark daily for 8 weeks were still in a vegetative stage, while those grown in 10 hours of light and 14 hours of dark had produced several inflorescences.

Individual counts were made of the number of seeds produced per raceme. Large crabgrass plants which were not crowded (36 in spacing) averaged 200 seeds while small crabgrass averaged 170. In extrapolating this number by multiplying by the average number of tillers produced per plant in a spaced nursery, it was found that small crabgrass had a potential seed production of 188,000 per plant and large crabgrass of 154,000 per plant. Shattered seed was collected on plastic placed under field grown plants and the number determined by counting a weighed subsample. Up to 210,000 seeds (93 grams) per plant were produced by individual small crabgrass plants and 145,000 seeds (85 grams) by individual large crabgrass plants.

Under normal field conditions where plants are crowded, fewer total seeds will be produced per plant. The total production per unit area obviously will be of a large order of magnitude.

Since crabgrass seed can remain dormant in the soil for many years, crabgrass can be expected as an abundant weed for several years following a year of heavy crabgrass infestation if the heavy stand is allowed to go to seed.

FIELD GERMINATION OF CRABGRASS

Time of Germination

Procedure Germination was observed in the field at Storrs over a 3-year period in cornfields where crabgrass had self-seeded the previous season.

Results and Discussion Crabgrass seed displayed a pronounced primary dormancy, i.e., no germination occurred during the year the seed was produced. This confirms the reports of Toole and Toole (17) and Gianfagna and Pridham (4). By the following spring primary dormancy was greatly reduced as evidenced by a flush of emergence at the onset of warm weather.

Phenological observations at Storrs over a 3-year period showed a correlation between emergence of crabgrass on bare soil and the time of blooming of the common lilac *(Syringa vulgaris L.)*. First emergence was recorded on May 11, May 12, and May 23 in 1964, 1965, and 1966, respectively. King and Kramer (7) found that germination in the vicinity of New York, N. Y., occurred between flower withering of *Forsythia spp.* and the beginning of the flowering of dogwood *(Cornus florida)*. Gianfagna and Pridham (4) reported that crabgrass started germinating about May 25 at Ithaca, N. Y.

Since soil under sod warms more slowly than bare soil, germination in sod is delayed.

Influence of Seed Depth on Emergence

Procedure Seed was planted in field soil in No. 10 cans at specified depths.

Results and Discussion When seeded in pots in the greenhouse seedlings of both species of crabgrass germinated readily from the 2-inch soil depth (Table 5).

TABLE 5. Effect of depth of seeding on emergence of crabgrass.

Depth of Seed (inches)	Percentage of Emergence	
	Large Crabgrass	Small Crabgrass
0.5	38	73
1.0	35	66
1.5	31	73
2.0	35	30
2.5	28	10
3.0	14	0

In the seed lots involved, small crabgrass germinated more readily near the surface than did large crabgrass. However, as the seed depth increased, large crabgrass emergence was greater than for small crabgrass. At the lowest depth of 3 inches, only large crabgrass emerged.

In a similar experiment seeds of neither species placed at the 4-inch depth germinated. In contrast, emergence of yellow foxtail *(Setaria lutescens)* emerged as readily from the 4-inch depth as from the 2-inch depth.

Field Germination as Influenced by Soil Cover

Procedure In an area with a heavy mulch of dead crabgrass plants from the previous season, plots were established with treatments as specified in Table 6. The black plastic and saran cloth frames were placed over bare soil prior to germination of the crabgrass.

Results and Discussion Stand counts, height and dry matter production are given in Table 6.

TABLE 6. Effect of soil cover on germination and growth of small crabgrass.

Treatments	Plants per sq. ft. June 28	Av. ht. in. August 5	Dry wt. gm. August 5
Bare soil	112	5	18
Dead mat	0	–	–
Black plastic	71	–	–
Saran I[1]	192	9	19
Saran II[2]	233	14	19

[1]30% shading
[2]60% shading

Exclusion of light *per se* did not prevent germination, since some occurred under the black plastic. The plants which did germinate were dead within a week. The failure of germination under the dead mat of the previous year's crabgrass stand was clearly related to lower soil temperatures under the mat than under the black plastic. The greater germination under the Saran cloth was due to more favorable moisture conditions than in the bare soil. The height of the crabgrass was inversely correlated with the amount of light. The growth became spindly and etiolated as shading increased. There were no differences in dry matter, despite a three-fold difference in height.

Comparable trends were obtained with large crabgrass in a separate experiment.

INFLUENCE OF LIGHT QUALITY ON GROWTH OF CRABGRASS

Procedure This work was done by H. L. Cilley and Stuart Dunn in the facilities at the University of New Hampshire previously described by Cilley (1).

Plants received 16 hours of light, alternating with 8 hours of darkness daily. Temperature was 70° F during the light period and 60° for darkness. Two 96-inch Sylvania Very High Output (VHO) fluorescent lamps were used for each treatment: cool white, red, and blue light. By adjusting the distance of the lamps above the plants the intensity of light quality was set at 700 microwatts per square centimeter (uw/cm^2) for plant level at the start. Intensity was measured with an Eppley thermopile. The more rapidly growing plants soon received more light than the others. An attempt was made to compensate for this by adjustment of the lamp distance from the plants at intervals of time.

Seeds were germinated on filter paper moistened with 0.2% KNO_3 solution. After 7 days, seedlings were transplanted to 1½-pint polyethylene boxes filled with moist vermiculite, three plants per box. At this time 12

boxes of plants were placed under each of the three colors of light. At 14 days the plants were thinned to one vigorous plant per box, and allowed to remain under the lights until the end of the experiment, at maturity. The plants were supplied with a standard nutrient solution at weekly intervals.

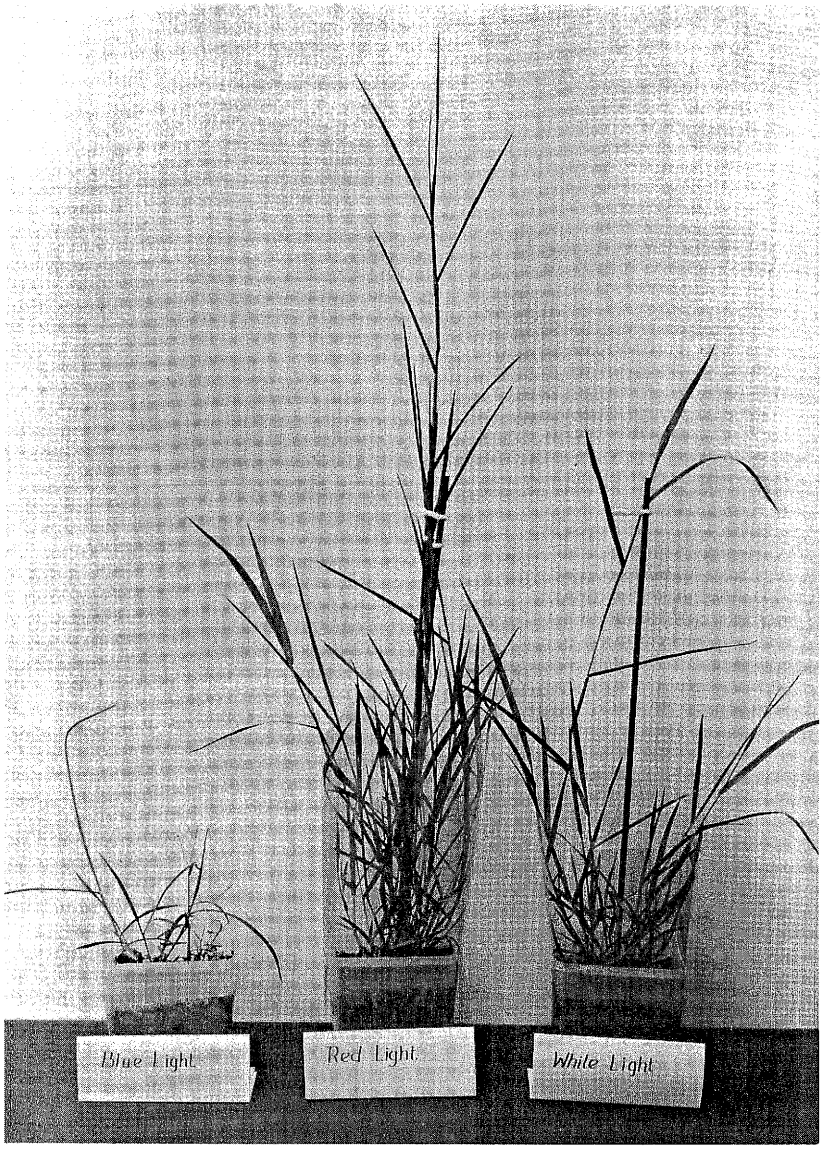

Figure 9. Crabgrass plants grown under different lights for 75 days.

Formation of flowers and seeds (or fruits) was regarded as indication of the successful completion of the plants' life cycle under any set of conditions. Flowering dates were recorded under the different light qualities and the effects of the lights on yields were measured by harvesting the plant tops and recording their fresh and dry weights. Other measurements were taken at harvest time, in an effort to find criteria other than dry weight for measuring development of the plants, which could be obtained without sacrificing the plant. These are listed in Table 7. Analysis of variance was calculated for each set of data.

Results and Discussion Flowering under blue light was much earlier than under red or white light. With blue light, flowers were first observed 62 days after starting the seeds in petri dishes. Other plants in blue light flowered in rapid succession until all were in flower by 88 days. First flowers were seen under red light at 102 days. All plants in both red and white light flowered and produced seed before the plants were harvested at 180 days.

TABLE 7. Comparative measurements of crabgrass plants grown under fluorescent lamps.

Type of Measurement	Unit Used	Mean values for light qualities		
		White	Red	Blue
Diameter 1 cm. below fourth node	mm.	.94	1.03	.79**[1]
Length of main stem	cm.	77.55	83.45	32.13**
Length of fourth internode	cm.	7.64	7.24	3.40**
Number of spikes per branch	—	4.27	4.34	2.82**
Length of spikes	cm.	8.23	7.79	6.22**
Number of branches per stem	—	3.13	2.74	3.10[ns]
Fresh weight	gm.	14.54	10.45	5.08**
Dry weight	gm.	5.76	5.08	1.83**

**indicates significance at the 1% level

[ns]not significant, this amount of difference could have been due to chance alone

[1] F values are for a significant difference for blue, as compared with red and white.

Size of plants was much smaller in blue light (Figure 9), as contrasted with white light plants and red light plants. All measurements except number of branches per stem were statistically smaller than under either white or red light (Table 7).

Blue light appears to be adverse to the growth and development of the plants tested. This stress on the physiology of the plant might cause earlier flowering, which in turn could result in greater survival of the species. Small samples of seed from each group of plants grown under the lights were tested for germination and found to be viable.

In general, the other measurements taken on the plants followed this same pattern of small size for blue light plants compared to those under the other light colors (Table 7). Diameter of the fourth internode was measured one centimeter below the fourth node and averaged about 20% less for blue light plants than those under red or white light. Length of the fourth internode and the number of spikes per branch each were approximately 50% less for plants in blue light than for either of the other two lights. Spike length was about 25% less under blue light. Although significantly smaller in this respect, the blue light plants produced enough viable seed to insure survival of the species.

Fresh and dry weights are standard measurements for plant yields, while dry weight can be regarded as a reliable indication of net photosynthesis. However, such procedures require sacrifice of the plant and termination of any work with that individual. Fresh weight for plants in blue light averaged about 50% less than for the other two lights, while dry weight yields for blue light averaged only about 33% of the yields for the plants under red and white light. Only for fresh and dry weight yields were the values for plants under white light greater than those for red light; for all other measurements the reverse was true.

Analysis of variance showed a highly significant difference between values for blue light and those for either of the other two light qualities, for every measurement except the number of branches per stem, but no significant difference between the red and white light plants, except in fresh weight (Table 7). There the white light plants were significantly greater in weight at the 5% level than were the red light plants. General appearance of the plants under red light was better than those grown under either of the other lights (Figure 9).

COMPETITION BETWEEN LARGE CRABGRASS AND ALFALFA AS INFLUENCED BY NUTRIENT LEVELS OF P AND K

Keeley (5) and Keeley and Peters (6) studied the influence of phosphorus and potash levels in nutrient solutions on growth of crabgrass and alfalfa alone and grown together in association.

Procedure Experiments were conducted in the greenhouse at the Agronomy Farm at Storrs during the months of January through June, 1964. Supplemental light was used giving a day-length of 16 hours. Duration of each experiment was 25 ± 3 days. Plants were grown in 2-liter polyethylene vessels containing ½-strength Hoagland No. 1 nutrient solution, aerated constantly and changed every few days to maintain a nearly constant nutrient ion level. Each vessel contained four plants of either large crabgrass or alfalfa *(Medicago sativa)* or a combination of two of each species per vessel when grown in association. The seedlings were 7 weeks old when placed in the vessels. The K levels were either 15 or 118 ppm while the P levels ranged from .75 to 1.5 ppm at the low level to 3.9 to 20 ppm at the high level depending upon the particular experiment. At harvest dry matter of both the roots and shoots were determined. Levels of P in the tissue were determined with the metavanadate method. The K was determined by a flame photometer.

The efficiency (in terms of removal of P and K from nutrient solutions as expressed in amounts per gram of plant tissue) was determined in 5 to 7-week-old seedlings of both species at two nutrient levels. The nutrient level was determined in the solution at the beginning and end of the 24 hour experimental period and the plants harvested at the end to determine dry weights.

Results and Discussion Figure 10 gives the response of crabgrass and alfalfa based on the combined means of three experiments. When large crabgrass was grown in association, there was an increase in yields regardless of P or K levels. This increase must be associated at least in part to less interspecific competition as the number of crabgrass plants per vessel was reduced from four to two.

The crabgrass yields were very responsive to P and K levels growing either alone or in association. If either or both P and K were at the lower level, yields were depressed by more than half. Alfalfa was influenced relatively little by the P and K level.

The percentage of P and K remained the same when grown alone or in association except for some depression of K when both P and K were low.

Dry matter yields of crabgrass were greater than for alfalfa, approaching four times as much in some experiments. If alfalfa and crabgrass were grown in association, the alfalfa yields were depressed over alfalfa alone only if the P level was at the low level. There was an accompanying depression in percent P in the alfalfa plant tissue. There was no decrease associated with K levels when the two species were grown together. While there was a decrease in percent P and percent K in alfalfa tissue at the lower level of these elements, it was not reflected in the yields.

A minimum percentage for P required for maintenance of normal growth was established for alfalfa at 0.13–0.14% and for large crabgrass 0.18–0.23%. A similar minimum was not established for K but a level for K

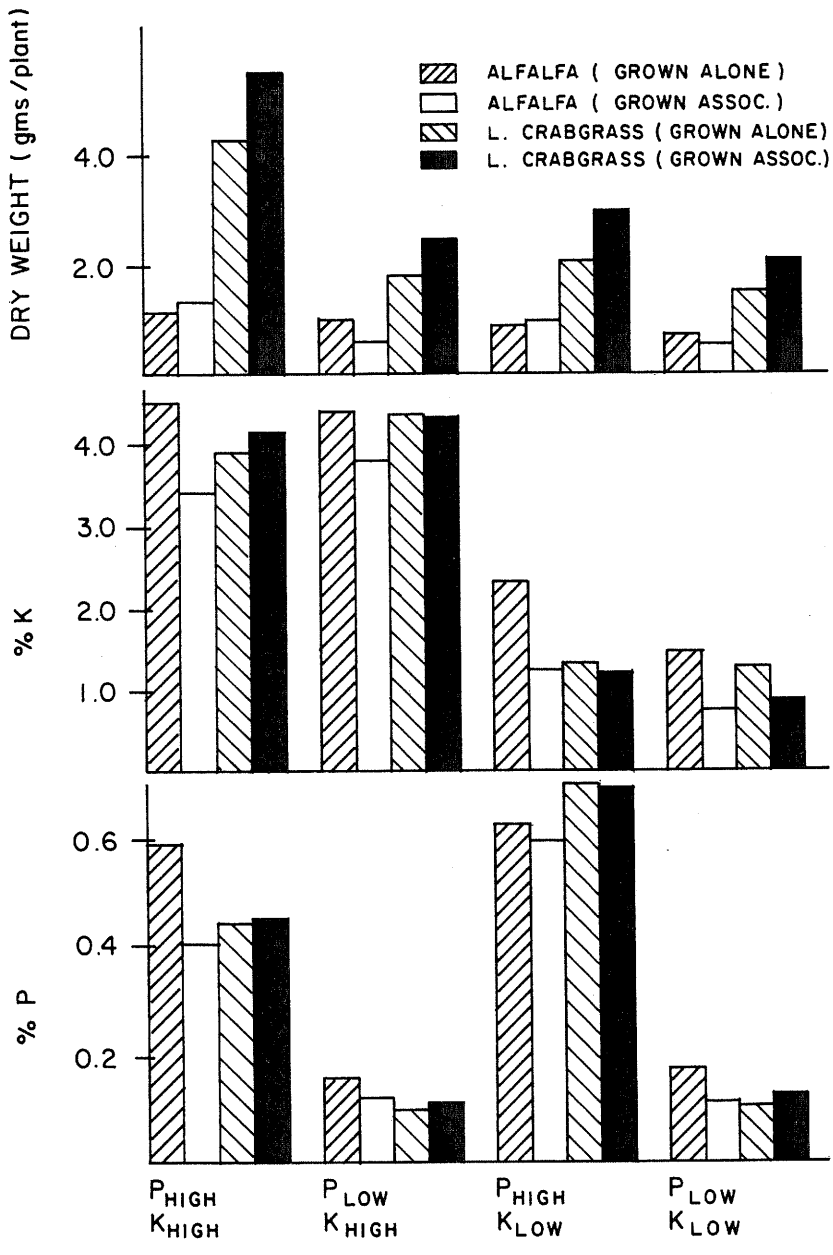

Figure 10. Effect of P and K levels on yield, percent P and K of large crabgrass and alfalfa. Based on combined means of three experiments.

of 1.91–1.41% was accompanied by a reduction in dry matter yield.

The apparent competitiveness for P of large crabgrass grown with alfalfa cannot be explained in the basis of efficiency of P removal (Table 8). While more P was absorbed at the high P level than at the low level, at a particular level there was no difference in uptake between species per unit weight. The rapid growth rate and large root absorbing surface of large crabgrass was the principal factor in decrease in crabgrass yields at lower nutrient levels and for the apparent competition with alfalfa for P at the low P level.

TABLE 8. The effect of nutrient level and plant age on the efficiency of phosphorus and potassium removal by alfalfa and large crabgrass.

Treatment		Uptake (meq/g total plant)			
Species	Level	Week 1	Week 2	Week 3	$\bar{X}$
			P Uptake		
Alfalfa	P–high	0.046	0.052	0.026	0.041
L. Crabgrass	P–high	0.057	0.036	0.017	0.037
Alfalfa	P–low	0.015	0.022	–	0.019
L. Crabgrass	P–low	0.023	0.011	–	0.017
			K Uptake		
Alfalfa	K–high	0.155	0.026	0.044	0.075
L. Crabgrass	K–high	0.116	0.079	0.026	0.073
Alfalfa	K–low	0.009	0.004	–	0.007
L. Crabgrass	K–low	0.083	0.084	–	0.084

Crabgrass was no more efficient than alfalfa in removing K from the nutrient solution when the K level was high but was 10 times more efficient when K levels were low. Even though large crabgrass did not critically compete with alfalfa for K under the levels of this experiment, levels of K may occur when alfalfa would be unfavorably affected in association with crabgrass.

Vengris et al. (18) have reported a higher level of P, K, N, Ca and Mg in crabgrass than in corn tissues. They found 3.49% K in crabgrass as compared with 1.19% in corn.

TOLERANCE OF CRABGRASS TO ATRAZINE

When atrazine first became widely used on farms in the late 1950's, its use resulted in corn fields nearly free of annual broad-leaf and annual weeds. Weed control was so adequate that in New England, at least, most farmers stopped cultivation entirely. After a few years, however, it became apparent that crabgrass was increasing in incidence, especially on farms growing continuous corn receiving atrazine applications yearly. This problem has been detailed by Peters (8, 13). A report was also received from France indicating

that crabgrass has been difficult to control in that country (Longchamp, personal communication). It was apparent that crabgrass had been a minor species in the annual weed spectrum long associated with corn in southern New England. Once released from the competition of annual broadleaf weeds and other annual grasses, crabgrass proliferated. There has been no indication that mutant biotypes with resistance to atrazine have developed. Firstly, the time span has been too short and, secondly, several experiments have shown that crabgrass has an inherent resistance to atrazine.

Many field applications of atrazine have depressed crabgrass sufficiently to prevent it from being seriously competitive to corn but the incomplete control obtained leads, through tillering of the remaining plants, to a seed set which intensifies the problem each successive year.

Variation in Activity of Atrazine on Annual Grass Species Applied on Seed.

Procedure Seed of four grass species were planted in a Paxton fine sandy loam soil in pint polyethylene cups. Atrazine at rates of 0, 1, and 2 pounds active ingredient, was sprayed in 40 gallons of water per acre directly on the seed before covering with 1/4 inch of soil. The cups were placed in a growth chamber at 70-80° F cycle with a 16-hour day and grown for 35 days.

TABLE 9. Influence of atrazine on emergence and eventual kill of four annual grasses.

Grass species	Rate of Atrazine lb. ai/A								
	0			1			2		
	% Emerg.	Ht. cm.	%[1] Kill	% Emerg.	Ht. cm.	%[1] Kill	% Emerg.	Ht. cm.	%[1] Kill
Large Crabgrass	65	12	0	52	23	0	59	17	0
Small Crabgrass	81	12	0	53	13	0	59	13	0
Yellow Foxtail	95	16	0	0	—	100	0	—	100
Barnyardgrass	84	19	0	45	10	1	23	6	10

[1] Mortality of emerged plants after 35 days of growth

Results and Discussion As indicated by Table 9 no emergence of yellow foxtail occurred. Barnyardgrass emergence was reduced by one-half but there was only a small reduction in emergence of the crabgrasses. There was no mortality of crabgrass after emergence nor was there an effect on the height of small crabgrass. The greater height of large crabgrass with treatment was associated with a more spindly growth. Barnyardgrass was reduced in both height and percent survival in proportion to the rate of atrazine.

In summarizing, the order of susceptibility to atrazine was yellow foxtail, barnyardgrass and crabgrass with a rate of 4 pounds having relatively little effect on the latter.

Influence of Stage of Growth on Crabgrass Control

Procedure Field applications of atrazine were made in silage corn fields in several years and reported by Peters and Keely (14), Peters (10) and Peters and O'Leary (16).

Results and Discussion A summary of results are given in Table 10.

TABLE 10. Effect of post-emergence applications of atrazine on control of crabgrass.

Year	Date of Application	Stage of Growth	Control Ratings[1]	Stand Counts per sq. ft.		Dry Matter Yield T/A	
				CK	Atrazine	CK	Atrazine
1962	June 11	Pre-emergence	6.7	–	–	–	–
1962	July 6	1-2 in., 2-4 tillers	2.0	–	–	–	–
1964	June 23	½-2 in., tillering	3.0	16.7	12.9	–	–
1965[2]	June 14	4 in.	0.0	–	–	1.0	1.2

[1] 0—No control, 10—complete control

[2] 1 gal. per A of non-phytotoxic weed oil with 39 gal. H_2O/A used as diluent

Control of crabgrass was very limited at the 1-inch size. Since growers generally are unaware of plants smaller than this, applications of atrazine are seldom applied early enough to be effective. By the time the crabgrass had reached 4 inches in height there was no effect on the crabgrass even when non-phytotoxic oil was included.

Grass Response to Atrazine in Nutrient Solutions

Procedure To eliminate the influence of soil on the availability of atrazine to plants, large crabgrass and yellow foxtail were grown in ½-strength Hoagland's solution to which atrazine was added. Atrazine was added to the nutrient solutions when the foxtail averaged 4.5 inches and the crabgrass 3-4 inches tall. Concentrations of atrazine were ½, 1, 2, 4, and 8 ppm for crabgrass and ½, 1, 2, and 4 for the foxtail. Within 2-½ weeks the yellow foxtail was killed by all atrazine concentrations but the crabgrass showed no effect except at 8 ppm, which caused some chlorosis and wilting.

In another experiment, seedlings of alfalfa and large and small crabgrass were grown in quartz sand, transplanted to the nutrient solution and allowed to become well established. Atrazine was added to give concentrations of 0,

1, 5, and 10 ppm of active material when the large crabgrass was 12 inches, the small crabgrass 14 inches, and the alfalfa 7 inches tall. After 26 days the plants were harvested, oven dried, and analyzed for atrazine residues by Geigy Agricultural Chemicals.

TABLE 11. Growth of crabgrass and alfalfa in nutrient solutions containing atrazine.[1]

Atrazine concentration (ppm)	Height in Inches			Total dry wt. (gm. - av. per pot)					
	Large Crabgrass	Small Crabgrass	Alfalfa	Large Crabgrass		Small Crabgrass		Alfalfa	
				Tops	Roots	Tops	Roots	Tops	Roots
0	45	50	23	9	4	7	4	6	1
1	30	42	9	7	6	10	5	1	1
5	33	42	9	4	3	6	2	1	–
10	25	38	12	2	2	7	3	1	1

[1] Data taken 27 days after addition of atrazine.

Both crabgrasses displayed much more resistance to the atrazine than did alfalfa. Small crabgrass was the most resistant of the two grasses.

Chemical analysis made to determine the atrazine content of the three species are given in Table 12.

TABLE 12. Atrazine residues in plant tissues after growth in nutrient solutions containing atrazine.

Treatment ppm	Residue in ppm[1]				
	Large Crabgrass		Small Crabgrass		Alfalfa
	Tops	Roots	Tops	Roots	Tops
0	<.10	<.10	<.20	<.20	<1.00
1	.16	.20	.10	.20	–
5	.35	.50	.17	.97	9.5
10	2.10	1.80	.46	1.20	17.0

[1] Analyses were performed by the Geigy Chemical Company, Ardsley, New York.

The order of species resistance was the inverse of the atrazine content in the tissues at harvest. Alfalfa had a much higher atrazine concentration than did the two crabgrasses, while large crabgrass contained more residue than the very resistant small crabgrass. The low atrazine content can be explained by either a reduced atrazine uptake from solution or by metabolism of the atrazine within the plant tissue after absorption, resulting in a breakdown of the atrazine molecule.

EVALUATION OF SEVERAL HERBICIDES FOR CONTROL OF CRABGRASS IN CORN

Since atrazine has proven to give limited control of crabgrass, a number of experiments were carried out at Storrs to find herbicides or mixtures of herbicides which would give crabgrass control as well as control of other annual grasses and broadleaf weeds. Since atrazine residues sometimes cause injury to crops planted after corn (Peters, 13), there also has been concern in finding effective herbicides with shorter soil residual properties. This work has been detailed by Colby and Harris (2), Peters and Keeley (14, 15), Peters and O'Leary (16), and Peters et al. (10, 11, 12).

Procedure The evaluation experiments were carried out at Storrs at the Agronomy Research Farm on a Paxton fine sandy loam on naturally occurring infestations of crabgrass. Large crabgrass was the dominant species but small crabgrass was also present in lesser amounts.

Results and Discussion Data from two experiments comparing other herbicides with atrazine are given in Tables 13 (Peters, 10) and 14 (Peters, 11).

TABLE 13. 1964 comparisons of atrazine and other herbicides on crabgrass and corn yields.

Chemical	Rate lb./A ai or ae	Stand ratings[1] 7/19/64	Stand counts per sq. ft. 7/8/64	Corn silage T/A 25% dry matter
Control		0	16.7	7.0
2,4-D LV ester	1	5.3	14.4	18.8
Atrazine	1	2.0	16.4	15.7
Atrazine	2	1.3	11.3	16.6
Simazine	2	2.3	8.1	16.8
Linuron	1	4.0	9.9	16.2
Linuron	2	2.3	7.4	19.8
Butylate + 2,4-D	4 + 1	7.7	3.7	21.3

[1] 0—no control; 10—complete control

In the 1964 work (Table 13) the triazines repressed crabgrass growth sufficiently to double the yields of silage corn but control as measured by either stand ratings or stand counts was relatively poor. Of the two triazines, simazine was the most effective on crabgrass. The 2,4-D treatment was more effective in terms of crabgrass stand count and corn yields than either of the triazines. The most effective treatment was the butylate + 2,4-D treatment. The 2,4-D was included since other work has shown butylate to be weak on

TABLE 14. 1965 comparisons of atrazine and other herbicide treatments on crabgrass and corn yields.

Chemical	Rate lb./A ai or ae	Crabgrass Response: Stand ratings[1] 8/25/65	Crabgrass Response: T/A dry wt. 9/9/65	Corn silage yields T/A 75% Dry Matter
Control		0	1.03	12.3 f[2]
Atrazine	2 ppi	2.0	.93	17.0 cde
Atrazine	2 pre-E	5.4	.63	19.6 abc
Atrazine + Cultivation	2 pre-E	6.7	—	21.2 abc
Atrazine + Non-phytotoxic weed oil	2 + 1 G post-E	2.7	1.17	13.7 f
Propachlor (CP 31393)	3	7.0	.27	20.2 abc
D-263[3]	6	8.0	Trace	21.5 ab
Atrazine + Prometryne	1 + 1	6.3	.35	22.6 a

[1] 0—no control; 10—complete kill
[2] Duncan's Multiple Range Test (.05)
[3] 1,1-dimethyl-4-6-diisopropyl 5 and 6 indanyl ethyl ketone

some broadleaf weeds, notably common ragweed, *Ambrosia artemisiifolia.* The activity of linuron 2 lb./A on crabgrass was greater than atrazine but comparable to simazine.

In most field tests, however, linuron has been more effective than either simazine or atrazine in crabgrass control. Because of some hazard to germinating corn from linuron, a combination of atrazine 1 lb. and linuron 1 lb. ai/A has been recommended. Since linuron causes severe contact injury, any post-emergence treatment including this herbicide can be applied only as a directed spray.

In a comparison of different methods of applying atrazine (Table 14) the advantage of a single cultivation following a pre-emergence treatment was shown. The effectiveness of cultivation decreases rapidly after the crabgrass plants pass the ½ to 1-inch size, since by this time they are sufficiently deep rooted to resist a certain amount of soil movement. The incorporation of atrazine (pre-plant treatment) decreased its effectiveness as compared to the pre-emergence treatment. The post-emergence treatment in oil had very little effect on crabgrass. This poor control was reflected by a corn yeild no greater than in the check.

The herbicides propachlor and D-263 gave much better control of crabgrass than any of the atrazine treatments. In this experiment, combining

prometryne with atrazine gave some increase in control over atrazine alone.

In a 1965 experiment (Peters and O'Leary, 16) excellent control of crabgrass was obtained from pre-emergence applications of alachlor (CP-50144). The control obtained from 1½ lb. ai/A was better than from propachlor 4 lb. ai/A. Neither propachlor nor alachlor give satisfactory broadleaf weed control; thus atrazine should be applied with these acetanilide compounds to provide broad spectrum control.

SUMMARY AND CONCLUSIONS

1. *Digitaria sanguinalis,* large crabgrass, has a larger seed and a gray fertile lemma as contrasted to a smaller seed with a black fertile lemma in *Digitaria ischaemum,* small crabgrass.
2. *D. sanguinalis* under comparable conditions is a larger and more upright plant than *D. ischaemum,* thus the common names, large and small crabgrass, respectively.
3. The common names hairy and smooth crabgrass are inappropriate since the degree of pubescence of *D. sanguinalis* varies from complete pubescence to pubescence only at the nodes.
4. After the fourth leaf stage of growth is reached in seedling plants, further increase in plant size is by means of tillering.
5. Spacing has a marked effect on tiller development. Large crabgrass plants produced ten times as many tillers at a 36-inch spacing than at a 6-inch spacing. Lateral spread of individual plants was also influenced by spacing.
6. Initial stand had little influence on the ultimate percentage ground cover of crabgrass. Because of the multiple tillering and sprawling habit of growth, a complete ground cover will eventually result from an initial population of only 2-3 plants per square yard.
7. Crabgrass grew actively in growth chambers at 60-80° F temperature range but very poorly at 40-60° F.
8. Shading resulted in a dry matter yield reduction of 30% at 60% shading, and 25% at 30% shading.
9. Because of reduced growth at low light intensities, closer row spacing and higher corn plant populations are cultural practices which will reduce competition from crabgrass by hastening the time when the canopy shades the ground.
10. Tillers tend to grow prostrate, rooting at the nodes. Culms partially covered by soil readily struck root; thus cultivation is of limited value in controlling well-established crabgrass plants.

11. Origin of seed influenced plant development. Seed from Maryland produced much larger plants, heading 2 weeks later than seed from Connecticut.
12. Crabgrass is a short-day plant. Plants germinating late in the season started flowering much sooner than plants which germinated early.
13. Once blooming started, seed continued to form until frost killed the plants. Blooming of large crabgrass started at least one week sooner than with small crabgrass.
14. Crabgrass seed did not germinate in the field during the year it was produced. Dormancy was lost by the following spring under field conditions.
15. Germination occurred in mid-May in southern New England, which is phenologically associated with the blooming of the common lilac *(Syringa vulgaris L.)*. Under a heavy vegetative mulch germination is delayed or prevented because of lower soil temperatures. Exclusion of light, per se, did not prevent germination since germination occurred under black plastic.
16. Plants growing in blue light were smaller and bloomed sooner than in red or white light.
17. When crabgrass was grown in association with alfalfa in nutrient solutions at two levels of P and K, there was an increase in crabgrass growth over crabgrass alone since the alfalfa plants were less competitive than other crabgrass plants. Alfalfa yields in association with crabgrass were depressed at the low P level.
18. Crabgrass grown alone was depressed much more than alfalfa alone by low P and K levels.
19. The rapid growth rate and large root-absorbing surface of large crabgrass was the principal factor in the decrease in crabgrass yields at the low P and K level and the apparent competition with alfalfa for P at the low P level.
20. Crabgrass displays greater tolerance to atrazine than either yellow foxtail *(Setaria lutescens)* or barnyardgrass *(Echinochloa crusgalli)*. Small crabgrass is the most tolerant of the two. When grown in nutrient solutions containing atrazine, crabgrass tissue contained much less atrazine than alfalfa, indicating either less absorption or a metabolic breakdown of any atrazine absorbed.
21. A single cultivation before the crabgrass plants were over ½-1 inch tall following a pre-emergence application of atrazine gave good control.
22. Simazine, linuron and butylate, propachlor and alachlor were all shown to be more effective for crabgrass control than atrazine. Alachlor gave the most consistent control without injury to corn.

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