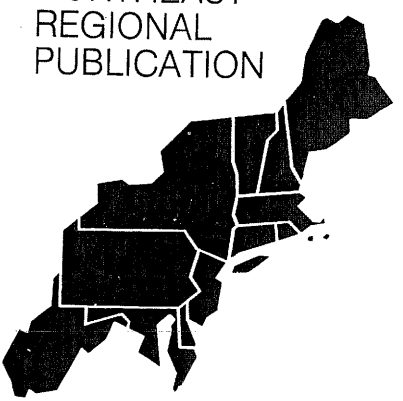
Life History Studies as Related to Weed Control in the Northeast

9. Galinsoga

NORTHEAST REGIONAL PUBLICATION



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This bulletin is one of a series pertaining to life history studies of weeds that are important in the Northeastern States. The series is being published by the Northeast Regional Weed Control Technical Committee (NE-42).

Bulletins previously published deal with the following weeds: **nutgrass** (Rhode Island Agr. Exp. Sta. Bul. 364, 1962), **quackgrass** (Rhode Island Agr. Exp. Sta. Bul. 365, 1962), **horsenettle** (Rhode Island Agr. Exp. Sta. Bul. 368, 1962), **yellow foxtail and giant foxtail** (Rhode Island Agr. Exp. Sta. Bul. 369, 1963), **barnyardgrass** (Delaware Agr. Exp. Sta. Bul. 368, 1968), **large and small crabgrass** (Storrs [Conn.] Agr. Exp. Sta. Bul. 415, 1971), **common purslane** (U. of Mass. Res. Bul. 598, 1972), **common ragweed** (Cornell U. Agr. Exp. Sta. Bul. 1033, 1978).

Contents

Galinsoga

R. D. Sweet

Introduction

Weeds are always a potential threat to crops desired by people. For centuries tillage, rotations, and hand labor were used for weed control. In the past 25 years or so, in the developed countries, chemical herbicides have received considerable emphasis with a corresponding decrease in dependence on the traditional methods. Currently, for example, hand labor is used for weed control only in crops having a very high value per acre, and cultivation is omitted in many corn fields. An effective safe herbicide typically gives spectacular results the first few years at a nominal cost and, understandably, is an attractive practice for many farmers. Most crop fields, however, contain a mixture of weeds, often not closely related botanically. Under these circumstances an herbicide or a combination of herbicides may control several species fairly well and, at the same time, permit others to escape. Even though an escaped species, initially, may be of minor consequence, it can become a major problem in as little as 3 to 5 years, if both the environment and the cultural practices for the crop are favorable for the weed. *Galinsoga* in the northeastern states seems to fit this circumstance, for the author has observed it in the past 12-15 years to become a major weed in such vegetable crops as beans, cabbage, peppers, and tomatoes. The principal herbicides used in these crops, trifluralin, EPTC, DCPA, and nitrofen, are not particularly toxic to *Galinsoga.* In contrast, *Galinsoga* has not been observed as a serious pest in corn, small grains, or forages where both the herbicides and the cultural practices differ greatly from those in vegetables.

In 1971 Northeastern Regional Research Project NE-42 (revised) was initiated as a cooperative study on the life cycle, ecology, and control of several weeds including *Galinsoga parviflora* Cav. and *G. ciliata* (Raf.) Blake. The states involved with these 2 species were Connecticut, New Jersey, and New York. This publication sets forth the findings of these investigations as well as pertinent information from studies by other investigators.

Nomenclature, Distribution, and Description

Canne (1977) gave a comprehensive report on the taxonomy of the genus *Galinsoga* and attempted to reconcile and clarify the considerable confusion and contradictions that exist in the literature on this genus. The difficulties concern not only the delimitation of the genus itself, but also the names and descriptions of the species generally acknowledged as belonging to *Galinsoga*.

One important species in both the United States and Europe is *Galinsoga parviflora* Cav.; its name and description are widely accepted. On the other hand, a second important species, *G. ciliata* (Raf.) Blake, presents a quite different situation. Thellung (1916) provided considerable information on two important European species, but referred to them as *G. parviflora* and *G. quadriradiata*, with no mention of *G. ciliata*. St. John and White (1920) reported on *Galinsoga* in North America without reference to Thellung's paper, and thus, one cannot be certain whether or not their failure to mention *G. ciliata* means that they agreed with Thellung's proposed nomenclature. Lousley (1950) suggested that *G. quadriradiata* var. *hispida* and *G. aristulata* are synonymous with *G. ciliata*. Muenscher (1955) describes *G. ciliata*, but does not mention *G. quadriradiata* in his text, which is widely known by weed scientists in the northeastern states. On the other hand, Canne (1977) and Warwick and Sweet (1983) prefer *G. quadriradiata* to *G. ciliata*. Because it is beyond the scope of this paper as well as my expertise to present a competent critique of the taxonomy of *Galinsoga*, it is proposed to offer *G. quadriradiata* as the preferred designation, even though *G. ciliata* may be more familiar to most readers of this work. Eventually the designation of *G. quadriradiata* as preferred by Canne (1977) will probably prevail. However, references in existing publications to *G. ciliata* will stand as given by the authors.

G. Parviflora and *G. quadriradiata* (= *G. ciliata*), recognized as the 2 most weedy species of *Galinsoga*, are widely distributed in the United States from Maine to Georgia and westward to Mexico and Oregon. Both are also found in Ontario, Canada (Muenscher 1955; Canne 1977; Warwick and Sweet 1983). Braden and Cialone (1971) worked with both species in New Jersey. Vengris (1953) found *G. parviflora* in the Connecticut River Valley, whereas Ashley (1972) reported on *G. ciliata* at Coventry, Connecticut. Beste (personal communication) found both species at Beltsville, Maryland; only *G. ciliata* at a research farm 10 miles north of Beltsville; only *G. parviflora* at Salisbury, Maryland, and at 3 other locations 11, 40, and 75 miles from Salisbury.

Lousley (1950) considered *Galinsoga* to be native to Peru and reported that *G. parviflora* was imported to Kew Gardens in the late 1700s and spread from there. On the other hand, he stated *G. ciliata* was not reported in Britain until the 1930s. Duperrex (1946) found that *G. parviflora* was not introduced into Switzerland until 1925, whereas *G. quadriradiata* (*G. ciliata*), introduced into Germany about 1800, did not reach Switzerland until 1942. Unfortunately, these dates do not coincide with the findings of Kronfeld (1889) who lists herbarium records of *G. parviflora* in England, Germany, Switzerland, and Italy throughout the 1800s.

Complicating the history as well as the origin of *Galinsoga* is the confusion over names of species. According to Canne (1977), the evidence strongly suggests that the origin of *Galinsoga* was the mountainous areas of west-central Mexico. Canne further states that *Galinsoga* is now established in Africa, India, Japan, the Philippines, Pacific Islands, and Australia.

Muenscher (1955) gives the following description of *G. ciliata*:
Annual; reproducing by seeds and rooting stems. Gardens, cultivated fields, and waste places, mostly in rich soils. Widespread and becoming common from Maine and Ontario to Georgia and westward to Oregon and Mexico. Introduced from tropical America. July-September.

Description: Stems erect or spreading, much branched, slender green, pubescent, 30-60 cm high. Leaves opposite, simple petioled, crenate-serrate, ovate, glabrous. Heads numerous, terminal and auxillary, several flowered, less than 1 cm in diameter; involucral bracts 4-5, ovate, thin, green; receptacle conical, chaffy; ray flowers 4-5, corolla white, 3 toothed, pistillate, scarcely longer than the disk flowers; disk flowers perfect, with yellow corrola. Achenes about 1.5 mm long, wedge shaped, 4 sided, finely white-haired, dark brown to black; pappus a fringe of chaffy scales.

In the Agricultural Handbook, no. 366, *Selected Weeds of the United States*, 1970, p. 410, the following description of *G. parviflora* is presented:

Small-flowered *Galinsoga*. Annual herb, reproducing by seeds; stems erect or spreading, much branched, slender 30-70 cm tall, glabrous or sparsely pubescent; leaves opposite, ovate to lance-ovate, pointed at the tip, thin, 2-7 cm wide, serrulate or crenulate, glabrous or sparsely appressed-hairy; flower heads small, numerous, scattered at the ends of the branches, in leafy cymes; ray flowers very small white, 4-5 in number, surrounding the small yellow disk flowers; pappus of the disk flowers without awns, equaling or longer than the corolla; achene about 1.5 mm long, wedge shaped, 4 sided, dark brown to black, with a fringe of tiny scales at one end, or glabrous. June-November.

Weedy gardens, dooryards, lowland fields, and waste places, especially damp areas with rich soil. A cosmopolitan weed. Naturalized from Mexico and South America. Throughout all the United States, excepting areas along the northern border and along the central Atlantic coast. (See comments p. 2.)

Ivany (1971) in comparing *G. parviflora* and *G. ciliata* states that the latter is denser and lower growing, has larger leaves, shorter internodes, thicker stems and petioles, and much more numerous hairs on all plant parts. Braden and Cialone (1971) noted that achenes of *G. ciliata* were relatively short and wide as compared with those of *G. parviflora*. They reported that cotyledons of *G. ciliata* averaged 58.0 marginal hairs, whereas those of *G. parviflora* averaged only 2.7. Haskell and Marks (1952) state the $2n$ number for chromosomes of *G. parviflora* to be 16 and of *G. ciliata* to be 32. Canne (1977) suggests that where *G. parviflora* is reported to have a $2n$ of 32, it was undoubtedly based on misidentification.

Morphology and Anatomy

In field surveys Ivany (1971) found 2 species present in vegetable crops in New York. He identified them as *G. ciliata* and *G. parviflora.* They were found as homogeneous stands of a single species and, in some instances, a patchwork mixture, rather than a complete mixing of 2 species. Even in fields with mixtures there was no indication of a range in biotypes or in intermediates.

Ivany grew plants from both species in the greenhouse and recorded phenotypic differences between the 2 species, both pictorially and with written descriptions. He stated that *G. ciliata* was a compact, robust plant with fairly large leaves, much pubescence, and many branches with terminal flower heads (fig. 1). *G. parviflora* was taller, more open, with smaller leaves, less pubescence; the branches had somewhat smaller and less-prominent flower heads (fig. 2). Both species have opposite leaves with the pairs at each succeeding node rotated 90°. The leaves of *G. ciliata* are nearly as wide as long and have many hairs and a serrated margin. Those of *G. parviflora* are smaller, are longer than wide, and have few hairs; the margin is wavy rather than deeply serrated (fig. 3). The nodal morphology is similar for the two species, but the internodes of *G. ciliata* are much shorter than those of *G. parviflora* (table 1). Furthermore, *G. parviflora* also tends to have one more node than *G. ciliata.* Both features contribute to its extra height. *G. ciliata* has more-prominent ray flowers, and its tubular flowers are deeper yellow than those of *G. parviflora.* The mature fruit, achene, of *G. ciliata* is shorter and wider than that of *G. parviflora.*

Table 1. Internode length of *G. ciliata* and *G. parviflora* at 7 weeks in the greenhouse

	Node no.				
Species	*1*	*2*	*3*	*4*	*5*
			cm		
G. ciliata	3.0	5.6	7.8	10.4	—
G. parviflora	3.3	6.3	10.7	12.3	15.0

Note: Average of 5 plants, each species. Measurements from midnode to midnode.

To determine if phenotypically different ecotypes of *Galinsoga* occurred, Ivany (1971) obtained seed lots from Connecticut, Florida, New Jersey, and several locations in New York. These were germinated in the greenhouse and, at the 2-leaf stage, were transplanted to the field. Plots were single rows 4 feet long, with 10 seedlings per row. The lots could be readily identified as to species. Within a row, as well as between rows of the same species from different locations, there was remarkable uniformity. Time of emergence, speed of growth, time of flowering, and overall morphology were similar for each lot of a given species. Ivany suggested that because of flower structure, lack of wind pollination, and a difference in chromosome number, $2n$ of 32 and 16 for *G. ciliata* and *G. parviflora*, respectively, there is likely to be little or no cross-pollination.

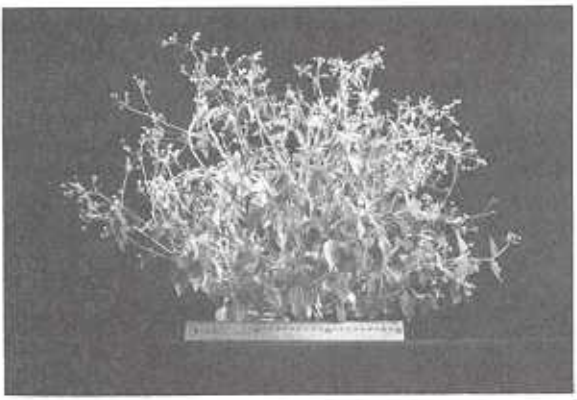

Figure 1. *G. ciliata (G. quadriradiata).* Note the upright, many-branched, compact habit.

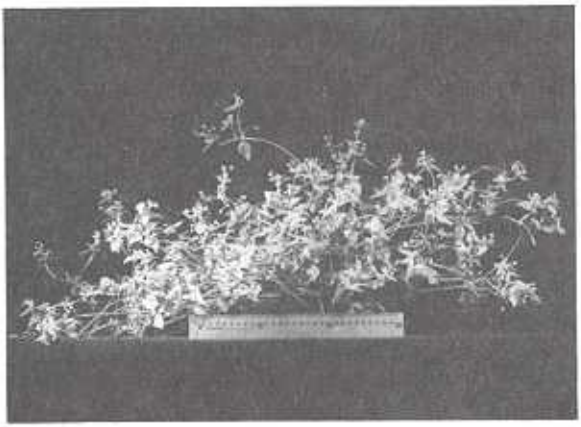

Figure 2. *G. parviflora.* Note the moderately branched, relatively open habit. Some biotypes are more upright.

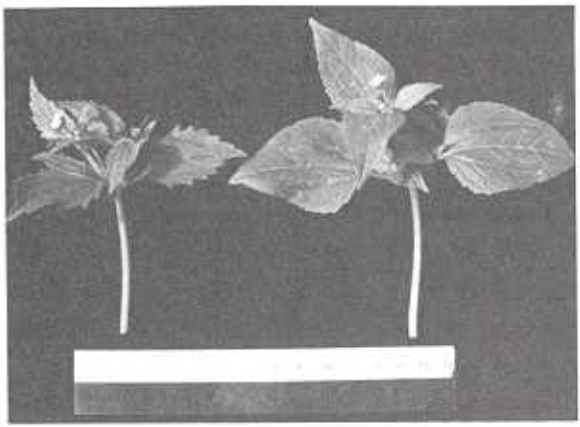

Figure 3. *G. ciliata (G. quadriradiata) on left, G. parviflora on right. G. parviflora* always has relatively smooth leaf margins and few hairs. Leaf size varies and is not a reliable character for identification.

Ivany (1971) also made studies of the vascular anatomy of both *G. ciliata* and *G. parviflora*. He examined roots, stems, and petioles and compared his findings with those of Lawalree (1948), who had investigated stems and laterals of *G. parviflora*. In general, Ivany's findings were similar to those of Lawalree. He summarized his rather extensive studies as follows: "The vascular system of the two species of *Galinsoga* consists of a single ring of twelve collateral vascular bundles, six of which are leaf traces and are smaller than the others. The petiole has three large vascular bundles which arise from the dichotomy region of the main axis bundles in the internode beneath the leaves. The roots are polyarch in arrangement and have an exarch maturation pattern."

Germination and Emergence

In extensive studies conducted in New York, Ivany (1971) investigated germination and emergence in the field, greenhouses, and growth chambers.

Time of emergence. A Cornell University field at Ithaca with an infestation of *G. parviflora* was noted in 1968 and, after plowing in 1969, was deliberately left fallow. In the early spring of 1970 the area was left undisturbed, and a series of 0.5-m^2 plots were staked. On May 20 and three later dates, counts were made of the number of *G. parviflora* seedlings that had emerged per plot. All seedlings were pulled and removed from the area. Immediately after each time of data taking, the plots were lightly raked to a depth of about 0.5 cm and were given about 1.0 cm of irrigation if they were dry. An area adjacent to the experimental plots was left undisturbed until late August, when it was disked heavily to destroy the dense top growth of *G. parviflora*.

The results (table 2) show that germination occurred mostly in May and June with considerably less the latter part of July. It is probable that the lower number at that time was due to a lack of viable seed, rather than a physiological response of the seed to season. The shallow stirring brought little or no seed to the surface, and with 11,000 seedlings emerging from 0.5 m^2, it is likely the supply was exhausted. This

Table 2. Emergence of *G. parviflora*, East Ithaca, N.Y., 1970

Date of count	*Number emerged**
May 20	4104
June 10	5867
July 6	969
July 21	75
Total	11,015
LSD 0.1	2278

* Average of 4 plots, each 0.5 m^2 in area.

reasoning is further supported by the fact that the adjacent area, which was disked heavily in late August, developed a dense mat (not counted) of new seedlings within 2 weeks' time.

In a second experiment about 10 miles distant at Freeville, N.Y., Ivany (1971) seeded *G. parviflora* in very shallow furrows, at intervals of 14 days, beginning in May and continuing into September. There was a remarkable similarity in the speed of emergence at the various planting dates. The earliest and latest plantings required 8 days, whereas all others required 6. He did not take data on percentage emergence, but noted no obvious differences between planting dates.

The findings from these two experiments are in general agreement with those of Pladeck (1933) who reported that in the vicinity of Washington, D.C., *G. ciliata* emerged principally in June, but was not limited to this period. Also Usami (1976) stated that in the vicinity of Tokyo *G. parviflora* emerged from March until November.

Depth of seeding. Ivany (1971) studied depth of seeding with *G. ciliata* in the greenhouse, using achenes (seed and achene are used interchangeably throughout) that had been carefully screened and cleaned to obtain lots uniform in size and color and, presumably, uniform in maturity. The seeds were not removed from the achenes, all of which were black and with the papus still attached. A greenhouse potting soil was placed in styrofoam flats, and 100 achenes were placed on the soil surface of each. Some flats were sprinkled with an additional amount of soil to cover the seed with 0.25 cm or 1.0 cm of soil. The flats were covered with a sheet of glass to minimize surface drying and were watered by means of subirrigation. The greenhouse temperature was 21° C at night and 26.5° C during the day. The experiment was conducted in the winter with about an 11-hour photoperiod. The design was a randomized complete block with 4 replications. Data on emergence were recorded at 14 and 32 days.

Depth of seeding had a pronounced influence on emergence (table 3). Emergence from the surface was nearly 98%, whereas at the relatively shallow depth of 1.0 cm, not one seedling emerged. At 0.5 cm, however, 55% emerged. Ivany repeated this test and included both *G. ciliata* and *G. parviflora*. The results were almost identical for both species and agreed exceedingly well with those from the earlier test. Typically, oxygen, moisture, and temperature need to be favorable for most nondormant viable seeds to germinate. It is unlikely that any of these 3 factors

Table 3. Emergence of *G. ciliata* in the greenhouse when seeded at several depths

	Emergence	
Depth	*14 days*	*32 days*
	%	
Surface	93.0	97.7
0.25 cm	13.9	55.5
1.00 cm	0.0	0.0
	LSD 0.05 11.5	34.9

could have been limiting at 0.5 cm or 1.0 cm in the moist potting soil. The results strongly suggest that light could have been a factor. *Galinsoga* is a composite and plausibly is similar to lettuce, *Lactuca sativa*, also a composite, whose fruit is an achene that requires light for germination. Furthermore, these experimental results fit field observations by me and by Ivany (1971) that *Galinsoga* germinates at the soil surface or at very shallow depths.

Light. Braden and Cialone (1971) and Ivany (1971) reported that seeds falling from the mother plant of *G. ciliata* and clearly under the canopy did not germinate until the plant matured and the canopy became fairly open. On the other hand, seed that fell at the edge of the canopy germinated promptly. Several possible causes for this difference can be postulated: (1) temperatures under the canopy were too cool or did not have sufficient diurnal fluctuation; (2) soil under the canopy stayed too dry; (3) light quality was altered under the canopy and inhibited or failed to stimulate germination (Taylorson and Borthwick 1969); (4) total light reaching the seed was limiting. Ivany's data on depth of seeding tend to support the last hypothesis.

An experiment with *G. ciliata* was reported by Ivany (1971) in which the influence of light was investigated during imbibition as well as for subsequent periods of 7, 14, and 27 days. Light during imbibition was supplied from cool white fluorescent tubes and incandescent bulbs in growth chambers, but subsequent light treatments were from natural greenhouse light. Additional flats were covered with aluminum foil to provide dark treatments. The same seed lot and planting techniques were used as in the depth of seeding study. An initial dark period had little influence on germination (table 4); but when the dark period was extended to 7 or 14 days, there was a progressively more severe reduction in germination. However, even this drastic effect was completely overcome by exposing the flats to natural daylight for 11 hours per day for 2 weeks.

Table 4. Effect of light and dark treatments for 27 days following seeding on emergence of *G. ciliata*

*Treatments**				*Percent emergence*	
24 hours	*2–7 days*	*8–14 days*	*15–27 days*	*14 days*	*27 days*
1. light	11 hr	11 hr	11 hr	74	99
2. dark	11 hr	11 hr	11 hr	67	98
3. dark	dark	11 hr	11 hr	52	100
4. dark	dark	dark	11 hr	0	95
5. light	dark	11 hr	11 hr	48	99
6. light	dark	dark	11 hr	0	92
			LSD 0.01	28	N.S.

*During the first 24 hours light was supplied by fluorescent tubes; the remaining light treatments were natural greenhouse light for 11 hours.

Working in Connecticut, Kahl and Ashley (1977) collected achenes of *G. ciliata* 3 times during August and September. In 2 instances they were placed in envelopes that excluded light and stored for several days at room temperature until germination tests were initiated. In the 3d instance they were air dried in fluorescent light for 5 days and then tested. One hundred achenes were used in each petri dish or flat, and during the dark treatment each dish or flat was placed in a black-cloth photographer's bag, the resulting rise in temperature being 2° C. At the end of either 2 or 3 weeks, final germination counts were made. Surprisingly, in spite of the marked difference in initial handling of the various seed lots, there was excellent agreement between all tests. In the light, germination ranged from 94% to 98% and, in extended dark, was only 13% or 15%. Significance was at the 1% level, and the results agree closely with those of Ivany (1971).

In an attempt to determine the amount of light needed to promote germination of *Galinsoga*, Ivany (1971) conducted 2 tests, each with both species. In one he used intensities of 240, 780, and 1,250 ft candles, and in the other, intensities of 150, 490, and 750. In each test the highest intensity was obtained by fluorescent tubes; the intermediate and lowest intensities were obtained by shading with buff or green Saran shade cloth, respectively. In both tests *G. parviflora* averaged about 90% germination regardless of light intensity. *G. ciliata* showed a significant trend towards higher germination as light intensity decreased. For example, at 9 days, germination increased from 51% to 80% in the 1st test and from 52% to 75% in the 2d test as intensity decreased from high to low. After 16 days the trend was less marked, but it still was significant at the 5% level. Unfortunately, in these tests the techniques for obtaining the 2 lower light intensities were different. No determination was made by Ivany to learn if the different kinds of shade cloth changed light quality as well as foot candles. This needs to be done before the data can be properly interpreted.

Because variation in results could be due to inherent differences in seed lots, Ivany (1971) compared the germination of 10 different lots. Several of these were ones that he had used in earlier studies; others were from various states in the Northeast. None of the lots were freshly harvested, but he failed to record the complete specific history for any of them. In direct contrast to his earlier findings as well as those of Kahl and Ashley (1977), no seed lot of either *G. parviflora* of *G. ciliata* responded to light by giving significantly better germination. Ivany suggested that aging probably was the most significant factor involved and that it ultimately brought about the same physiological situation within the seed as did exposure of fresh seed to light. Because lettuce seed may also show a similar lack of sensitivity to light on aging (Shuck 1934), this appears to be a valid hypothesis.

Temperature. In the field *Galinsoga* germinates early in the spring, while the soil is still cool, and continues to emerge throughout the summer and fall, particularly if the soil is stirred. In the field it is impossible to identify seeds as to their age and, thus, how many times they have been exposed to winter cold or summer heat. With heavy infestations, the entire furrow slice in fields regularly plowed undoubtedly contains seeds of various ages and exposures. Some questions this situation raises are, Is low temperature required for germination of older seed? Does extra high summer temperature prevent germination? Is there an interaction between temperature and light?

Ivany (1971) conducted 6 experiments that at least partially answer these questions. In an experiment designed to determine the effect of cold temperatures on subsequent germination, flats with potting soil were seeded on the surface with 100 achenes each of *G. ciliata* and subirrigated. They were put in plastic bags and placed in dark chambers with temperatures of -18°, 0°, 10°, and 21° C for periods of 1, 2, and 4 weeks. At the end of the storage period, flats were moved to a greenhouse held at 21° C nights and 26.5° C days and a natural photoperiod of about 11 hours of light. The plastic bags were removed and a sheet of glass was placed over each flat to admit light and to minimize moisture loss. There were 4 replications arranged as a factorial. Counts of emerged seedlings were made 20 and 34 days after the end of storage periods. The data show clearly that a cold treatment is not necessary for germination (table 5). In fact the lowest storage temperature, -18° C, tended to slow the rate of germination, particularly at the 20-day stage of observation. In a similar subsequent test, both *G. ciliata* and *G. parviflora* were included. Similar results were obtained with both species as compared with the earlier test, with -18° C causing a lowering of germination.

Table 5. Emergence of *G. ciliata* in the greenhouse 20 and 34 days following 1, 2, or 4 weeks' exposure to various temperatures

	Weeks of exposure					
	1		*2*		*4*	
Exposure	*20 days*	*34 days*	*20 days*	*34 days*	*20 days*	*34 days*
°C				%		
-18	73	83	57	85	84	97
0	93	93	92	94	96	97
10	91	96	92	94	78	89
21	96	99	79	94	99	100
LSD 0.05	11	9	11	9	11	9

In the field, bare soil surface can reach 40°-50° C for an hour or so on bright summer days. Under these conditions fresh seed could fall from the mother plant and be exposed to relatively high temperatures. Although the seed would probably be dry when it first touches the soil surface, it is likely that sometimes there would be sufficient soil moisture for the surface to become moist overnight, and the seed could imbibe moisture. On the other hand, in a hot dry period, the soil surface probably would not contain sufficient moisture to permit seed imbibition even during the nighttime hours. Ivany (1971) studied the influence of 50° C temperature for 1, 6, and 24 hours on the subsequent ability of *G. ciliata* seed to germinate at 20° C, when it was either dry or on moist filter paper for 6 hours before exposure to the high temperature. With imbibed seed, 50° C heat was extremely damaging even for 1 hour, but with dry seed there was little or no effect (table 6). One can surmise from these findings that under extreme conditions in the field some seed of *Galinsoga*

may be destroyed, but it is not likely that this would be a major factor influencing population levels.

In an experiment designed to study the effect of alternating temperature with seed exposed to light or dark, Ivany (1971) found a slight advantage to alternation. Contrary to his other investigations, in this test light had no effect. Because he used seed from the same lots as those used in earlier tests, he suggested that perhaps aging could have accounted for these results. He urged that more work be done in this area so that the influence of light and dark as well as any interaction with seed aging can be more clearly established.

The author has made some field observations that may be of help in predicting longevity. A research field at Cornell University that had a moderately heavy infestation of *G. ciliata* was put under a control program of cultivations plus production of sweet corn and snap beans in which atrazine or dinoseb herbicides were used just before crop emergence, plus one cultivation when the crop was about 10 inches tall. After 3 seasons only minor stands of *Galinsoga* were observed. There were no control portions of the field, and no counts were made of the rate of *Galinsoga* disappearance. Nonetheless, these findings are evidence that *Galinsoga* seed is not long lived in cultivated fields, and this fact could prove to be helpful in long-term control programs.

Table 6. Germination of dry and imbibed *G. ciliata* seed at 20° C after exposure to 50° C temperatures

Hours of exposure	*Condition*	*Percent emergence*	
		13 days	*25 days*
1	imbibed	37	77
1	dry	75	99
6	imbibed	10	34
6	dry	56	91
24	imbibed	0	0
24	dry	69	95
0	—	71	97
	LSD 0.05	9	3

Growth, Development, and Maturation

Both *G. ciliata* and *G. parviflora* were studied by Ivany (1971) in the field, the greenhouse, and chambers. In several experiments he recorded emergence, height, lateral development, fresh and dry weight, and formation of flower heads. His most-detailed work was repeated several times in the greenhouse during the winter at an average photoperiod of 11 hours. Typically, he grew 1 plant per 30-cm pot for a period of 12 weeks. He found both species increased rapidly in all categories throughout the experiment (table 7). Because of its longer internodes *G. parviflora* was taller than *G. ciliata*; also laterals started at 20 days on *G. parviflora* and at 25 days on *G. ciliata*. They did not follow the typical sigmoidal curves reported for weeds such as ragweed and barnyardgrass or for annual crops such as beans and corn. Part of this difference is probably due to the fact Ivany did not measure the seedlings until 30 days from seeding and during the first days after emergence growth is slow for many small-seeded species including *Galinsoga*. Another important reason is the patterns of growth of larger plants as described later.

Table 7. Height, fresh and dry weight per plant of *Galinsoga* grown in the greenhouse in winter

Species	*Days from seeding*	*Height*	*Fresh wt.*	*Dry wt.*
		cm	*g*	*g*
G. ciliata	30	4	2	0.1
	40	9	6	0.3
	50	19	32	1.9
	60	37	86	6.0
	80	76	244	21.9
G. parviflora	30	6	1	0.1
	40	16	8	0.4
	50	34	36	2.1
	60	54	82	5.1
	80	104	233	22.7

In one test Ivany made special observations on lateral development and flowering. Each lateral terminated in one or more flower heads in a leafy cyme. At the more basal nodes of the main plant, laterals formed 4-5 nodes before terminating in flower heads; at the more apical nodes they terminated after only 2 nodes. In the field *Galinsoga* continues to make more laterals, primary, secondary, and tertiary, which terminate in flower heads until the plant is destroyed by humans or freezing temperatures. Ivany recorded more than 300 flower heads, each with 25 achenes that germinated at least 90%. His work was under relatively poor light. Even at these levels, one plant could produce at least 7,500 seeds. Thus, only a few escaped plants per acre could quickly establish a serious infestation.

Photoperiod. Salisbury (1968) gave a comprehensive listing of the response of plant species to photoperiod and its interaction with temperature, and reported the Compositae family exhibits the full range of responses with various species. He did not classify *Galinsoga.* Ivany studied day-length response of both *Galinsoga* species. During the winter, seeds were germinated and grown at 8- and 16-hour photoperiods. In the light period all plants received the relatively poor natural light plus supplemental light from a mixture of fuorescent and incandescent bulbs, which added about 1,500 ft candles. The test was conducted for 30 days, at which time all plants had visible flowers. There was a large difference in plant height and fresh weight depending on photoperiod, but there was little difference in number of days to flowering (table 8). Ivany concluded that the great increase in height and fresh weight was probably due to the increased energy of the long photoperiod rather than to a true photoperiodic response. He further commented that in every experiment in the greenhouse or field where direct comparisons were possible, regardless of the factor being studied, *G. ciliata* and *G. parviflora* always produced the first flower at the 6th and 7th nodes, respectively.

Table 8. Effect of 8- and 16-hour photoperiods for 30 days on flowering of *Galinsoga*

Day length	*Species*	*Visible flowers*	*Nodes to 1st flower*	*Ht.*	*Fresh wt.*
hours		*days*	*no.*	*cm*	*g*
8	*G. ciliata*	28	6	10	8
16	*G. ciliata*	24	6	31	56
8	*G. parviflora*	30	7	21	16
16	*G. parviflora*	28	7	35	47
			LSD 0.05	1.4	5.2

Light intensity. *Galinsoga* is more often a problem in low-growing vegetables than in the taller or more densely growing crops such as sweet corn and potatoes. Also, in the photoperiod studies reported, it appeared that the light quantity was important. This factor was studied by Ivany (1971) in the greenhouse and growth chambers. In a representative experiment in the greenhouse during the summer, *Galinsoga* in the cotyledon stage was transplanted into 13-cm pots. Photoperiod was 14 hours, and light intensity was maintained at approximately 8,000, 5,000, and 1,500 ft candles. The highest intensity was from natural sunlight; the intermediate and lowest intensities were obtained by use of one layer of either buff or green Saran cloth, respectively. Plants were harvested and data obtained on height, fresh and dry weight, and flowering, 27 days after transplanting. The experimental design was a randomized complete block with 3 replications, each with 3 plants.

As would be expected, dry weight decreased as light decreased (table 9). Height of both species was not decreased except at the lowest level. Fresh weight of *G. ciliata* was unchanged at the intermediate level, whereas that of *G. parviflora* was reduced about 40%. Both were severely reduced at the lowest intensity. Flowering was reduced drastically at the lowest level with only 10% as many buds found. This was correlated with a severe reduction in laterals where flowers are typically formed.

Table 9. The effect of reduced light intensity at 14-hour days on the growth of *Galinsoga*

Intensity	*Species*	*Height*	*Fresh wt.*	*Dry wt.*
ftc*		*cm*	*g*	*g*
8000	*G. ciliata*	23	23	2.2
	G. parviflora	40	36	3.0
5000†	*G. ciliata*	27	25	1.5
	G. parviflora	38	22	1.6
1500‡	*G. ciliata*	16	2.3	0.1
	G. parviflora	22	2.8	0.1
	LSD 0.05	4.0	4.4	0.1

*Approximate levels at midday.
†One layer of buff Saran cloth.
‡One layer of green Saran cloth.

Temperature. Ivany (1971) studied *Galinsoga* growth at 3 temperature ranges in greenhouses during the winter when the days averaged 11 hours. When seedlings were at the 4-leaf stage, they were transplanted singly to 15-cm Styrofoam pots filled with Cornell Mix A, primarily peat and vermiculite (Boodley and Sheldrake 1982). They were then placed in greenhouses having 26°-20° C, 20°-15° C, and 15°-10° C day and night temperatures, respectively. Three harvests were made at 10-day intervals, and data recorded on height and fresh weight. Actual numbers of laterals and flower heads were not recorded, only general observations. There were no differences between species, and as would be expected, growth was less at the lowest temperature. The decrease was relatively slight between 26°-20° C and 20°-15° C, with a highly significant drop of about 40% in both height and fresh weight at the end of 30 days when results for 20°-15° C and 15°-10° C were compared. On a percentage basis, the decreases were even more severe at the first harvest, averaging at least 50%.

Fertilizers. *Galinsoga* is often found in vegetables and other horticultural crops that are usually well fertilized. Rarely is it well established along roadsides, soil banks, excavation sites, and the like as is ragweed (Dickerson 1968). One can infer

from this that *Galinsoga* requires high levels of N, P, and K for good growth. Ivany (1971) conducted several experiments in the greenhouse with both species in which he manipulated the quantities of N, P, and K available. In some tests he changed individual nutrients from zero to levels accepted as adequate for excellent plant growth; in others he left the ratio the same and varied the total quantity available. When any one of the essential nutrients was omitted, growth was drastically reduced. Lack of N completely eliminated flowering, whereas lack of P or K only reduced flowering. Because intensive crops are likely to receive high levels of N, this drastic influence on growth and flowering could play at least a partial role in the distribution of *Galinsoga.* On the other hand, perhaps a more important aspect could be the ability of *Galinsoga* to compete with other crops for N. Ivany also did some work on this aspect, and it is presented in the section on competition.

Seed maturation. *Galinsoga* plants, within a few weeks of emergence, have flower heads in various stages of maturity; and as the season progresses, additional heads are formed. Seeds fall to the ground and soon form new seedlings, which develop and repeat the process. Ivany (1971) mentioned that at Ithaca 3 to 4 generations could easily occur if the original mother plant emerged in late May or early June. Usami (1976) reported similar data for the vicinity of Tokyo. Additional information on maturity and germination are needed if instructions are to be given as to how early a plant must be destroyed to prevent formation of viable seed. The greenhouse work of Ivany (1971), who tagged flower buds and flower heads at several stages, helps in this regard. He visibly identified buds, tagged them, and then made harvests at these stages of maturity:

- Appearance of ray flowers; capetilum concave
- Capetilum convex; surface rough and turning yellow, but with petals still attached
- Full maturity with pappus of the achene fully expanded

Achenes were carefully removed from the flower heads and air dried for 3 days before being placed in petri dishes containing moist filter paper. One-hundred seeds were placed in each of 4 dishes and put in a growth chamber at 26.5° C-20° C day-night temperatures and a 16-hour day length. Germination counts were made 4 times in 10 days.

At the first harvest no seeds were sufficiently mature to germinate. Eight and 13 days later, when the flower head surface was rough and concave, *G. ciliata* and *G. parviflora* germinated 96% and 90%, respectively (table 10). One can estimate that 1 and 1 ½ weeks after ray flower appearance in *G. ciliata* and *G. parviflora,* respectively, each produces mature viable seeds. Thus, a practical recommendation would be to destroy plants as soon as possible after visible flowers are present. These findings agree with those of Pladeck (1933). Other authors working with composites have reported similar results: Crowley (1933) states dandelion (*Taraxicum officinale* Weber) germinates 6 days after full bloom; Kinch and Tarmunde (1957) noted perennial sowthistle (*Sonchus arvensis* L.) and Canada thistle (*Cirsium arvense* (L.) Scop.) had viable seeds 4 and 6 days, respectively, after flowers opened.

Table 10. Flower head maturity and germination of *Galinsoga*

Stage of maturity	Age, days*	Species	Germination period, days 3	4-5	6	10
			%	%	%	%
Ray flowers visible	7	*G. cil.*	0	0	0	0
	5	*G. par.*	0	0	0	0
Head surface concave,	15	*G. cil.*	0	88	—	96
rough	18	*G. par.*	20	83	—	92
Mature, pappus	20	*G. cil.*	—	81	92	100
extended	24	*G. par.*	—	85	98	99
		LSD 0.05	3.2	6.3	3.7	2.7

*Days from first visibility of flower buds.

Rooting of cut pieces. The ability of a plant to form adventitious roots from cut pieces or from intact stems touching the ground is important because this characteristic could influence development patterns. From the practical view, this abiity is of critical importance because such weeds are difficult to control by means of surface tillage, hand hoeing, or pulling. Growers report *Galinsoga* can form roots from cut pieces or intact stems. There are no references on this aspect except the work of Ivany (1971) in which he cut plants that had 4 nodes just above the cotyledonary node and placed them in potting soil in flats that were kept watered and maintained in a greenhouse at 26.5° C-10° C day-night temperatures and a 12-hour day length. There were 6 plants per flat with 4 replications arranged as a randomized complete block. After 30 days the plants were removed from the soil, and lower parts washed to determine the extent of rooting. For *G. ciliata* 54% of the cuttings had adventitious roots, whereas for *G. parviflora* only 33%. Thus, both species have the ability to regenerate roots; *G. ciliata* would perhaps be somewhat more of a problem in the field than *G. parviflora.*

Competition

Substantial numbers of research papers have been published since 1900 on competition between weeds and crops. Excellent summary or review-type papers are available: Clements (1907), Milthorpe (1961), and Donald (1963). Black, Chen, and Brown (1969) reviewed the biochemical aspects of competition, and Yip (1975) presented a thorough review of the competitiveness of crop cultivars, particularly in relation to light. In general, these authors agree that competition occurs most often for light, water, and minerals and to a very much lesser extent for CO_2. Occasionally, allelopathy, or toxicity due to exuded substances, is implicated in competition.

Competitiveness. In spite of the numerous studies already reported, no mention could be found at the time these studies were initiated regarding the competitiveness

of *Galinsoga*. In discussions with growers and extension agents in New York the author learned that they did not consider *Galinsoga* to be as strong a competitor as other broad-leaved annual weeds such as redroot pigweed and lambsquarters. They did not believe it caused severe yield reductions or losses in crop quality. Instead, they described *Galinsoga* as a nuisance weed that severely interfered with either hand or machine harvesting of vegetables.

In Connecticut, Ashley (1972) reported on competitiveness of *G. ciliata* with snap beans *Phaseolus vulgaris* cv. Tendercrop. A field of Merrimac fine sandy loam, 3% organic matter, that was known to have a heavy infestation of *G. ciliata* was chosen for the study. Four bean seeds per foot were hand seeded in rows 10 feet long and 3 feet apart. Soon after emergence, they were thinned to 2 plants per foot. *Galinsoga* stands of 0, 1/2-1, 1-2, and 2-3 plants per square foot were established by removing seedlings not needed. Plots were single rows with guard rows on each side. There were 3 replications. Two harvests were made as beans reached market maturity. *Galinsoga* was cut at ground level, and fresh weight per plot recorded. Ashley stated that rainfall was ample as the experiment was being established, but did not mention moisture conditions during the course of the test.

The competitive effect of *Galinsoga* was considerable, particularly at its highest density (table 11). At that density, 2-3 weeds per square foot, bean yield was only about half that of the weed-free plots. As the density of *Galinsoga* changed, bean yield changed inversely, and the total fresh weight of *Galinsoga* recorded remained roughly the same for all plots. Similar losses in bean yield due to *Galinsoga* were found by Senesac and Minotti (1979), but under these same severe conditions redroot pigweed caused much greater losses. These findings are in sharp contrast to the opinions expressed by growers and extension agents, mentioned earlier. One factor that might account for this difference is that in Ashley's study, the in-row spacing of beans was only about half that used by many bean growers. Also, because growers cultivate beans, they rarely experience the severe conditions imposed in both these investigations.

Table 11. Effect of population of hairy *Galinsoga* on yield of snap beans

Galinsoga (No./ft²)		*Fresh wt. bean pods (lb/30 ft²)*	*Fresh wt. Galinsoga (lb/30 ft²)*
0		15.1	0.0
0.5-1		10.4	9.6
1-2		10.3	17.9
2-3		7.6	21.4
	LSD 0.05	1.8	2.1

Source: Data from Ashley (1972).

At Ithaca, New York, field studies with snap and dry beans in competition with *Galinsoga* and other weeds were reported by Hatfield, Warholic, and Sweet (1978). They found that a mixture of *Galinsoga* and redroot pigweed reduced yields of each bean type by about 20%. The density of weed stand was not recorded, and no

attempt was made to determine the relative loss caused by each weed species. Stilwell and Sweet (1975), also doing field studies at Ithaca, found that yield of seeded cabbage was reduced an average of 10% each of 2 years by a very dense, mixed stand of *G. ciliata* and *G. parviflora*. In unreported studies Warholic, Hatfield, and Sweet found that Hudson cultivar of potato, noted for its competitiveness (Yip 1975), was able to overwhelm *Galinsoga* in untreated plots and produced a normal crop. Nishimoto (personal communication 1977) stated that in Hawaii vine growth of tomato was reduced from 26 lb in weed-free plots to 20 lb in those heavily infested with *Galinsoga*. Fruit yields tended to parallel vine growth.

Factors in Competition

The results of the above research show that reduction in yield of vegetables from competition with *Galinsoga* varies from little or none with competitive crops to as much as 50% in snap beans under severe situations. No attempts were made to determine the causes for reduced yields. Ivany (1971) reported on a series of tests designed to elucidate the causes of competition from *Galinsoga*, and more recently Kahl and Ashley (1979) published some of their findings.

Plant population. The amount of space available to a plant usually influences its size and general morphology. Typically, under crowded conditions, plants make more elongated growth early, even though final height is not increased. In many species, growth of laterals is sharply curtailed. In *Galinsoga*, a reduction in growth of laterals could have a profound effect on reproductive capability because flowers are borne principally at the ends of laterals.

Two field experiments were conducted by Ivany (1971) to determine the influence of spacing on *Galinsoga* growth. In the 1st test, *G. ciliata* was grown on sandy loam, and in the 2d, both *G. ciliata* and *G. parviflora* were grown on silt loam. Both soils had been fertilized liberally for several years, and during the course of the tests irrigation was supplied whenever necessary. Thus, growth was excellent. Ivany transplanted seedlings at the 3- to 4-node stage into a rectangular pattern to obtain spacings of 15 x 15 cm and 60 x 60 cm. In the 2d test he also included 30 x 30-cm spacing. There were 16 plants per plot, and the innermost 4 were used for data. The experiments were designed as randomized complete blocks with 3 replications. About 3 weeks after transplanting, the tests were terminated, and data obtained on plant height and fresh weight, also on length of laterals. Visual observations were made on the morphology of laterals.

The results from both tests were similar. The most dramatic differences due to spacing were in fresh weight (tables 12 and 13). There was relatively little difference in plant height due to spacing. However, *G. parviflora* demonstrated its typical taller height than *G. ciliata's*. Ivany stated that although the weight of laterals was not taken, their morphology was strikingly different at the various spacings. Length was fairly constant (table 12), but diameter, number of nodes, degree of branching, and size of leaves increased as spacing increased. Particular attention should be given to the data on fresh weight per plant and fresh weight per unit area. Although in both tests weight per plant decreased significantly as spacing decreased from 3,600 to 225 cm^2/plant, the weight produced per unit area was increased

about 5- to 6-fold. From this, one could surmise that the degree of competition due to *Galinsoga* is likely to be highly dependent on population densities. Unfortunately, dry weights were not recorded by Ivany, and the question can be raised as to whether they would have followed the same pattern. However, considerable data, available in the literature by several authors, on a range of species indicate that in population density studies the trends are identical whether fresh weights or dry weights are used to determine the results (ragweed, Dickerson 1968; sweet corn, Stilwell 1976; dry beans, de Azevedo 1977; redroot pigweed, Muhammed 1978; yellow nutsedge, Yip 1978).

Table 12. Effect of spacing on the growth of *G. ciliata* on sandy loam soil

		Fresh wt		*Lateral length*		
				Node no.		
Spacing	*Height*	*per plant*	*per unit area*	*1*	*3*	*5*
cm	*cm*	*g*	*% of 60 x 60*		*cm*	
15 x 15	62	184	633	52	46	31
60 x 60	60	465*	100	50	45	35
LSD 0.05	n.s.	47.7	—	n.s.	n.s.	n.s.

*Laterals at the wide spacing were larger diameter, more branched, and had shorter internodes and larger leaves. They account for much of the increased weight.

Table 13. Effect of spacing on height and fresh weight of *Galinsoga* on silt loam soil

				Fresh wt.	
Species	*Spacing*		*Ht.*	*per plant*	*per unit area*
	cm	*cm²/plant*	*cm*	*g*	*% of 60 x 60*
G. cil.	15	225	61	482	523
G. par.	15	225	73	472	676
G. cil.	30	900	51	964	261
G. par.	30	900	68	889	300
G. cil.	60	3600	51	1474	100
G. par.	60	3600	67	1117	100
		LSD 0.05	7.8	224	—

Note: All plots contained 16 plants each, and data were taken on the inner 4.

Light intensity. In dense populations only the uppermost portions of plants are exposed to full light. In the spacing tests reported, light could have been the most-important factor causing reduction in growth. Ivany (1971) studied the effect of light intensity in growth chambers and greenhouses on both *G. ciliata* and *G. parviflora*, as well as tomato, cv. Heinz 1350. Information on the latter's response in comparison with that of *Galinsoga* could give some insight as to why it is often a problem in that crop. Because *Galinsoga* often becomes established while field tomatoes are in their early vegetative stage, Ivany used the seedling stage for both weeds and crop. Treatments involved a range of light intensities from 1,100 to 8,300 ft candles, and seedlings were grown at 16-hour days for either 3 or 4 weeks with these exposures. Measurements were made on plant height and on fresh and dry weight of aboveground growth. All 3 species responded similarly. Growth was slight at 1,100 ft candles, increased greatly between 2,200 and 5,200, but did not increase further at 8,300 ft candles. From these studies it can be concluded that neither tomato nor *Galinsoga* tolerates shading, and in the field the plant that becomes established first is likely to dominate that specific site.

Water. The ability of a species to compete in a mixed population may be related to its ability to obtain water from the soil. Water relations are extremely complex, and only in situations where roots thoroughly permeate the soil is there likely to be a relationship between a plant's ability to extract water and its competitiveness. Amount and pattern of root growth as well as water use per unit of dry weight produced are important additional factors that influence plant competition for water.

Ivany (1971) conducted a greenhouse test in the winter with 12-hour photoperiods in which natural light was supplemented by fluorescent tubes to provide abut 1,200 ft candles on a cloudy day. Temperatures were 26.5° C and 20° C, day and night, respectively. Styrofoam pots, 15 cm in diameter, were lined with relatively tall plastic bags and filled with 1,140 g of air-dry potting soil. Four hundred ml of tap water were added to each pot to bring the soil to saturation. Seeds of beans cv. California Light Red Kidney, sweet corn cv. Jubilee, and seedlings of both species of *Galinsoga*, which had been started in flats, were transplanted to the pots. Two weeks later all pots were thinned to one plant each, and on a weight basis all received sufficient water to bring them back to saturation. The plastic was then twisted about the base of the plant and fastened to prevent loss of water by evaporation. Every successive 3 days, pots were reweighed and appropriate amounts of water added. At time of the initial weighing, 2 plants of each species were harvested, and fresh and dry weights taken to determine increases. After 23 days the experiment was terminated, and gain in fresh and dry weights determined. The design was a randomized complete block with 3 replications of 3 plants each.

Sweet corn clearly was the most efficient of the 4 species in amount of water required per gram of dry matter produced (table 14). The other 3 species required nearly twice as much water per unit of dry weight. On the basis of water used per plant, beans required about 50% more than did the other 3 and must be considered highly consumptive. Only minor differences existed between the 2 *Galinsogas.*

A completely different approach to water use by *Galinsoga* was reported by Kahl and Ashley (1979). They compared the growth of *G. ciliata* with that of tomato, cv. Heinz 1350, in nutrient solutions of various osmotic strengths, which were obtained

Table 14. Gain in fresh and dry weight and water use by beans, sweet corn, *G. ciliata*, and *G. parviflora* over 23 days in the greenhouse during the winter

Species	*Fresh wt. gain*	*Dry wt. gain*	*H_2O added*	*H_2O/g dry wt.*
	g	*g*	*ml*	*ml*
Dry beans	61	10.1	3319	328
Sweet corn	86	12.3	2387	194
G. ciliata	50	5.2	2052	396
G. parviflora	43	5.9	2291	388
LSD 0.05	3.4	0.4	110	—

by additions of polyethylene glycol, mw 1,000. Stress levels were -0.5, -3, -5, -7, and -9 bars. They stated that both species responded generally as expected, that is, the greater the stress, the slower the rate of growth. However, the amount of growth retardation was less for *Galinsoga* than for tomato at any given level of stress. For example, tomato growth was significantly reduced at -5 bars, but -7 was required for a similar reduction in *Galinsoga*. Water potential in root xylem of tomato was reduced at -7 bars, whereas that of *Galinsoga* required -9 bars.

These data strongly suggest that soil moisture stress would be a limiting factor in tomato growth before it would be with *Galinsoga*, and as a result the latter would have a competitive advantage.

Nutrients. As mentioned earlier, Ivany (1971) studied the requirements of both *Galinsoga* species for major nutrients. Those tests did not give information as to how those species compare with crops. A partial answer is supplied by another experiment conducted by him in the greenhouse during the winter. Fluorescent lights were used to supplement normal low light, and the temperature was maintained at 26.5° C days and 20° C nights. Styrofoam pots 23 cm in diameter were lined with a plastic bag and filled with the appropriate nutrient solution. Plants received full or one-half levels of nutrients based on Hoagland's No. 1 (1950). They were covered with a plastic lid with 1 hole for the aeration tube and 3 for seedlings of tomato, *G. ciliata*, or *G. parviflora*. Nutrient solutions were added as needed for returning the container to the original level. After 24 days, distilled water was substituted for the nutrient solution, and plants were maintained in that medium for 10 more days. The test was then terminated, and fresh and dry weights were obtained for shoots and roots. The experimental design was a randomized complete block with 3 replications.

When given full nutrient solution, tomato and *Galinsoga* were similar in production of fresh weight of both tops and roots (table 15). With nitrogen reduced to one-half, fresh weights of tops of all 3 species were sharply decreased. Fresh weights of tomato and *G. ciliata* roots were not influenced, but *G. parviflora* roots were significantly increased in weight. With potassium reduced to one-half, results were similar to those with low nitrogen. In contrast, reduced phosphorus had no effect on fresh weights of either tomato or *G. parviflora* tops or roots, whereas

shoots, but not roots, of *G. ciliata* were decreased. Dry weights did not show the same results as fresh weights. For example, even though fresh weights of shoots of all 3 species were decreased by low nitrogen, dry weights were unchanged. Unexpectedly, dry weight of tomato roots was increased by decreased phosphorus. This suggests "normal" levels were too high.

Table 15. Fresh and dry weights of *Galinsoga* and tomato grown in various nutrient solutions for 24 days and distilled water for 10 days

	Fresh weight (g)					
	Tomato		*G. ciliata*		*G. parviflora*	
Treatment	*Shoot*	*Root*	*Shoot*	*Root*	*Shoot*	*Root*
Hoaglands No. 1	268	57	235	51	227	58
N/2	182	58	168	54	183	82
P/2	265	72	190	41	234	55
K/2	229	50	218	55	233	80
LSD 0.05	21.7	17	21.7	17	21.7	17
	Dry weight (g)					
Hoaglands No. 1	16.8	2.9	15.8	2.7	19.8	3.5
N/2	13.1	3.0	13.6	3.2	21.6	5.1
P/2	19.6	4.5	11.9	2.2	20.8	3.1
K/2	15.5	2.8	16.1	3.2	23.6	4.7
LSD 0.05	4.7	1.5	4.7	1.5	4.7	1.5

Note: N/2, etc., = one half the full amount of N in Hoagland's No. 1.

The nutrient work of Ivany is difficult to interpret either in relation to growth of a single species or in regard to the competitive ability of a species. Perhaps some of the unusual findings are due to the relatively poor light levels under which the studies were conducted or to inappropriate nutrient solutions. Another difficulty lies in the fact that the critical factors in crop competition with *Galinsoga* are not known. Fresh weight of tops could indicate how well a plant species might compete; but on the other hand, plant growth might best be measured on a dry weight basis, because this parameter is often the preferred measure of actual use of light and nutrients. In this context, dry weight may be the best measure of competitive ability, and on this basis perhaps *G. parviflora* is a better competitor than *G. ciliata.*

Root relations. The experiments with nutrient levels described do not answer questions concerning the importance of toxic root exudates or differential root absorptive ability. Three additional tests by Ivany (1971) provide considerable insight into both aspects. In one test a heavy stand of both *Galinsogas* was grown in

separate containers for a period of 50 days. Plant tops were removed at the soil line, and the containers seeded to either sweet corn or tomato. At the same time additional containers containing new mix were also seeded. The plants were allowed to grow for 50 days, then the tops were removed, and fresh weights taken. Both crops were severely retarded when seeded in used mix. Tomatoes made only 10% and sweet corn 25% as much growth as those in new mix. These results could mean that nutrients were depleted, that decaying roots adversely affected the carbon/nitrogen ratio, or that a toxicity factor was present in the used mix.

In a 2d test containers of *Galinsoga* were grown as before, and the tops removed. The used soil was carefully removed and cut in half from top to bottom, and each half was mixed with fresh mix and placed in new containers. Fresh mix was also placed in control containers. All were seeded to either sweet corn or tomato and fertilized with soluble complete fertilizer the same day. At weekly intervals all plants received additional applications of soluble fertilizer. Much of the detrimental influence from a previous crop of *Galinsoga* noted in the earlier test was overcome by the addition of fertilizer (table 16). There still was some retardation of sweet corn by *G. parviflora* and of tomato by *G. ciliata*. It must be concluded that *Galinsoga* roots have a slight influence on succeeding crop growth in addition to nutrient depletion.

Table 16. Growth of tomato and sweet corn in potting mix that had previously grown *Galinsoga* for 45 days

		Fresh weight per plant	
Previous species		*Sweet corn*	*Tomato*
		g	*g*
G. ciliata		19.0	3.7
G. parviflora		16.7	4.2
None		22.5	4.9
	LSD 0.05	4.8	1.1

Note: Previously used mix diluted with 50% new mix, before seeding sweet corn and tomato. All treatments fertilized at reseeding and weekly thereafter.

In a 3d greenhouse test in this series, waxed paper containers (7 x 7 x 11 cm) were used in a technique that permitted roots to be kept separate or to be intermingled, while tops remained separate. Soil volume was constant on a per plant basis, and spacing of tops was always the same. The tops of the containers were removed, and the containers were fastened together in dual units by taping. In some units adjacent sidewalls were removed to provide a 5 x 10-cm opening between the two containers. Units were filled with potting soil, and 2 seedlings of tomato cv. Heinz 1350, *G. ciliata*, and *G. parviflora* were transplanted into each half of the dual unit in all combinations. Seedlings were grown for 36 days and then harvested. Data were obtained on height and fresh weight. The test was designed as a randomized complete block with 3 replications.

When considered as a main effect, root situation, that is roots separate vs. together, was highly significant (table 17). Both height and fresh weight were usually improved by roots being allowed to intermingle, and there was no interaction with species pairing. Certainly under this particular set of conditions with these 3 species, allelopathy was not an important factor. On the other hand, sweet corn was not included; yet this species appeared to be damaged when planted into soil in which *Galinsoga* had previously grown. More study is needed to determine when, if at all, allelopathy can occur between *Galinsoga* and crop plants.

Table 17. Height and fresh weight of *Galinsoga* and tomato when grown with roots together or separate

*Pairing species**		*Roots*	*Height (cm)*			*Fresh weight (g)*		
			T	*Cil*	*Par*	*T*	*Cil*	*Par*
T	T	together	18	—	—	48	—	—
		separate	15	—	—	34	—	—
T	Cil	together	19	38	—	38	34	—
		separate	15	34	—	36	28	—
T	Par	together	19	—	54	36	—	37
		separate	16	—	52	32	—	32
Cil	Cil	together	—	36	—	—	29	—
		separate	—	39	—	—	34	—
Cil	Par	together	—	34	46	—	23	26
		separate	—	32	45	—	24	28
Par	Par	together	—	—	49	—	—	27
		separate	—	—	42	—	—	23
		LSD 0.05	4.5	4.5	4.5	8.0	8.0	8.0

*T =tomato; Cil = *G. ciliata*; Par =*G. parviflora*.

Chemical Control

Several characteristics of *Galinsoga* contribute to the difficulty in obtaining control as well as to aiding in its rapid establishment as an important species, once it has made an appearance in fields devoted to vegetable crops. These include

- emergence of seedlings throughout the growing season;
- lack of sensitivity to photoperiod, which permits flowering and seed formation the entire season;
- lack of dormancy in most newly formed seeds, which permits germination soon after they drop to the soil;
- ability to root and form new plants from cut pieces; and
- tolerance for many of the principal herbicides used in vegetable crops.

Response to Herbicides

A summary of *Galinsoga* response to herbicides is presented in table 18. Agronomists, horticulturists, and others should use this table as a starting place in selecting chemicals that might aid in developing controls in specific situations. No attempt has been made to indicate either the crops that have official approved status or the rates of application, because crops are added or removed from original labels and rates of application may vary according to crop, soil, rainfall, and timing. Herbicides marked "poor" are unlikely to control *Galinsoga*, regardless of dosage or timing. "Variable" chemicals sometimes are effective. Those listed as "good" are consistently active against *Galinsoga* when used at recommended rates and timings.

Table 18. Response of *Galinsoga* to herbicides

Chemical		*Time of*		*Source of*
Common name	*Trade name*	*application**	*Control§*	*data*
alachlor	Lasso	pre,e.post	G	Ashley 1972
atrazine	AAtrex	pre,e.post	G	Ivany 1971
benefin	Balan	ppi	P	Braden & Cialone 1970
bensulide	Prefar Betasan	ppi	P	Romanowski 1974
bentazon	Basagran	post	V	Ashley 1972
bifenox	Mowdown	pre,e.post	G	McLaughlin & Sweet 1974
butralin	Amex	ppi	P	Stilwell & Sweet 1975
butylate	Sutan	ppi	G	Hughes & Sweet 1978
CDEC	Vegadex	pre	V	Braden & Cialone 1970
chloramben M.E.	Vegiben	pre	P	Ashley 1972
chlorbromuron	Bromex Maloran	pre,e.post	V	Cialone et al. 1970
chloroxuron	Norex Tenoran	pre,e.post	G	Cialone et al. 1970
chloramben	Amiben	pre	P	Boldt & Sweet 1972
chlorpropham	Furloe Chloro-1PC	pre	P	Sanok & Dallyn 1970
cyanazine	Bladex	pre,e.post	G	Hughes & Sweet 1978
DCPA	Dacthal	ppi,pre	P	Hargan et al. 1862
diclofop	Hoelon	pre,e.post	P	Rao & Sweet 1977
dinitramine	Cobex	ppi,pre	P	Stilwell & Sweet 1975
dinoseb	Premerge	pre,e.post	G	Ivany 1971
diphenamid	Dymid Enide	ppi,pre	V	Ivany 1971
EPTC	Eptam	ppi	V	Ivany 1971
ethalfluralin	Sonalan	ppi,pre	G	Mohammed & Sweet 1976
fluchloralin	Basalin	ppi	P	Hatfield et al. 1978

(continued on next page)

Table 18. Response of *Galinsoga* to herbicides *(cont.)*

Chemical		*Time of*		*Source of*
Common name	*Trade name*	*application**	*Control§*	*data*
flurodifen	Preforan Soyex	pre	G	Ashley 1972
H22234	Antor	pre	G	Mohammed & Sweet 1976
H26910		pre	G	Hatfield & Sweet 1977
linuron	Lorox	pre,e.post	G	Hargan et al. 1962
stoddard solvent	Many brands	pre,e.post	G	Warholic & Sweet 1977
metolachlor	Dual	pre	G	Mohammed & Sweet 1976
metribuzin	Sencor Lexone	pre,e.post	G	Boldt & Sweet 1972
naptalam	Alanap	ppi,pre	P	Romanowski 1974
napropamide	Devrinol	ppi,pre	G	Mohammed & Sweet 1974
nitralin	Planavin	ppi	P	Stilwell & Sweet 1975
nitrofen	TOK	e.post	P	Braden & Cialone 1970
oryzalin	Surflan	ppi,pre	G	Hatfield et al. 1978
paraquat	Paraquat CL	e.post	G	Romanowski 1974
pebulate	Tillam	ppi	G	Mohammed & Sweet 1974
pendimethalin	Prowl	ppi,pre	G	Hatfield et al. 1978
profluralin	Tolban	ppi	P	Stilwell & Sweet 1975
propachlor	Ramrod	pre	G	Sanok & Dallyn 1970
trifluralin	Treflan	ppi	P	Braden & Cialone 1970

*ppi = preplant incorporated; pre = preemergence; e.post = early postemergence; post = postemergence.
§G = good control; P = poor, i.e., generally not acceptable; V = control is variable.

Control in Specific Crops.

Not until about 1970 did more than a few investigators begin reporting detailed studies on control of *Galinsoga.* Most of these experiments emphasized control with herbicides, and no definitive work has been reported on seed longevity, mechanical controls, rotations, and the like.

Beans. In tests with snap beans, Ashley (1972) evaluated 15 named or numbered herbicides applied preplant incorporated (ppi), pre- or postemergence, depending on the preferred time for a given chemical. He obtained good control of *G. ciliata*

without crop damage from alachlor, dinoseb, and EPTC. Seven dinotroaniline herbicides were tested by Hatfield, Warholic, and Sweet (1978) against *Galinsoga* in both snap and dry beans. Oryzalin and pendimenthalin were effective and safe on both crops. Except for high rates of dinitramine, which was injurious, other herbicides were safe but ineffective. Dinoseb is very effective on *Galinsoga* (Ivany 1971) and safe on beans and probably should be one of the principal controls.

Cabbage and broccoli. When these two crops are planted late in the season for a fall crop, the fields usually are tilled several times before planting. Under these circumstances neither *Galinsoga* nor other weeds are likely to be problems. On the other hand, early plantings are much more vulnerable. Stilwell and Sweet (1975) reported on 3 experiments with early field-seeded cabbage and broccoli, designed specifically for control of both *G. ciliata* and *G. parviflora.* They used several herbicides applied at 1 to 5 different times from ppi to late postemergence. The experiments each had 35 to 50 treatments. The only herbicide consistently safe and effective was alachlor at 1.0 lb per acre (about half the normal rate) applied either preemergence or early postemergence to the weeds. An unusual but safe effective treatment was ammonium nitrate fertilizer applied at the rate of 50 lb of N as a liquid spray when *Galinsoga* was less than 3 inches tall and the crops had 3-4 true leaves. In 2 years' work with 7 dinitroanilines, Hatfield, Warholic, and Sweet (1978) found that only oryzalin and pendimenthalin were effective on *Galinsoga*, but both herbicides were injurious to cabbage.

Carrots and parsnips. Stoddard solvent, a standard herbicide for carrots and parsnips for 30 years, is effective against *Galinsoga* only when it is in the cotyledon stage, according to Havis (1949) and Dallyn (1950). DCPA and trifluralin are effective against several grasses and broadleaves and are tolerated very well by both carrots and parsnips, but neither controls *Galinsoga.* Linuron is very active against *Galinsoga* and many other weeds, but is toxic to seedling crops at normal rates. If spraying is delayed until carrots and parsnips are large enough to tolerate linuron, *Galinsoga* and other weeds often overwhelm the crops. Rao and Sweet (1977) reported several experiments in which linuron at rates as low as 4-8 oz per acre controlled *Galinsoga* if applied when the weeds were emerging or in the tiny seedling stage. If new flushes of *Galinsoga* emerged, repeat applications were safe. Carrots and parsnips, regardless of size, tolerated linuron at these low rates.

Cucurbits. Few herbicides are recommended for use in cucurbits in the northeastern states. Bensulide, butralin, dinoseb, and napthalam, either singly or in combination, are mentioned by several states. Unfortunately, only dinoseb is effective against *Galinsoga* (Ivany 1971), and it sometimes causes crop damage. Where mulching is feasible and economic, black plastic film will provide excellent control (Topoleski 1976).

Lettuce. Romanowski (1974) evaluated herbicides for controlling *Galinsoga* on mineral soils. He tested 25 different herbicides and found none effective and safe on lettuce. Tanaka et al. (1975) evaluated 9 herbicides for *Galinsoga* control in lettuce

in Hawaii. Two were injurious to the crop, and 7 failed to control the weed. These poor results were perhaps to be expected because *Galinsoga* and lettuce are both composites. Romanowski (1974) recommended that, because herbicides were either ineffective on *Galinsoga* or toxic to the crop, a "stale seedbed" technique be used. In this method the field is prepared for planting, but seeding is delayed for several days until *Galinsoga* and other weeds emerge. They are then killed with a contact nonresidual herbicide such as paraquat. Seeding is done just before or just following chemical application.

Onions. Weed control in transplanted onions on mineral soils was investigated by Sanok and Dallyn (1970, 1971). They obtained excellent control of *Galinsoga* with either chloroxuron or propachlor, whereas DCPA and chlorpropham were ineffective. More recently Sanok, Selleck, and Creighton (1979) stated that propachlor followed by repeated applications of nitrofen was effective and safe on seeded onion. On muck soils Warholic and Sweet (unpublished results in New York) have had good results with CDAA. This herbicide is unsatisfactory on mineral soils with less than approximately 10% organic matter, because of its high volatility and solubility. It is adsorbed when organic matter levels are high to an extent that it is an effective herbicide.

Peas. The standard chemical for weed control in peas grown in the northeastern United States is dinoseb at low rates postemergence to both weeds and crops. It is highly effective against *Galinsoga* as well as other broadleaves, but is ineffective against annual grasses. Dinitroanilines are generally excellent grass killers. Hatfield, Warholic, and Sweet (1978) reported that all 7 herbicides in this class that they evaluated were safe on peas and effective on grasses. One material, oryzalin, also controlled *G. parviflora.*

Potatoes. Much of the potato acreage in the northeastern United States is treated preemergence with alachlor, dinoseb, or linuron, singly or in combination. More recently growers are also using metribuzin. All 4 herbicides are effective against *Galinsoga*, and the crop is intertilled several times. Furthermore, competitive cultivars such as Hudson can overwhelm any *Galinsoga* seedlings that escape the herbicides and tillage (Yip 1975).

Tomatoes. Seeded tomatoes were reported to be excessively injured by all 7 dinitroanilines tested by Hatfield, Warholic, and Sweet (1978). Nishimoto (personal communication) as well as Mohammed (1978) stated that metribuzin at 2-4 oz per acre controlled *Galinsoga* if applied while the weeds were emerging or were in the small seedling stage. On large *Galinsoga* higher rates of metribuzin were required and sometimes injured the crop. Ivany (1971) found that diphenanid applied preplant incorporated or preemergence gave erratic control. Mohammed (1978) showed that low rates of diphenamid at time of seeding, followed by low rates of metribuzin as needed, provided a safe and effective control program.

Strawberries. Very little literature exists on control of *Galinsoga* in strawberries. Two herbicides often used for a mixture of weed species are diphenamid and chloroxuron, applied singly or in combination. Beste (personal communication) treated dormant strawberries, cv. Sunrise, in March and recorded *G. parviflora* stands 2 and 3 months later. In the control there was a moderate stand of 2 per square foot. Diphenamid gave poor control with 20% reduction after 2 months and no control after 3 months. Chloroxuron, either alone or in combination with diphenamid, gave 100% control after 3 months.

Nonchemical Controls

No specific research on nonchemical controls of *Galinsoga* was conducted under the NE-42 (revised) project, and no references to such studies were found in the literature. Some suggestions can be made based on field observations and the results from the studies on seed formation, germination, dormancy, and rooting from cut stems. If done in a timely manner while populations are still minor, cultivation and hoeing would be economically feasible in high-value crops. Crop rotation, particularly when coupled with rotation of herbicide families, is likely to be highly beneficial. For example, in fields that are part of the Cornell Vegetable Research Farm, rotations with potatoes, tomatoes, and sweet corn and linuron, metribuzin, and atrazine herbicides, respectively, have been carried out plus several cultivations. Infestations have been contained at levels well below those that cause crop damage or interference with harvesting. On the other hand, fields limited to snap or dry beans, beets, cucumbers, and other vine crops, as well as the crucifer crops, which are mechanically cultivated but receive herbicides such as EPTC and trifluralin, quickly develop infestations that interfere with harvest. *Galinsoga* can quickly get out of hand where only mechanical controls are used, and most commercial growers use herbicides as their principal control method.

Summary and Conclusions

Information was presented on *Galinsoga parviflora* Cav. and *G. ciliata* (Raf.) Blake, 2 species generally conceded to be the most important in the genus. Aspects included were nomenclature, origin, distribution, anatomy, morphology, growth, flowering, competitiveness, and control. Much of the material was generated at Cornell University and the University of Connecticut with funds from Regional Project NE-42 (revised). Pertinent findings from other investigations were also reported.

G. parviflora is universally accepted as the name of one species, but Europeans and Americans differ as to the name of the other. In the United States and Canada *G. ciliata* has been the usual designation, whereas in Europe *G. quadriradiata* has been customary. Recent thorough taxonomic studies concluded that *G. quadriradiata* was to be preferred. The author chose to continue with *G. ciliata* when that designation was used by the person whose work was cited.

Authorities differ somewhat as to the place of origin of *Galinsoga*, but agree that it came either from the mountains of Mexico or from those of Peru and surrounding regions. It was introduced into Europe and the United States, perhaps in the late

1700s, and presently is also well established in Africa, Australia, India, Japan, various Pacific islands, and the Philippines. In North America, in addition to Mexico, *Galinsoga* occurs from Maine and southern Ontario to Georgia and westward to the Pacific, particularly in the coastal areas of Oregon.

A somewhat unusual anatomical feature is the presence of oil-bearing structures. Plant species with these are fairly tolerant of petroleum herbicides such as stoddard solvent. The $2n$ chromosome number of *G. ciliata* is 32 and that of *G. parviflora* 16. Reports of $2n$ being 32 for *G. parviflora* are undoubtedly due to incorrect identification.

The overall appearance or morphology of *G. ciliata* and *G. parviflora* differs somewhat. The former is shorter and much more dense or compact because of its shorter internodes and one less node before termination in a flower head. Also the stems and petioles of *G. ciliata* are thicker, and its leaves slightly larger than those of G. parviflora. Leaves of *G. ciliata* tend to be slightly more ovate than those of *G. parviflora*. All plant parts of *G. ciliata* are much more hairy than those of *G. parviflora*; one investigation found this to be true by a factor of about 20.

Dormancy was not a controlling factor in seed germination. Seedlings emerged throughout the growing season, but in the Northeast emergence was greatest in late May and early June. Fresh seed germinated at least 90% and sprouted within a few days of falling to the soil surface. No seedlings emerged from depths below 1.5 cm. Light was required for good germination of fresh seed, but not for that several months old.

For the first 10-15 days after emergence, growth of *Galinsoga* was relatively slow. By this time the first true leaves had developed, and soon growth became rapid and was sustained at a high rate for 6-8 weeks. Approximately 40-45 days after emergence, the main stem of *G. ciliata* had developed 6 nodes and *G. parviflora* 7, and both terminated in flower heads. At 4 and 5 nodes, respectively, laterals emerged at the more basal nodes; and as the main stems developed, the laterals emerged at other nodes and followed the same course of development with termination in flower heads. This process was repeated continuously until frost. There was no response to photoperiod. In open areas plants generally were about twice as wide as tall; in restricted situations lateral growth and branching were greatly reduced, but plant height remained about the same. Viable seeds were formed 8-12 days after the first visible signs of flower buds. Seeds dropped to the ground within a few days of maturation, and sprouting began within 2-3 days if soil surface moisture was adequate. The new seedlings followed the same course in growth and development as the original plant. A new generation required 6-7 weeks for seed maturation and frequently occurred 3 times a growing season in central New York and 4-5 times in the mid-Atlantic States.

Competition to vegetables from *Galinsoga* was only about one half as severe as that from redroot pigweed under similar conditions. In water use per gram of dry weight produced, *Galinsoga* was only half as efficient as sweet corn, but equal to beans. Water stress was much less damaging to *G. ciliata* than to tomato. Reductions in levels of light and levels of major mineral nutrients caused about the same responses in *Galinsoga* as in tomato. There was no evidence of an allelopathic factor in competition between *Galinsoga* and vegetables. The principal losses in vegetables from competition with *Galinsoga* appear to be due to inefficiencies at harvest rather than to losses in crop yield or quality.

Research on controls for *Galinsoga* has dealt exclusively with herbicides. No

studies have been reported on the value of nonchemical methods such as tillage, mulching, cropping systems, and rotations. Many labeled herbicides have been evaluated for their toxicity to *Galinsoga*, and the results have been summarized in tabular form in the text. In crops such as corn, soybeans, dry and snapbeans, and potatoes, several safe, effective herbicides are available. However, many vegetables are damaged by herbicides toxic to *Galinsoga*, and those safe on the crops often are ineffective against *Galinsoga*.

Several special characteristics of *Galinsoga* make it difficult to control:

- Tolerance to most herbicides safe on vegetables
- Lack of response to photoperiod, thus permitting both vegetative growth and flowering throughout the growing season
- Lack of dormancy in fresh seed
- Ability of seed to germinate on the soil surface
- Ability to form roots on cut pieces

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