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Prospects for Biological Control of Velvetleaf (*Abutilon theophrasti*)

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Abstract

Velvetleaf, an annual malvaceous plant, is thought to be native to the People's Republic of China (PRC). Its historical use as a fiber crop may date back to 2000 B.C. The fiber has been used for rope, cordage, bagging, coarse cloth, fishing nets, paper stock, and for caulking boats. Introduction into North America may have occurred in the 17th Century as colonists searched for fiber sources. Although a commercial failure in the new world, velvetleaf thrives today as a major weed of maize, soybeans, and cotton. Yearly control costs in the U.S.A. are estimated to exceed $343 million. Control by biological means may be a method that will reduce velvetleaf's negative impact on U.S.A. agriculture. Recent surveys in India indicate that biotic agents associated with the plant are causing some degree of stress to vegetative and reproductive tissues. Further studies are underway in India to elucidate specificity and efficacy of these biotic agents, and relationships between agent and weed. Additional surveys are needed to find other natural enemies of velvetleaf in the PRC and adjacent territories. At the completion of these surveys, prospects for biological control of velvetleaf can be properly evaluated.

Les Perspectives de la Lutte Biologique Contre l'*Abutilon theophrasti* ('Velvetleaf')

On croit que le 'velvetleaf' (feuille-veloutée) une plante malvacée annuelle, soit indigène de Chine (RPC). L'usage historique de cette plante, comme fibre de culture, pourrait remonter à 2000 avant J.C. La fibre a été utilisée dans la fabrication de cordes, cordages, toile à sac, filets de pêche, et pâte à papier, ainsi que pour le calfeutrage des bâteaux. L'introduction en Amérique du Nord pourrait remonter au 17ième époque, où les colons cherchaient des sources de fibre. Quoiqu'ayant fait échec commercialement au nouveau monde, le 'velvetleaf' prospère aujourd'hui comme mauvais herbe importante parmi le maïs, le soya et le coton. Aux États-Unis, la lutte annuelle coute, on estime, plus de $343 million. La lutte biologique contre le 'velvetleaf' pourrait réduire ses effets négatifs sur l'agriculture américaine. Des enquêtes récentes en Inde ont indiqué que des agents biotiques en association naturelle avec cette mauvaise herbe sont à l'origine de certains pressions sur les tissus végétatifs et reproductifs. D'autres études sont en cours en Inde pour élucider la spécificité et l'efficacité de ces agents biotiques et pour définir leurs relations avec la mauvaise herbe en question. D'atures enquêtes serraient nécessaire en Chine et dans les territorires voisins pour découvrir d'autres ennemis naturels du 'velvetleaf', à la suite desquelles on pourrait évaluer de façon plus sûre les perspectives de la lutte biologique contre le 'velvetleaf'.

Introduction

Abutilon theophrasti Medik. (Malvaceae), is commonly called velvetleaf in the United States. It has also been called buttonweed, butterprint, Indian mallow, abutilon hemp, and Chinese jute. The species was originally described from India in 1787 (Il'in 1949; Riedl 1976). Synonyms are: *Abutilon avicennae* Gaertn. [1791], *Sida abutilon* L. [1753], *Sida tiliaefolia* Fisch. [1808], *Abutilon abutilon* (Linn.) Huth. [1893], *Sida mollis* Pavolini [1908], *Abutilon molle sensa* Dunn [1911], and *Abutilon avaricennae* var. *genuina* Skvortzow [1930].

Velvetleaf is a cool temperate annual with a simple erect stem which may grow to 4 m (Fig. 1). The large alternate, long petiolate leaves are broadly ovate, deeply cordate, long acuminate, crenate, green on both sides, and velvety with a dense covering of stellate hairs. The pale yellow flowers have five petals which are slightly notched apically and the calyx is cleft to or just below the middle. The flowers are borne on both the main stem and short terminal branchlets in racemes or, in the case of large plants, in racemose-paniculate inflorescences. The seed pods contain 12–15 carpels, are densely covered with soft bristles, and are tipped by aristate recurved beaks. The pod is mostly black at maturity (Il'in 1949) (Fig. 1).

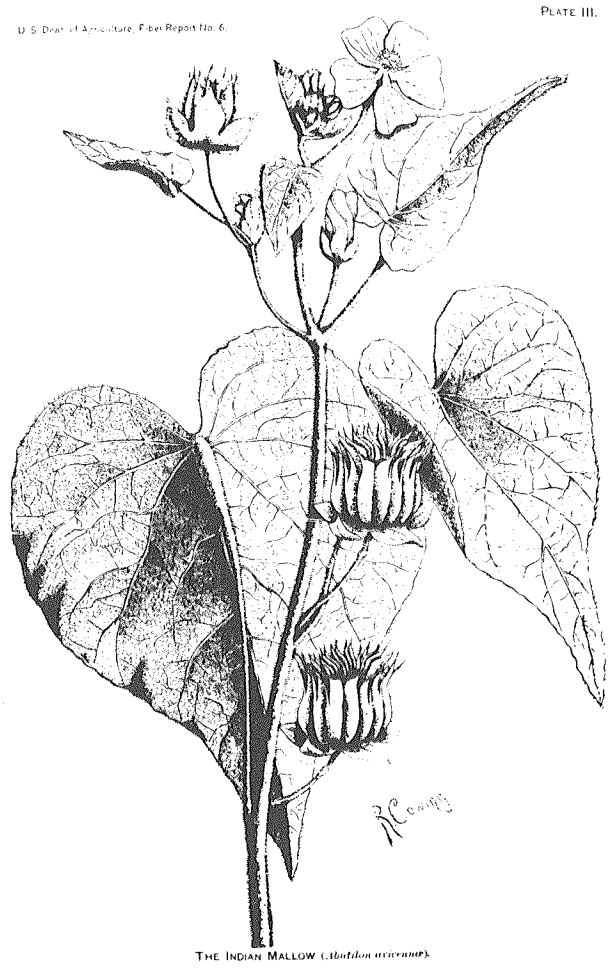

Fig. 1. *Abutilon theophrasti* Medik. from USDA fiber Report No. 6, 1894 (*A. avicennae* Gaertn. = *A. theophrasti*).

China is stated to be the origin of velvetleaf according to Vavilov (1951) and Li (1970). Locality records obtained from U.S., Asian, and European herbaria were used by the senior author to obtain an indication of the distribution of the plant in China. The majority of the collections had been made between latitude 30° N and 34° N in a band from the East China Sea to Northern Burma (Fig. 2).

According to Kirby (1963), velvetleaf is generally cultivated in China along with other crops, such as sorghum and winter wheat. The plants are harvested when in full

flower and the whole plants are retted in water for the extraction of the fiber from the stem. Velvetleaf fiber grown in China and possibly Russia is used domestically and not exported. Prior to World War II, however, a considerable amount of this fiber was exported from China to Japan, Great Britain, and Germany (Dempsey 1957).

According to Hu (1955), the species is 'cosmopolitan in the temperate region of the northern hemisphere' and in China, *Abutilon theophrasti* var. *chinensis* (Skvortzow) with green stems is cultivated extensively while *A. theophrasti* var. *nigrum* (Skvortzow) with reddish-black stems is less common. In the USSR, *A. theophrasti* occurs as a weed of cotton, millet, and other crops and is usually found in the southern steppe and desert zones, in field margins, gardens, parks and river valleys (Il'in 1949).

The distribution of velvetleaf seed throughout the Northeast and North Central U.S.A. occurred as a result of the attempted use of the plant as a source of domestically grown fiber.

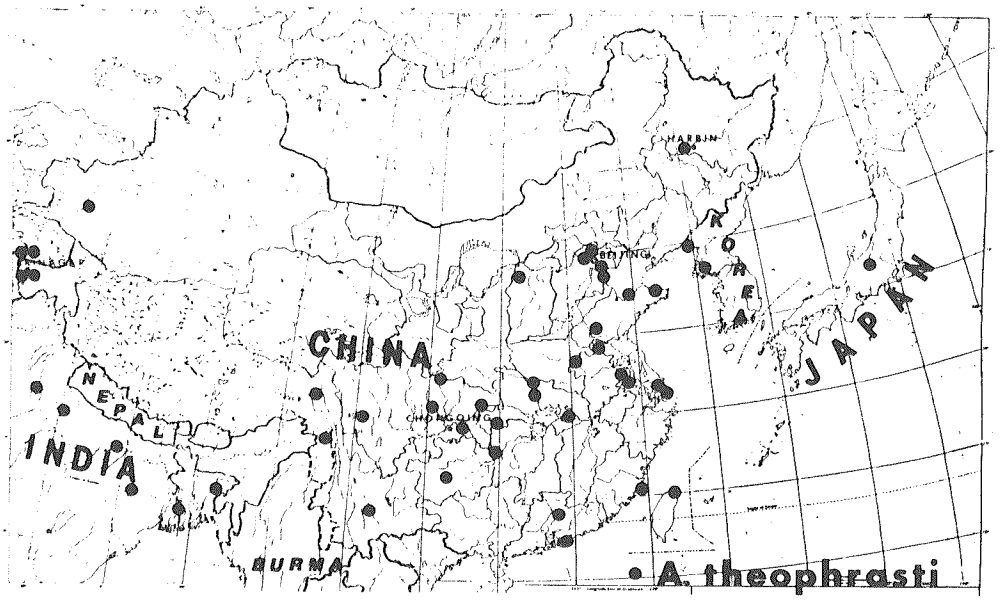

Fig. 2. Distribution of velvetleaf from India, through the People's Republic of China to Japan. Localities determined by herbaria records.

Velvetleaf was probably introduced into North America before 1700 as a potential source of fiber (Spencer 1984). Periodic attempts were made to establish velvetleaf as a fiber crop in the U.S.A. until 1972 (Dempsey 1975; Spencer 1984). These trials, over a period of *c.* 300 years, were unsuccessful and there are no records of velvetleaf as a commercial fiber crop in North America.

The plant appears well adapted to the temperatures, rainfall and soils of the major maize and soybean production areas of the U.S.A. Velvetleaf was estimated to be a weed problem in 33% of the maize and 38% of the soybean production land in 21 States of the midwestern U.S.A.; this weed was estimated to have cost farmers $343 million in control efforts in 1982 (Spencer 1984). Khedir and Roeth (1981) calculated that each velvetleaf plant in infested fields surveyed in Nebraska contributed *c.* 40 viable seeds to the seed population in the soil. Winter (1960) determined that undisturbed velvetleaf plants may produce 8000 seeds/plant. Inter- and intra-specific

competition, seed predation, environmental factors and agronomic practices affect potential velvetleaf reproduction by limiting the number of viable seeds each plant contributes to the soil 'bank'. These seeds may remain viable for 20–50 years (Ewart 1908; Muenscher 1955).

Although we have information on the cost and extent of the problem in North America, we know very little about the weediness of velvetleaf in other areas where it has been introduced. Velvetleaf was reported to be found through the Middle East, North Africa, Europe, Scandinavia, and South America (Kirby 1963; Dempsey 1975; Spencer 1984). This distribution may be due to widely scattered attempts to use velvetleaf as a fiber crop.

Dempsey (1975) listed insects attacking *A. theophrasti* in different countries. These insect species are polyphagous, attacking cotton and other economic plants in and outside the family Malvaceae. Records of velvetleaf's insect enemies compiled by CIBC (1976) also showed them to be polyphagous with their host-plant range including economic plants.

Velvetleaf was one of several weeds targeted for biological control research in a joint PL-480 project between Dr. K.E. Frick, USDA/ARS, Stoneville, MS, and the CIBC Laboratory in Rawal Pindi, Pakistan. This project (#FG-PA-259) was conducted from 1975–80. Researchers in Pakistan found velvetleaf in low numbers in the Chitral Valley, north of Rawal Pindi and west of the Kashmir, India border.

On the request of N.R. Spencer and with funding from the International Research Division, Office of International Cooperation and Development, U.S. Department of Agriculture, Dr. Shashi B. Babbar searched books and periodicals in India for references to *A. theophrasti*. The following libraries were visited:

A. New Delhi
   1. Centre of Advanced Studies Library, Department of Botany, University of Delhi.
   2. Science Library, University of Delhi.
   3. Central Library, University of Delhi.
   4. Library, Indian Agricultural Research Institute.

B. Dehra Dun
   1. Central Library, Forest Research Institute and Colleges (FRI&C).
   2. The Library of Systematic Botany Branch, FRI&C.

C. Howrah
   1. Reference Library, Botanical Survey of India (BSI), Indian Botanic Garden.
   2. Central Library, BSI, Indian Botanic Garden.

D. Calcutta
   1. Library of the Industrial Section of BSI at Indian Museum.

E. Srinagar
   1. Library of Botany Department, Kashmir University.
   2. Central Library, Kashmir University.

A total of 564 botanical works were found and scanned for information on *A. theophrasti* (citations to earlier names were also examined). Of these, only 46 contained references to *A. theophrasti*. Dr. Babbar visited five herbaria and recorded the collection sites of *A. theophrasti* specimens. These herbaria were:

1. Herbarium of the Botanical Survey of India, Dehra Dun.
2. Herbarium of the FRI&C, Dehra Dun.
3. Central National Herbarium, BSI, Indian Botanic Garden, Howrah.
4. Herbarium of the Industrial Section of the BSI.
5. Herbarium of the Botany Department, University of Kashmir, Srinagar.

A total of 24 localities were identified as sites where *A. theophrasti* had been collected. Velvetleaf reported from localities such as Calcutta and Bombay may have been plants grown at botanical gardens. Chandrabose (1973) reported *A. theophrasti* from Coimbatore, the most southerly record for India. Fig. 2 shows the more northern sites in India and Pakistan, as well as the PRC, where *A. theophrasti* has been recorded. The 24 localities given for *A. theophrasti* are shown in Table 1.

Velvetleaf in India

Published records of *A. theophrasti* in India go back more than 200 years. Roxburgh (1832) described it as *Sida abutilon*, as 'a native of various parts of India, though not common'. He reported velvetleaf seed was received from Peking (*sic*) and cultivated in the (then) Bengal Province as a substitute for hemp and flax. The species was grown in the former East India Company's Botanical Garden, Calcutta, and in the Serampore Botanical Garden in the late 18th and early 19th centuries (Voigt 1844). Hooker (1875) included 12 species of *Abutilon* from India, naming *A. theophrasti* as *A. avicennae*, while Watt (1889) mentioned this species as one of the seven Indian *Abutilon* spp. of economic

Table 1. Localities where *Abutilon theophrasti* Medik. was identified from literature references and herbaria references.

I. **India**
- A. Jammu and Kashmir
  1. Muzaffrabad Town
  2. Lower Kishen Valley
  3. Wular Lake
  4. Gulmarg
  5. Jhelum River
  6. Srinagar
  7. Sambar
- B. Haryana
  1. Daryapur, Hissar
  2. Karnal
- C. Uttar Pradesh
  1. West of Bijnaur
  2. Domakhand, Gorakhpur
- D. Rajasthan
  1. Aklera Road, Khanpur
- E. West Bengal
  1. Calcutta
- F. Maharashtra
  1. Bombay
- G. Tamil Nadu
  1. Valankulum, Coimbatore

II. **Pakistan**
1. Rawalpindi
2. Chitral
3. Tartora (Khyber)
4. Kurram

III. **Afghanistan**
1. Guzar Bash
2. Mazar-i-Sharif
3. East Turkestan
4. Kashghar

IV. **Bangladesh**
1. Dacca

importance. The latter author believed it to be native to northwest India, Sind (now in Pakistan) and Kashmir, with its distribution extending to North Asia, South Europe, and North America. Until Chandrabose (1973) published a short note on velvetleaf's occurrence in Coimbatore, Tamil Nadu, where he had collected specimens in 1968, the species was only known from widely separated localities in Northern India, such as Gorakhpur in Eastern Uttar Pradesh (Kanjilal 1966), Daryapur in Haryana (Nair 1978), and Gulmarg in Jammu and Kashmir (Singh and Kachroo 1976). Prain (1903) remarked that *A. theophrasti* was somewhat rare in Bengal and Dacca (now in Bangladesh). The Central National Herbarium of the BSI, Howrah (Calcutta) has specimens from Khanpur in Rajasthan and Sambal in Jammu and Kashmir.

The only available reference to *A. theophrasti* (as *A. avicennae*) in Nepal is by Lancaster (1981). Surveys in Nepal by one of us (Sankaran) showed *A. theophrasti* was

not found or even known there and that Lancaster (1981) had mistaken the widely cultivated and better known Indian jute *Corchorus* (Tiliaceae) for *A. theophrasti.*

The relative scarcity of *A. theophrasti* on the Indian subcontinent pointed to the need for surveys to locate the species wherever it occurs and to investigate possible causes for its rarity, particularly any natural enemies that keep velvetleaf's population reduced and scattered. On the basis of earlier distribution records, surveys were conducted by one of us (Sankaran) during 1983–84 in several areas of India, including Calcutta and Darjeeling (West Bengal), Coimbatore (Tamil Nadu), Dehra Dun, Gorakhpur and Varanasi (Uttar Pradesh), Khanpur (Rajasthan), Gulmarg and Srinagar (Jammu and Kashmir), Diphu, Gauhati, Jorhat, Lakhimpur and Sibsagar (Assam), Shillong (Meghalaya) and Itanager (Arunachal Pradesh). Botany Departments of the Universities in these areas were queried, including those in Gorakhpur, Jorhat, Kalyani, Shillong, Srinagar and Varanasi.

A. theophrasti was seen only in Coimbatore and in the area surrounding Srinagar. All the plants seen in the Kashmir Valley had green stems like *A. theophrasti* var. *chinensis.* Singh and Kachroo (1976) did not mention the presence of the species in Srinagar.

In Coimbatore, *A. theophrasti* was present in a small localized patch of wetland, which is part of a temporary lake, that remains flooded for over six months in the year. This land is used for growing vegetables, and the weed occurred as stray plants along the margin of vegetable plots.

Phenology of *Abutilon theophrasti* in the Kashmir Valley

Field observations during July–October 1983 provided information on the phenology of *A. theophrasti* in the Srinagar area of the Kashmir Valley. During a typical year, *A. theophrasti* will germinate in May or June; however, in 1983, germination had been delayed by a cool spring and the growing period was further shortened by snows in October. The first visit to Srinagar was made in early July 1983. A late spring with the minimum temperatures *c.* 12°C retarded plant growth. Most *Abutilon* plants were less than 25 cm high and in early vegetative growth although few were 38–45 cm high and had begun to flower. Cultivation of maize, grain legumes, and rice had started by this time.

During the second visit in early September, velvetleaf plants in many areas had reached their maximum vegetative growth (*c.* 150 cm), with large leaves, conspicuous flowers and fruit capsules. Some fruit capsules were mature and about to dehisce. In mid-October, plants in most areas visited were in final stages of their annual cycle. The majority of fruit capsules had shed their seed and leaves were turning yellow. Maize had been harvested and left-over *Abutilon* plants were very prominent in the fields. Rather early for the year, the Kashmir Valley experienced its first snowfall in October 1983.

Heavy snowfall during winter is common in the Kashmir Valley. After the onset of spring, when soil temperature and moisture levels become favourable, overwintering *A. theophrasti* seeds germinate. In the USSR flowering occurs during July–September and fruiting during August–October (Il'in 1949).

Insects Associated with Velvetleaf in India and Pakistan

The CIBC (PL-480 project #FG-PA-259) carried out a survey for natural enemies of several weeds including *Abutilon* in Pakistan during 1975–80. This survey covered nine species of *Abutilon,* including *A. theophrasti.* A large number of insects were

recorded from other *Abutilon* spp. but only one species, *Atherigona orientalis* Schiner (Diptera: Muscidae) was reared from *A. theophrasti*. A stem gall-fly, *Hexomyza abutilonicaulis* Spencer (Diptera: Agromyzidae), recorded from other *Abutilon* spp., was shipped to the U.S.A. in 1979 for trial against *A. theophrasti*. It was reared with great difficulty on *A. theophrasti* in quarantine (USDA/ARS, Stoneville, MS, Res. Quarantine Facility) for no more than two generations when all the imported stock died (CIBC 1981; Frick and Quimby 1982). This gall-fly was not found on *A. theophrasti* in Pakistan.

One of the primary objectives of the surveys in India was to document the occurrence of *H. abutilonicaulis* on *A. theophrasti*. We have not found this stem gall-fly on velvetleaf in India.

A remarkable phenomenon noted even on small *A. theophrasti* plants was that the plants were able to discourage arthropod enemies by trapping the small, immature stages in the sticky glandular hair on the stem, leaf, and fruit capsules. The trapped organisms were observed dead and decomposing on the plants. The most common insect found thus immobilized was a *Haplothrips* sp. (Thysanoptera: Phlaeothripidae).

In the Kashmir Valley, the polyphagous *Heliothis armigera* Hübner (Lepidoptera: Noctuidae) was found to bore into immature and partially mature fruit capsules, but the level of damage inflicted by this insect was not significant. No *Heliothis* eggs were found on plants but young larvae were sometimes seen on the plants when flowers and fruit capsules started developing. Surprisingly, *Heliothis* was hardly ever noticed as a pest of maize in fields were the weed occurred almost as an intercrop.

In one area (Pattan) near Srinagar, some flower buds were found to have aborted and started wilting. At the slightest touch such flower buds dropped to the ground. Most of these buds did not show any insect or other organisms when they were dissected. A few buds yielded larvae of a midge, identified by Dr. K.M. Harris, Commonwealth Institute of Entomology, London, as *Clinodiplosis* sp. Dr. Harris has commented (pers. comm.) that the larvae of this widespread genus of midges are known to occur as secondary invaders in rotting plant tissues. Further collections and observations are necessary to identify the midge species and to understand its exact relationship with the flower buds and possible plant pathogens.

In another area near Srinagar, some *A. theophrasti* stems had lesions. The damage appeared as oval or irregular patches of decomposing stem tissue covered by soft brown cuticle, with a small hole located in the center. Efforts to find the causative agent are scheduled for the summer of 1984.

The following is a list of other insects collected on *A. theophrasti* in India and identified by CIE.

Coleoptera: Chrysomelidae
- *Luperomorpha nigripennis* Duv.
- *Monolepta* sp.

Homoptera: Cicadellidae
- *Balclutha* sp. *?hortensis* Lindberg
- *Macrosteles quadripunctulatus* (Kirschbaum)
- *M. sexnotatus* (Fallen)
  (These two *Macrosteles* spp. are vectors of European aster-yellows.)
- *Psammotettix striatus* (L.)
  (Vector of winter wheat mosiac.)

Psylloidea: Aphalaridae
- *Aphalara maculipennis* Low

Heteroptera: Lygaeidae
- *Oxycarenus laetus* Kirby

Large numbers of *L. nigripennis* and *Monolepta* sp. were seen on leaves of *A. theophrasti* and on the leaves and ears of maize plants in September but no damage was noticed. These chrysomelids apparently breed on one or more other weeds in the same area. Leafhoppers were numerous and observed only at the end of the crop season (October) in one area (Hajjan) where the *Abutilon* plants were senescent and interspersed with other wild, low-lying vegetation. *O. laetus*, a pest of cotton, was the only insect attacking the plant at Coimbatore, where it severely impaired seed production and viability.

Diseases of Velvetleaf

Nothing is known of the diseases of *A. theophrasti* in India but a complex of fungal pathogens and at least three different viruses have been reported from other countries (Dempsey 1975). Almost all these are known to infect cultivated plants. Diseases of *A. theophrasti* have received special attention in areas where the plant is cultivated for fiber. Beceriescu (1979) published a handbook for control of diseases of velvetleaf and other fiber plants in Europe. In Illinois, where velvetleaf is a common weed in soybean fields, it serves as a wild host for three species of fungal pathogens of soybean (Hepperly *et al.* 1980).

A search for other pathogens infecting the plant in its wild state and in restricted habitats might determine if there are any that are host-specific and have potential as biocontrol agents.

Discussion

Velvetleaf merits further exploratory surveys for natural enemies in its native distribution range, and more detailed studies on the promising species. The recent surveys in the Indian subcontinent have only covered some of the areas along the periphery of the weed's native range, with the center of origin presumably somewhere in the PRC. The previous records of insects and plant pathogens attacking *A. theophrasti* are almost entirely from territories where the species has been introduced and cultivated for some centuries. Further surveys should extend to the PRC and areas immediately adjacent to it. Accessibility to these areas and facilities for field and laboratory studies are now limited, but should improve with more contacts with administrative agencies and collaboration with scientific institutions in the PRC.

From the available evidence it seems unlikely that velvetleaf originated in the Indian subcontinent. The virtual absence of this species in a wild state in the areas surveyed and the small number of species of insects associated with it would support this conclusion. The dusky cotton bug, *O. laetus*, found infesting the mature fruit capsules at Coimbatore, a cotton-growing area, may be limiting the spread of the weed.

While the stem gall-fly *H. abutilonicaulis* has been recorded from other *Abutilon* spp. in India and Pakistan, it has not been found to attack *A. theophrasti*. Of the seven susceptible *Abutilon* species occurring in Pakistan, three are highly susceptible and four show low susceptibility (CIBC 1979). Since the susceptible species also occur in India, *H. abutilonicaulis* may have co-evolved with them over time. The lack of susceptibility of *A. theophrasti* may indicate it is an alien species or that it has developed resistance to *H. abutilonicaulis*. *A. theophrasti* thrives in the Kashmir Valley like an introduced, agressive weed. The organism causing wilted flower buds and another unknown organism causing stem lesions in Kashmir are biotic factors that warrant further investigation.

Studies underway in Srinagar in 1984 and beyond, are combining the disciplines of entomology and plant pathology. This team approach may assist us in the evaluation of the potential for finding biocontrol agents in India.

Acknowledgments

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