potato plant in sucrose-containing medium.

To overcome the observed inhibitory effects, the CTP-*glgC16* gene was placed under the control of a tuber-specific patatin promoter, and transferred to potato plants. An increase of 35% to 60% in starch content was observed in tubers. A small-scale field trial gave similar results.

It was observed, however, that the degree of starch increase was not absolutely proportional to the amount of expression of enzyme, i.e. the expression of low levels of the CTP-*glgC16* gene resulted in high levels of starch production. One possible explanation is that the rate-limiting step in starch synthesis is not ADPGPP, but starch synthase. In this case, allosteric regulation of ADPGPP may be involved in the synthesis of starch. In order to study the relevance of allosteric influences on ADPGPP activity, the wild-type ADPGPP gene from *E. coli* was subsequently used for further plant studies.

The wild type CTP-*glgC* gene was used to transform potato and tomato plants. In both instances, a high level of enzyme expression was observed, but only a slight increase in starch content. This implies that the ADPGPP enzyme activity, and not enzyme amount, is rate limiting in the starch biosynthesis pathway.

In conclusion, it is very striking that a single enzymatic step regulates end-product levels in a complex multicellular organism. It is possible that the same principle can be used to study and possibly manipulate the levels of lipids, amino acids and carbohydrates.

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COMMENTARY

Invasive alien weeds in the Western Ghats

R. Muniappan and C. A. Viraktamath

The invasion of alien species has been a neglected subject until the General Assembly of the Scientific Committee on Problems of the Environment (SCOPE) came up with the need to address the ecology of biological invasions in 1982 (ref. 1). In 1986, an international workshop was held in Hawaii which identified the need for information on biological invasions in the tropics. In support of this recommendation, SCOPE sponsored an international workshop on 'Ecology of Biological Invasions in the Tropics' in September 1989 in India[2].

The term 'biological invasion' used by ecologists includes exotic plants and animals that are introduced and established. Agronomists identify the introduced pestiferous plants as 'exotic weeds' and entomologists and plant pathologists target them for classical biological control by introducing host specific natural enemies.

The nature of invasive plants and the characteristic features and properties that assist them in invading the tropical regions is given by Saxena[3]. Most invasive alien weeds in India are of neotropical origin. Weeds such as *Lantana camara* (lantana), *Chromolaena odorata* (Siam weed) and *Eichhornia crassipes* (Water hyacinth) were introduced into India as ornamental plants. They escaped cultivation and became wild. The absence of their natural enemies in the new and the favourable environment has led to their successful establishment and to become dominant species.

The seriousness of invasive alien weeds was recognized in the early 1900s by the Government of India. In 1916, Ramachandra Rao was detailed to study the distribution and natural enemies of the exotic weed, *L. camara*, throughout India and Burma[4]. He reported about 148 local herbivores recruited by this invasive weed and also gave a detailed account of the menace caused by other invasive weeds such as *C. odorata*, *Opuntia dillenii* (prickly pear), *Mimosa pudica* (sensitive plant), *E. crassipes*, *Lippia geminata* and *Jatropha grossipifolia*.

The Western Ghats constitute the region between Dangs district (21° N), Gujarat in the North to Kanyakumari district (8° N), Tamil Nadu in the South, traversing through the states of Maharashtra, Goa, Karnataka and Kerala. The Western Ghats play an important role in the maintenance of ecological balance and cultural and economic developments in South India.

This region has luxuriant vegetation comprising evergreen rain forests, mixed deciduous or monsoon forests and subtropical or temperate forests[5]. Invasive alien weeds have contributed to the deterioration of the Western Ghats by invading disturbed areas, vacant lands, pastures, farm lands, forests, and plantations, interfering in afforestation programmes, suppressing native vegetation, and possibly causing the extinction of some species, interfering in wildlife management, poisoning domestic and wildlife, increasing fire hazards, preventing recruitment of native species, reducing the aesthetic value of parks and reserves and affecting the socio-economic development. In the invasive alien weed-infested areas biotic diversity has been considerably reduced and single species dominance is noted.

Most of the invasive alien weeds were introduced intentionally for agricultural, forestry, pasture, ornamental and/or for other purposes. A few were accidentally introduced through transportation of people and their commodities.

In this article, we highlight some of the invasive alien weeds in the Western Ghats, their properties, steps taken to suppress them and further action needed to be taken for effective management.

Invasive weeds

Some of the alien weeds that have invaded Western Ghats are *L. camara*, *C. odorata*, *Ageratina adenophora*, *Mikania micrantha*, *Mimosa invisa* (spiny variety), *Bidens pilosa*, and *Prosopis juliflora*.

L. camara (Verbanaceae) was first introduced to Calcutta in 1809. Tireman[6] reported it to be a serious invader, creating problems in forest management. Ramachandra Rao[4] has given a detailed account of its distribution in India from the Himalayan foot hills to Cape Comorin. It has adapted well to tropical and subtropical climatic conditions and to semiarid to humid regions.

Tadulingam and Venkatanarayana[7] mentioned it to be a very troublesome weed in Coorg, the Wynaad, West Coast, Travancore, Cochin, Tinnelvelly, Yercaud, parts of Coimbatore, and up to 5000 feet in the Nilgiris. However, since World War II, the invasion of the Siam weed, *C. odorata*, has replaced *L. camara* in the western parts of the Western Ghats. *L. camara* is quite abundant in the rain shadow areas of the eastern part of the Western Ghats where *C. odorata* is uncommon. *L. camara* is a perennial, shallow-rooted and spiny shrub which forms bushes. The leaves are toxic to cattle and it produces small berries in clusters which are spread by birds such as the bulbul, sparrow, mynah, parrot, crow and ring dove. It does not do well in the dense shade of undisturbed heavy forests. Openings made for trails, logging and other operations result in invasion of the weed as in most places there may already be existing seed reservoirs in the soil dispersed by the birds.

Like most exotic weeds, *L. camara* has been a target for classical biological control. Ramachandra Rao made a thorough survey of locally occurring insects on *L. camara* in India and Burma. A list of natural enemies introduced and the current status of biological control of *L. camara* in India has been reported by Muniappan and Viraktamath[8].

The introduced natural enemies that feed on leaves, flowers and pods have slowed down the spread of this weed. There is room for introduction of increased number of natural enemies to suppress this weed in India.

C. odorata (= *Eupatorium odoratum*) (Asteraceae), commonly known as Siam weed in Asia, Gandhi Gulabi in Coorg and communist pacha in Kerala, was possibly introduced to Bengal[9] as an ornamental plant in the late 1800s. After World War II it was accidentally introduced into Kerala through the contaminated clothings of the soldiers returning from Bengal[10]. It is a shallow-rooted shrub which flowers during November–December, and whose seeds are spread by wind. It is highly allelopathic and toxic to domestic animals. The dried shoots are pithy and fire-prone during the summer but the clumps remain alive and readily sprout after the first rains. Wind-blown seeds of this weed readily germinate in the open and disturbed areas. Seedlings are not capable of survival under deep, shady vegetation in undisturbed forests. It has a definite climatic adoption and competes well with other vegetation in humid tropical zones up to a height of 1000 m in the Western Ghats.

C. odorata has established from Nagerkoil to Kudal in the southern part of Maharashtra along the coastal area and to Belgaum along the eastern slopes of the Western Ghats, an area that has been classified as very humid and humid[11]. *C. odorata* has spread to the Kodai Hills and also invaded Yercaud (Shevroy Hills), probably recently.

C. odorata has formed dense thickets in the forests of Western Ghats that had been cleared and planted with cashew, Eucalyptus, teak and rubber. It invades rapidly into the disturbed forests. It reduces floral diversity in areas where it has established.

In a recent survey, we found *C. odorata* is still migrating northwards at the border of Karnataka and Maharashtra. Its spread is inadvertently aided by the Forest Department by the planting of seedlings of forest trees such as *Eucalyptus* sp. and *Acacia* sp. which are raised in *C. odorata* seed-contaminated-soil-filled plastic bags from infested areas to uninfested areas. Similar spread does not occur in the southern border of Maharashtra, which is the northern edge of the invasion of *C. odorata* in the Western Ghats, as the forestry seedlings to this region are brought in from the inner areas of Maharashtra where this weed is yet to be established.

In 1971 the Government of Karnataka awarded a grant for the Commonwealth Institute of Biological Control (CIBC) substation in Bangalore to work towards biological control of *C. odorata*. CIBC imported the natural enemy, an arctiid *Pareuchaetes pseudoinsulata* from Trinidad and field released it at Coorg during the early seventies without success. However, continuation of the release of this natural enemy in the mid-eighties resulted in its establishment[12] at Trichur in 1985.

Ageratina adenophora (= *Eupatorium adenophorum*) (Asteraceae), commonly known as Crofton weed, is a native of Mexico. In India, it has invaded rangelands, vacant lands, roadsides and forests in Himachal Pradesh, the foot hills of the Himalayas, Northeastern India, and in the Western Ghats. In the Western Ghats it occurs in Munnar, Chincona, Nilgiris, Kodaikanal and Madikeri, and at Yercaud in the Shevroy hills above a 1000 m elevation. It is limited in distribution to humid temperate climate. It is quite serious in Kodaikanal, occupying most of the disturbed areas, but is not yet widespread in Yercaud. It is a perennial shrub which grows rapidly and produces many shoots and branches. It forms dense thickets and spreads by dispersal of seeds.

A host-specific gall-forming fly, *Procecidochares utilis* from Mexico, was introduced to India[13] in 1967. This fly has spread to all parts of India wherein *A. adenophora* has invaded. However, the effectiveness of the fly has been reduced due to attack by local parasites in India.

Mimosa invisa (Mimosoidae), the giant sensitive plant is a fast-growing, scrambling, invasive weed of South American origin. It may be annual or biennial. The stems are armed with four or five rows of sharp prickles and the plant produces a large number of seeds, which maintain viability for very long periods.

A spineless variety of this species is used as a cover crop in rubber, cashew, teak, and other plantations in the Western Ghats.

M. invisa invades vacant lands, sugarcane, banana and other cropped lands but does not invade closed forests. *M. invisa* thickets are quite dangerous to pass through and are impenetrable.

Distribution of *M. invisa* in the Western Ghats is limited to some patches. We found them in Mylampulli and Kalladikode villages in Palghat district and along the road from Kumily to Munnar at Nadumgandam area.

Like other weeds mentioned earlier, mechanical and chemical control methods are expensive and do not provide a long lasting effect. Therefore, in Australia and Western Samoa, a coreid bug, *Scamurius* spp. and a psyllid, *Heteropsylla* sp. collected in Brazil are used for biological control of this weed. These natural enemies will attack the spineless variety of *M. invisa*[14]. The option for India is either to introduce these natural enemies and refrain from using the spineless variety of *M. invisa* as a cover crop or find an alternate method of suppression of this spiny weed.

Mikania micrantha (Asteraceae) is commonly known as the 'mile a minute' plant. It is neotropical in origin and as a vine, climbs on local vegetation and smothers them. It produces numerous seeds which are spread by wind. The vines readily root at nodes when they touch the ground.

M. micrantha is adopted to humid tropical climatic conditions and has become a problem in forests and plantation crops. It has already established in the Trichur and Kottayam districts in Kerala. Mechanical removal and disposal is possible, but the process is very labour-intensive. Chemical control is difficult because of the other vegetation on which this vine climbs. Biological control using a host-specific thrips, *Liothrips mikaniae* from Trinidad, was tried in the Solomon Islands and Malaysia without much success[15].

Bidens pilosa is known as beggar's tick or Spanish needle, another exotic introduction from the neotropics. It is an erect and branched herb and its dispersal is achieved by the adhesive seeds that stick to the fur of animals and clothing of people. It is a problem in the coffee estates of Yercaud, Cardamom estates at Kailasanadu and Munnar, and roadsides in Thekkadi and Kodaikanal.

Conclusion

One of the primary reasons alien weeds become successful in introduced, new and favourable environments is the absence of natural enemies which keep them under control in their native environment. The wrongly introduced prickly pear, *Opuntia dillenii*, into South India in 1780 was effectively controlled by introducing the mealy bug, *Dactylopius tomentosus*, a native of Mexico, via Sri Lanka[16] in 1926. Alien weeds often become allelopathic to local vegetation as the local vegetation evolves without coming in contact with allelochemicals produced by the exotic species. In addition, invasive alien weeds become fire hazards in the dry season, as in the case of *C. odorata*. Some of these alien weeds exhibit insect-induced changes to ward off the host-specific natural enemies introduced for their control[17]. Plants like *M. micrantha* not only possess allelopathic properties but also smother local vegetation by climbing over them. Weeds belonging to the family Asteraceae produce large numbers of seeds per plant and disperse them via wind. Similarly, *L. camara* produces berries that are attractive to birds in order to utilize them for dispersal. Seeds of *M. invisa* are hardy and are capable of remaining in soil for a long time.

Many introduced alien weeds have invaded different habitats in India. Ecological studies on *C. odorata*, *A. adenophora* and *M. micrantha* have been carried out in northeastern India[18-21], but such work in other areas is scanty or non-existent. After Ramachandra Rao's survey of *L. camara* from 1916 to 1919 on the all-India basis, no such survey has been conducted. In fact, even the introduction of natural enemies for control of *L. camara* in India has been sporadic and uncoordinated[8]. Very little interdisciplinary and coordinated work is carried out, and even this limited amount of such work undertaken rarely crosses the state boundaries. Some ICAR projects such as the All-India Coordinated Project on Weed Control, mostly concentrate on the use of herbicides for weed control. The All-India Coordinated Project on Biological Control of Pests and Weeds encourages different states and regional institutions to carry out applied biological control programmes with the limited exotic natural enemies imported for this purpose. Most natural enemies introduced to India were first initiated, explored, identified, screened and utilized in other countries.

There is a need for cooperative projects which include ecologists, agronomists, weed scientists, entomologists, plant pathologists, and others in identifying already invaded weeds and in assessing their ecological problems, environmental concerns in different ecosystems, economic damage, and methods of control. Also, to identify possible future invader species, to recommend appropriate programmes to prevent their introduction and to take immediate and necessary steps to contain and eradicate them when introduced.

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Acknowledgement. This study was supported by the Grant No. FR1054900 of the Smithsonian Institution.

Received 12 October 1992; revised accepted 2 February 1993

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TECHNICAL NOTES

Effect of ultrasonication on the flotability of galena

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The ability of ultrasound to improve the grade and recovery of valuable minerals has attracted a lot of attention[1,2]. The state-of-the-art application of ultrasonics in mineral beneficiation reveals that acoustic field can produce conducive effects on mineral flotation[2]. Most of the earlier ultrasonic studies examined the effect of ultrasound on the removal of adsorbed layer of reagents from minerals[3,4], and in the emulsification of flotation reagents[5], while a few other studies revealed the effect of ultrasonic treatment during and after the flotation processes[6–8]. Successful applications of ultrasonication to mineral surface cleaning[9] and removal of surface precipitates[10] have also been reported. Eremin[11] studied the ultrasonic activation of an elementary flotation event and explained the process causing stimulation of hydrophobic interaction on the basis of increase in entropy of the aqueous system under acoustic treatment.

Various researchers have shown that an intensive acoustic field can modify the state of a material, leading to chemical or dispersive effects[1,12,13]. Chemical effects are characterized by cavitation and are accompanied by a local increase in pressure and temperature, while dispersive effects are realized when ultrasound is applied to a pulp containing a stabilizer such as a surfactant. This results in the formation of an emulsion. Ultrasonication thus improves the effectiveness of the reagent due to its more uniform distribution in the suspension and also in the enhancement of the activity of the chemicals used[8].

The present work aims at studying the ultrasonication effect on the flotability of galena under different experimental conditions. The influence of sonication time, slime removal and collector concentration on flotability is elucidated.

Hand-picked, high purity natural mineral samples in the form of lumps were crushed and ground in an agate mortar and separated into narrow particle size fractions for experimental studies. The fractions ($-250+90\ \mu m$) were used for flotation tests. Semi-quantitative spectroscopic analysis of the minerals showed the presence of the following impurities: Zn: 0.23%, Cu: 0.03%, SiO_2: 0.12% Fe: 0.15%, apart from galena (86.3%). The surface area of the sample determined by BET method was found to be $1.12\ m^2/g$ using pure N_2 as adsorbate at liquid nitrogen temperature.

The flotation tests were performed in a small laboratory cell at 20 g scale. A commercial sample of Na-isopropyl xanthate was used as a collector. The floated and unfloated materials were dried, weighed and analysed. All the experiments were carried out at natural pH (6.5).

It was noted earlier[14] that prolonged tumbling or conditioning showed some sign of improvement in flotability. Apparently the bonds holding galena and slimes together were disrupted and replaced by xanthate. But in the above process time needed would be too long to be useful in practice. Since ultrasonics was reported to yield good results in a similar process in a relatively short time[8], its use was tested in the present system. Ultrasonic treatment of galena/xanthate suspensions was carried out using a horn-type ultrasonicator, at a frequency of 20 kHz. To process the samples, the horn tip was immersed 5–7 cm deep into the samples. The power output was at approximately 220 W.

Figure 1*a* shows per cent galena floated as a function of conditioning time in the absence of ultrasonication at a pH of 6.5 and a collector concentration of 0.02 kg/tonne. Collector concentration and pH of the system were kept invariant unless mentioned otherwise. The flotability of galena increased marginally with increasing conditioning time. The flotation recovery was, however, rather low at this collector concentration; it was found that only by

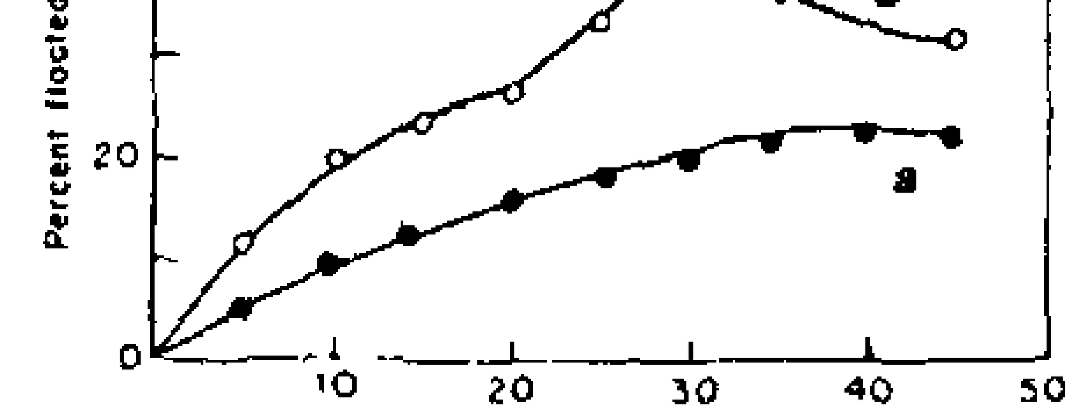

Figure 1. Effect of conditioning time on the flotability of galena