European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

EPPO data sheet on Invasive Alien Plants
Fiches informatives sur les plantes exotiques envahissantes

Sicyos angulatus

Identity of *Sicyos angulatus*

Scientific name: *Sicyos angulatus* L.
Taxonomic position: *Cucurbitaceae*
Common names: bur cucumber, star cucumber (English), calabacilla, chayotillo (Spanish), concombre anguleux (French), Kantenblatt-Haargurke (German), stekelaugurk (Dutch)
EPPO code: SIYAN
Phytosanitary categorization: EPPO List of invasive alien plants

Geographical distribution

EPPO Region: Austria, Bulgaria, Croatia, France (South-West, weed), Hungary, Italy (Northern Italy, possibly also in Sicilia, weed), Moldova (invasive plant), Romania, Russia, Serbia, Spain (North-East, weed), Turkey (Artvin and Trabzon Provinces), Ukraine (established in the western and central parts).
Asia: China, Japan (weed), the Republic of Korea (Andong), Taiwan (naturalized).
North America (native): Canada (Ontario, Québec), USA (Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hampshire, New Jersey, New York, Nebraska, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, West Virginia, Wisconsin).
Central America & Caribbean: Antilles (Guadeloupe, Martinique), Mexico (unconfirmed).[1]

[1]The plant is recorded as casual (meaning transient, not established) in Belgium (Flanders and Walloon), Czech Republic, Germany (e.g. in Berlin), Hungary, Norway and the United Kingdom. The plant was considered an invasive plant in the Generalitat de Catalunya (Spain) and is being eradicated. A record in Sweden was a confusion with *Echinocystis lobata* [*Walk among the S-weeds*, Report of a botanical excursion on 2003-09-27] (in Swedish). http://s-weeds.net/bfgruderat/bfgruderat2003.html).

History of introduction and spread

The native range of *S. angulatus* is in North America. In the 19th century, the species was imported into many European (and other) countries as a decorative ornamental plant (Larché, 2004). It is recorded by Clement & Foster (1994) as a bird seed or an oil-seed alien. In the United Kingdom, it has entered as a contaminant of bird seed (Hanson & Mason, 1985). In Norway, it entered as a contaminant of consignments of soybean grain imported from the USA in the 1970s and 1980s (Ouren, 1987), whereas in Japan, studies have shown that it entered via consignments of feed grain imported from the USA (Kurokawa, 2001). In some places, it has escaped and became a weed, mostly at a casual or sporadic level. In the Far East, at least in Japan, it is considered an invasive weed of crops. The plant has spread across the Republic of Korea within the 15 years since its first appearance in 1989, covering more than 110 ha in 2005 (Kil *et al.*, 2006).

Relatively recently, it became a more serious and actively spreading weed in some southern EPPO countries, including France and Spain. The plant is thought to have been first introduced in Spain and is spreading east and north-east by natural means (JF Larché, pers. comm., 2007).

Fig. 1 Detail of *Sicyos angulatus*' flower and fruit. Picture: J-M Tison (see colour image at onlinelibrary.wiley.com).

Fig. 2 *Sicyos angulatus* invading riversides in Italy. Picture: J-M Tison (see colour image at onlinelibrary.wiley.com).

Morphology

Plant type

Sicyos angulatus is an annual, herbaceous vine.

Description

Stems are hairy, forming a creeping vine up to 6 m long, with numerous branched, climbing tendrils. The root system consists of a shallow branched taproot. Leaves are alternate, broadly heart-shaped with five angular pointed lobes, and finely toothed. Tutin *et al.* (1964–1993) describe leaves 70 mm in length and width with a hairy petiole 26 mm long. Leaves can grow 200 × 150 mm, including the petiole (JF Larché, pers. comm.). The size of the leaves apparently depends on the ecosystem, illustrating the vine's morphological plasticity and adaptability (JM Tison, pers. comm., 2007). The upper surface of each leaf is relatively hairless, while the lower surface is finely pubescent, especially along the lower veins. Plants are usually monoecious, producing separate staminate (male) and pistillate (female) flowers on the same plant. Male flowers are 10–12 mm long; female flowers are smaller, 3–4 mm long, gathered in glomerules of 10. Flowers are whitish to green, composed of five united petals and five sepals (see Fig. 1). Retro barbed hairs are present on the ovary. Flowering time is from July to September, the fruits ripen from August to October (*Plants For A Future.* http://www.pfaf.org/database/plants.php?Sicyos+angulatus). The bur-like fruits are small and spiny, 1–1.5 cm long, one-seeded, produced in clusters of 3–20, initially green, turning brown, indehiscent, containing a single large brown flattened seed.

Similarities to other species

Sicyos angulatus is a relatively easy species to identify by its branched tendrils, distinctive leaf shape, clusters of pistillate flowers, and spiny clusters of fruits. It can be confused with non-invasive plants such as *Bryonia* spp., *Cucumis melo* and *Cucumis sativus*. *Sicyos angulatus* could also be confused with *E. lobata*, which is also considered invasive in some countries. These species can be differentiated by their fruits; only *S. angulatus*' fruits are non-fleshy, spiny and gathered in glomerules.

Biology and ecology

General

Germinations are very staggered, occurring from March. In the first part of its life cycle (from germination to climbing), *S. angulatus* does not seem to tolerate drought, preferring limono-clayey soils. *Sicyos angulatus* is fast-growing in early summer (up to 2 m in 3 weeks), and capable of producing shoots up to 6 m long. The flowering period extends from July to September–October, and the seeds ripen from August to October in Connecticut (US) (Connecticut Botanical Society, 2004). For example in Lleida (ES) in maize or irrigated crops, flowering begins from 15 August and fructification from 5 to 10 September until October (A Taberner, pers. comm., 2007). Flowers are pollinated by insects (bees, flies), and the plant is also self-fertile. Seeds can germinate throughout the growing season (Pheloung *et al.*, 1999). The seeds can survive for long periods in soil, and seed dormancy is likely to be a factor in their persistence (*PSU Weed Management Research Project Abstracts: Burcucumber*. http://weeds.cas.psu.edu/bcucumber.html#5). Tendrils can grow to up to 60 cm long.

In Europe, it appears that the plant does not establish permanent populations, and changes location (JM Tison, pers. comm. 2007).

In Indiana (US) (Smeda *et al.*, 2001), *S. angulatus* germinates from late April to October, and germination is stimulated by periodic rainfall. Relative growth rates of *S. angulatus* plants were greatest up to 10 weeks after establishment and declined once flowering was initiated. Without competition, spring (May)-established plants attained a fresh weight of up to 86 kg and could produce an average of more than 42 000 seeds per plant, up to 80 000 seeds per plant, according to Smeda & Weller (2001). With later establishment, a smaller biomass and a lower number of seeds were produced (more than 250 seeds per plant). Seedlings emerging up to mid-August produced germinable seed prior to frost, indicating that season-long control strategies are needed to minimize reproduction. This plant displays rapid development with periodic germination throughout the growing season. It is capable of producing large amounts of plant biomass and seeds.

Chromosome number: $2n = 24$ (Kerguélen, 1973–1984)

Sicyos angulatus reproduces by seeds. In experiments, it was found that intact seeds of *S. angulatus* failed to germinate and required mechanical scarification or stratification at 4°C for 18 weeks to modify the permeability of seed coat and increase germinability (Pheloung *et al.*, 1999). Emergence from different depths was studied in the glasshouse. The percentage of emergence of *S. angulatus* was highest in seeds buried 1–5 cm deep. Fewer seedlings emerged from depths of 10 cm or more,

or when the seeds were placed on the soil surface. This data suggests that tillage and herbicide timing could influence control of *S. angulatus* (Messersmith *et al.*, 2000). According to a different study on seed germinability, most seeds germinated when cold stratification was followed by aging (Kang-Jin *et al.*, 2003).

Habitats

The plant grows mostly as a weed of maize crops, but can also colonize soybeans. In Japan, it also grows in fields of sorghum for silage (S Kurokawa, pers. comm.). It has also been reported in an abandoned sunflower field in Spain (Diari Oficial de la Generalitat de Catalunya), but this is considered an anecdotal case. The plant is considered a very aggressive vine for irrigated intensive crops (JF Larché, pers. comm. 2007). It grows along roads and railways and in waste land and gardens, that is, in managed environments. It is also found in semi-natural habitats: banks of inland waterways (see Fig. 2) and water bodies, swamps, thickets, openings in floodplain forests, moist meadows in floodplain areas, and hedges bordering water courses with *Humulus lupulus* (JM Tison, pers. comm. 2007).

Environmental requirements

Sicyos angulatus has a preference for loamy or silty fertile soils, but can grow equally well on acid, neutral or basic soils. It requires adequate soil moisture. In France, *S. angulatus* grows well on floodable loamy clay soils.

Climatic and vegetational categorization

The preference of *S. angulatus* is for full or partial sun, and moist conditions. It cannot grow in shade. Its hardiness zone is nine (frost-tender). Kil *et al.* (2006) observed that successful colonization of *S. angulatus* was prominent on riversides with slow water flows and without an emergent plant belt.

In relation to Köppen's classification, *S. angulatus* is most typically found in areas with a warm to hot, wet summer (winter conditions are irrelevant because the plant is an annual). It is also found in areas with a dry summer, but with a cool, wet winter, presumably growing in seasons other than summer.

Sicyos angulatus is associated with the following vegetation zones: tropical mountain and subtropical rainforest, temperate steppes, temperate-zone deciduous forests, mixed conifer forests.

Natural enemies

Because some members of the *Cucurbitaceae* have economic importance, their insect pests are fairly well known in North America and in Europe. In its area of native distribution, *S. angulatus* is a food plant for insects which feed on its foliage, stems or flowers (*Wildflowers of Illinois in Savannas & Thickets*, http://www.illinoiswildflowers.info/savanna/plants/bur_cuke.htm). Insects that feed on *S. angulatus* include: the chrysomelids *Psylliodes punctulata*, *Systena blanda*, *Acalymma vittata* and *Diabrotica undecimpunctata* (larvae feeding on roots, adults on leaves and flowers), the leaf-feeding coccinellid *Epilachna borealis*, the bugs *Anasa tristis* and *Poecilocapsus lineatus*, the aphid *Aphis gossypii*, the leaf-feeding pyralids *Diaphania hyalinata* and *Diaphania nitidalis*, and the stem-boring sesiid *Melittia cucurbitae*.

None of these insects is efficient in limiting stands.

Uses and benefits

Sicyos angulatus is of minor importance as a garden ornamental, it is grown in particular as a screening plant. It has been used as a rootstock for cucumbers grown under glass in Europe, but seeds of *S. angulatus* are not produced commercially any more and the plant is no longer used as a rootstock in regular production (M. Steeghs, pers. comm. 2007).

Pathways for movement

The fruit has spines which allow it to attach to animals and people (JM Tison, pers. comm. 2007). Natural dispersal (for example by small mammals or birds), or dispersal by agricultural practices, transports fruits only over short distances. Seeds of the plant are dispersed by water (S. Kurokawa and JF Larché, pers. comm. Kil *et al.*, 2006). This mode of dispersal is confirmed by Kurokawa *et al.*, 2009, who performed inter-simple sequence repeat (ISSR) analysis on the *S. angulatus* populations widely distributed in Japan in order to infer the genetic relationship among populations. Kil *et al.* (2006) state that heavy rains leading to soil erosion and floods greatly amplify seed export.

A Japanese study (Kurokawa, 2001) focusing on the sources of weeds imported from other countries, including *S. angulatus*, did not find weed seeds in batches of imported maize seeds. However, it did find that many kinds of weeds seeds were mixed with imported grain. Thus, the source of exotic weeds is most likely to be imported feed grain, which is used as an ingredient in concentrated feed. Most of this imported feed grain comes from the USA. Treatment at port or at the feed factory does not affect exotic weed seed viability. Passage through the digestive system of livestock did not seem to reduce the germination rate of other imported weed species. In fact, for many species, it promoted germination. The technique of composting animal manure can affect the viability of seeds, with seeds having reduced viability if the compost is well fermented. However, animal manure is not always fully composted by farmers, or it is sometimes spread directly onto fields, which means that no weed seeds will be killed.

S Kurokawa found that one seed of *S. angulatus* was found in a consignment of soybean from the USA (pers. comm. 2007). It is also suspected that the first introduction of the species into the Tama-river (in Tokyo) was thought to be derived from the contaminants of soybean (imported) dumped by tofu factories into the riverside (S Kurokawa, pers. comm. 2007).

In France, it is thought that this plant was introduced for ornament at the end of the 19th century (JF Larché, pers. comm. 2006). He also reports that in 1998–1999, a farmer grew the plant, confusing it with melon.

Impact

Effects on plants

Sicyos angulatus is characteristically a weed of maize, soybean and sorghum crops. This is the case in its native range (it is officially classified as a noxious weed in Delaware and Indiana, and as a weed in Kentucky and Nebraska). In Europe, it is mainly found in irrigated maize fields. It has not been observed in soybean and sorghum fields: densities of soybean plants are lower than in maize, impeding *S. angulatus* climbing over the plant, and sorghum is not irrigated. In Japan, it grows in fields of maize and of sorghum for tillage. It is not a strong competitor for light and nutrients, and so does not reduce yields by direct competition. However, as an aggressive vining plant, it pulls maize or soybean plants to the ground, making them impossible to harvest (one plant of *S. angulatus* can pull down four rows of maize). Maize stems are broken by the traction and weight of the invasive plant.

Sicyos angulatus can germinate throughout the growing season. Even at very low populations (1 per m^2), it can make maize or soybean fields unharvestable by rapid development at the end of the season, causing collapse of wide areas of the crop (Webb & Johnston, 1981). Observations made in Japanese maize fields showed that yield was decreased by 80% by a population of 15–20 plants/10 m^2 and by 90–98% with 28–50 plants/10 m^2 (Shimizu, 1999). Studies in Japan suggest that the plant may also behave allelopathically (Uraguchi *et al.*, 2003).

Sicyos angulatus is also a host of the polyphagous pest *Heliothis virescens* in North America (which attacks field crops such as cotton, tobacco, legumes and vegetables). It has been suggested that *S. angulatus* could contribute to the build-up of early season and overwintering populations of the pest (Pheloung *et al.*, 1999). A similar situation could arise for *Helicoverpa armigera* (Lepidoptera) in Europe.

Recasens *et al.* (2007) have estimated the cost of the eradication campaigns in Catalunya (ES) between 2004 and 2010 at EUR 78 320, as detailed:

- 2004: destruction of the infested fields, costs of machinery, transportation, compensation to farmers on 16 000 m^2, at 0.20 EUR per m^2 cost 3 200 EUR
- 2005: monitoring (6 months of a technical officer: 12 000 EUR), manual eradication (35 days of a technical officer at 60 EUR per day: 2 100 EUR) and use of herbicides (120 EUR) results in a total of 14 220 EUR
- 2006: monitoring (6 months of a technical officer: 12 000 EUR), manual eradication (3 days of a technical officer at 60 EUR per day: 180 EUR), results in a total of 12 180 EUR
- From 2007 to 2010, estimates are identical to 2006, resulting in a total of 48 720 EUR.

Environmental and social impact

Observations made in invaded riversides in the Republic of Korea show that massive germination can lead to a 100% cover of the soil layer during the growing season. Average and highest seed densities at full maturation were 748 and 1128 seeds/m^2, respectively. A few seedlings per 10 m^2 were enough to cover the whole grass mat by July (Kil *et al.*, 2006). This monospecific cover is a threat to other species and to the whole ecosystem.

No particular social impacts, positive or negative, have been noted.

Summary of invasiveness

Examination of published records of European floras, and of recent records, suggests that *S. angulatus* is rapidly increasing its distribution area in Europe. It seems to be in its expansion phase. It can survive and persist, even as an annual, by producing abundant seeds, which overwinter and are readily dispersed locally. It is a harmful weed of agriculture, both in its native area and in some of its area of introduction.

Control

See National regulatory control systems (PM9) on *S. angulatus* EPPO (2010).

Regulatory status

Sicyos angulatus is officially considered a regulated weed, subject to official control measures, in several countries. Within its native range in North America, it is listed as a noxious weed in Delaware and Indiana, and as a weed in Kentucky and Nebraska. In Australia, it is a quarantine weed on the basis of its high score (18) in the Australian Weed Risk Assessment, indicating that the species has high potential to establish, spread and become a serious weed. The plant has the potential to enter Australia in feed maize as a contaminant (Pheloung *et al.*, 1999). In Japan, *S. angulatus* is considered a major introduced weed species. It is regulated under the new Invasive Alien Species Act enforced on 1 February 2006, which regulates raising, planting, storing, carrying, importing or handling invasive alien species Ministry of the Environment, Government of Japan (2010).

In the EPPO region, the 'Diari Oficial de la Generalitat de Catalunya' (DOGC nùm. 4315 – 03/02/2005) establishes obligatory control measures for *S. angulatus* as follows.

- Farmers and professionals are obliged to notify to the appropriate authorities any presence of the plant.
- Commercialization and movement of contaminated maize is forbidden in Catalunya.
- Destruction of the plant is obligatory when found in fields, there is financial compensation in cases of destruction of maize crops.

- In fields invaded by the pest, neither maize cultivation nor herbaceous crops should be repeated, the plant should be mechanically managed at the end of winter.
- The Plant Health Services monitor presence and absence of the plant and the cleaning of machinery.
- Farmers have to facilitate access to their fields by officially authorized persons.

Action plans for the near future include training of farmers so that they can recognize the plant and control it, monitoring and surveillance of fields to detect new spots, and eradication of the plant when found (Taberner & Sans, 2005).

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Appendix

Data on geographical distribution

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