

EPPO Datasheet: *Amaranthus tuberculatus*

Last updated: 2021-02-02

IDENTITY

Preferred name: *Amaranthus tuberculatus*

Authority: (Moquin-Tandon) Sauer

Taxonomic position: Plantae: Magnoliophyta: Angiospermae: Basal core eudicots: Caryophyllales: Amaranthaceae: Amaranthoideae

Other scientific names: *Acnida altissima* (Riddell) Standley, *Acnida tuberculata* Moquin-Tandon, *Amaranthus altissima* Riddell, *Amaranthus rudis* Sauer

Common names: rough-fruit amaranth, rough-fruited water-hemp, tall waterhemp (US)

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EPPO Categorization: A2 list

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EPPO Code: AMATU



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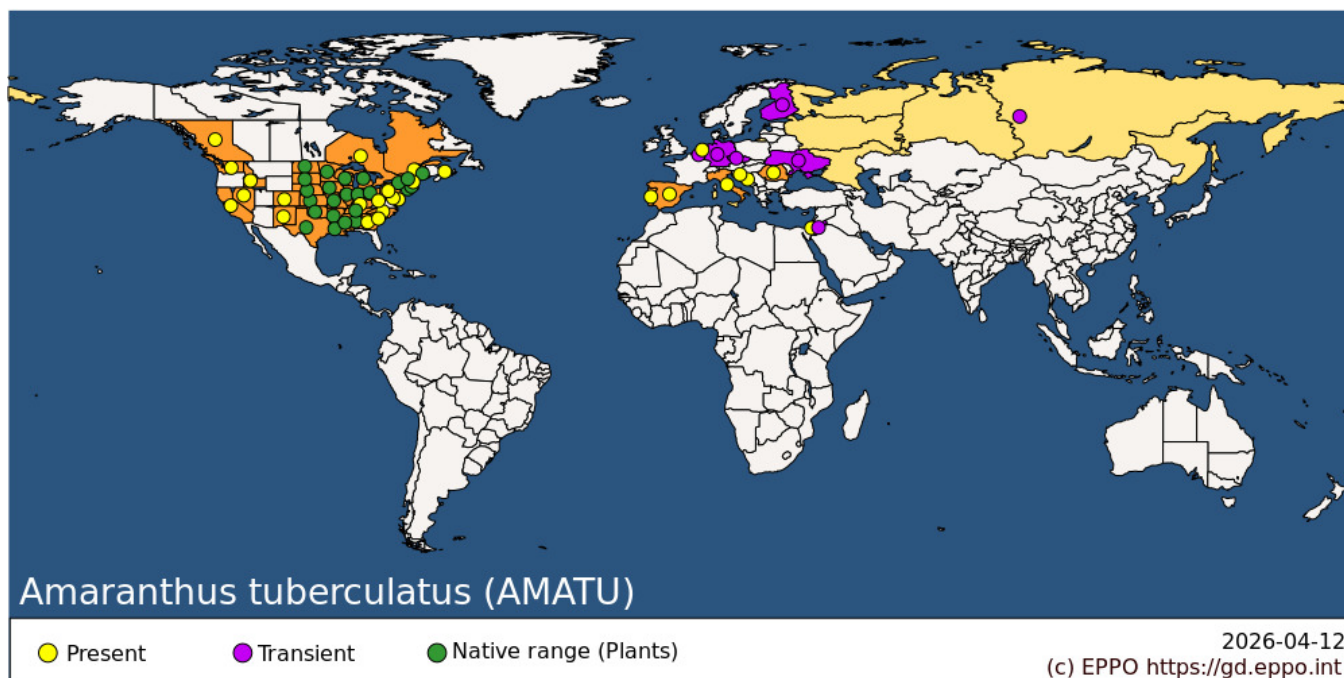
GEOGRAPHICAL DISTRIBUTION

History of introduction and spread

Amaranthus tuberculatus is native to North America (Central and Eastern Central United States), where the species is recorded as being weedy in the United States and Canada (Costea *et al.*, 2005; USDA?NRCS, 2019). There is some uncertainty to the status of the species in the Canadian provinces of Ontario and Quebec. The species ‘... has gone from virtual obscurity to being the most commonly encountered and troublesome weed’ in agriculture, in particular in the Midwestern United States over the last 30 years (Sarangi & Jhala, 2018; Sarangi *et al.*, 2019). In North America, *A. tuberculatus* occurs mostly at latitudes between 45° and 30° North (USDA?NRCS, 2019).

A. tuberculatus was introduced into the EPPO region presumably in the middle of the 20th century. However, the species might have already been introduced before (e.g. in Switzerland). The early records were of small and transient populations scattered across the EPPO region (e.g. Austria and the United Kingdom). The first naturalized populations presumably occurred from the middle of 1970s onwards in Italy. Established populations occur in Italy, Israel and most probably in Spain (Sánchez Gullón & Verloove, 2013).

Distribution



EPPO Region: Belgium, Bosnia and Herzegovina, Croatia, Czechia, Finland, Germany, Israel, Italy (mainland), Jordan, Netherlands, Portugal (mainland), Romania, Russian Federation, Spain (mainland), Ukraine

Asia: Israel, Jordan

North America: Canada (British Columbia, Ontario, Prince Edward Island, Québec), United States of America (Alabama, Arkansas, California, Colorado, Connecticut, Delaware, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Vermont, Washington, West Virginia, Wisconsin)

MORPHOLOGY

Plant type

Annual herbaceous.

Description

Misidentification of *Amaranthus* species can occur throughout its range due to the morphological variation within species and hybridization between species (Wetzel *et al.*, 1999). There are several identification keys that can be used to distinguish between *Amaranthus* species (e.g. Pratt & Clark, 2001; Horak *et al.*, 2019). Some of the key characteristics include flower morphology (needing magnification due to their small size), leaf shape, presence or absence of hair on the stem, seed head shape and seedling shape (Pratt & Clark, 2001). Iamónico (2015) provides short descriptions of *Amaranthus* species that can be found in the EPPO region.

The following description is primarily based on Costea *et al.* (2005) and Mosyakin & Robertson (2003): *A. tuberculatus* is an annual herbaceous dioecious species, with a taproot, and it reproduces only by seeds. Stems of mature plants are erect, sometimes ascending, up to (5–) 20–200 (–300) cm in height, glabrous or with sparse hairs. Leaves are long petioled, ovate, rhombic?oblong to lanceolate?oblong (2–10 cm long, 1–3 cm wide), while the upper leaves are reduced and narrow. Male and female flowers occur on separate plants (dioecious) and the terminal inflorescences are 10–20 cm long, usually unbranched or with numerous paniced branches. Fruits are about 1.5 mm long, transversal (circumscissile) dehiscent at the middle, rugose, often reddish. Seeds are elliptic to obovate, dark reddish brown to dark brown, and 0.7–1 mm in diameter.

BIOLOGY AND ECOLOGY

General

A. tuberculatus is a small-seeded, summer annual species. In its native range, *A. tuberculatus* is a late-emerging weed species. In Southern Ontario (Canada), it typically initiates emergence from the beginning of June to August. In Iowa (United States), emergence begins in mid-May to late May and continues through early August. Flowering depends on the photoperiod.

A. tuberculatus is a prolific seed producer (Costea *et al.*, 2005; Heneghan & Johnson, 2017). When allowed to develop for a full growing season, *A. tuberculatus* has demonstrated the ability to produce up to 1 million seeds per plant (Steckel *et al.*, 2003). There is no specific information regarding natural seed dispersal of *A. tuberculatus* (Costea *et al.*, 2005). The species can produce a large amount of seeds which are light in weight, though they have no special adaptations for wind-dispersal. Seeds are assumed to fall near the mother plant. However, natural local dispersal is most likely accomplished by water, as with other *Amaranthus* spp., as both seeds and fruits can float easily (Costea *et al.*, 2005). Seeds may be dispersed by raindrops and streamlets produced on the soil by rain.

Seeds persist for approximately 4–5 years in the soil in normal conditions (Steckel, 2007). However, seeds buried at 20 cm soil depth retained 3% viability after 17 years (Nebraska/United States, Burnside *et al.*, 1996). The seed bank of *A. tuberculatus* in crop fields may contain tens of thousands of seeds per m² as shown by Buhler *et al.* (2001), comprising up to 90% of the total seed bank (Iowa/United States). *A. tuberculatus* has a rapid growth rate at an average of 0.135 cm of growth per growing degree day (Steckel, 2007).

Habitats

In its native range, *A. tuberculatus* was initially described as growing in wet areas such as margins of rivers, ponds, marshes, lakes and creeks (Sauer, 1955). Nowadays, it is found in any disturbed habitats lacking permanent vegetation, in particular in summer crop fields, along roadsides and railroads up to 1000 m above sea level (Sauer, 1955; Mosyakin & Robertson, 2003; Costea *et al.*, 2005).

Within the EPO region, *A. tuberculatus* is present in a number of different environments, including floodplains and banks of major rivers such as the Po, Rhine, Maas and Waal (Verloove, 2019), ruderal habitats (e.g. railway tracks, port areas; Sánchez Gullón & Verloove, 2013; Junghans, 2016) and to a lesser extent crop fields (Banfi & Galasso, 2010; Masin & Scortegagna, 2012; Pellizzari *et al.*, 2015; Iamónico, 2015). Some data is available on *A. tuberculatus* showing that it is able to invade natural riverside vegetation in Italy (Iamónico, 2015).

Environmental requirements

A. tuberculatus occurs over a wide climatic range. In North America, it occurs preferably at latitudes between 45° and 30° North (USDA-NRCS, 2019). Costea *et al.* (2005) summarizes the ecological preferences of this species as follows: 'thermophyte, hygrophyte to mesophyte, heliophyte and nitrophilous'. It can tolerate a broad range of soil types and textures but prefers those that are well-drained and rich in nutrients (Costea *et al.*, 2005). *A. tuberculatus* also grows well on poorly drained soils (CABI, 2020). Plants can survive temporary flooding but have no salinity or frost tolerance (Costea *et al.*, 2005).

The species can survive and reproduce even under a high degree and duration of water stress (low water conditions). Grantz *et al.* (2019) showed that *A. tuberculatus* (Californian biotype) was highly tolerant to ozone and deficit irrigation (33% of field capacity) under greenhouse conditions. This competitive advantage allows the species to occur in areas that are prone to drought, such as recently discovered in Southern and Central California (Calflora, 2019), and facilitates its weedy behaviour there.

The species requires warm temperatures for germination and growth. Steckel *et al.* (2002) observed the highest germination rates under a temperature range between 25 and 35°C under controlled conditions (seeds collected from Illinois, United States). Above 20°C, the species had higher germination rates with an alternating temperature regimen (temperature varied by 40% of each constant temperature in a sinusoidal fashion during a 14-day period) than with a constant regimen (constant temperature during a 14-day period). Seeds failed to germinate significantly when exposed to temperatures less than 20°C. The minimum temperature for germination was 10°C for populations from Iowa (United States) and over 15/10°C for populations from Kansas (United States) (Guo & Al-Khatib, 2003; Leon & Owen, 2003).

Growth of *A. tuberculatus* is influenced by both temperature and light. For example, biomass accumulation, height and root volume were higher at 25/20°C and 35/30°C than at 15/10°C according to a greenhouse trial by Guo & Al-Khatib (2003). Steckel *et al.* (2003) demonstrated that in full sunlight a *A. tuberculatus* plants produced 720 g of biomass and under 40% and 68% shading plants produced only 550 and 370 g, respectively (under field conditions, Illinois, United States).

Natural enemies

Within the EPPO region, there are no host-specific natural enemies of *A. tuberculatus*. Generalist natural enemies will potentially attack the plant, but these are unlikely to inflict enough damage at the population level to influence establishment.

Uses and benefits

There are no known uses or benefits of *A. tuberculatus* for the EPPO region.

PATHWAYS FOR MOVEMENT

A. tuberculatus has presumably been introduced into the EPPO region as a grain contaminant. Records from ruderal sites in port areas and along (nearby) riverbanks indicate its introduction via imported goods (grain, animal feed mixture). *A. tuberculatus* has been intercepted in bird feed in the USA (Oseland *et al.*, 2020). In Israel and Romania, it is assumed that the species was introduced by fish food from North America (Greuter & Raus, 1986) and with soybean waste and cereals (Costea, 1996).

In Belgium, *A. tuberculatus* is usually found under grain conveyors, near grain mills, on unloading quays or along road verges. The weed is also observed growing from soybean waste (<http://alienplantsbelgium.be/content/amaranthus?tuberculatus>). In Canada, different *Amaranthus* spp. were intercepted in grain of maize, soybean, cereals, pulses, canola, sunflower and millet from the United States between 2007 and 2015 (Wilson *et al.*, 2016). Shimono & Komuna (2008) showed a contamination of spring wheat destined for milling for human food trade imported from Canada to Japan with *A. retroflexus*.

Although *A. tuberculatus* has not been intercepted as a contaminant of seed, this remains a potential pathway of seed from crops which are invaded by the weed in North America. Both the Canadian Food Inspection Agency (2018) and the USDA (2019) highlight the movement of *A. palmeri* seed as a contaminant of seed. *A. palmeri* has also been identified from certified soybean in seed lots and seed bags in Louisiana (J. Ferrell, pers. comm., 2020). Uncertified commercial seeds from Australia, the United States and Europe (e.g. novel forage seeds) have been demonstrated to harbour seed contaminants, including several *Amaranthaceae* species (Cossu *et al.*, 2019).

There are no reports of the presence of *A. tuberculatus* in seed mixtures and native seeds from North America; however, this has been reported for other *Amaranthus* species (including *A. palmeri*) and *A. tuberculatus* can potentially enter the EPPO region via this pathway.

Seed of *A. tuberculatus* may become a contaminant of machinery and equipment. However, there is probably very little movement of used machinery from the countries where the pest occurs into the EPPO region and if there is, it is

probable that such equipment would undergo phytosanitary procedures such as decontamination (e.g. in the EU, Regulation (EU) 2019/2072).

IMPACTS

Effects on plants

A. tuberculatus is a competitive annual weed in maize, soybean and cotton in the United States Corn Belt and Canada (Schryver *et al.*, 2017; Sarangi *et al.*, 2019), though competitiveness varies with density and time of emergence relative to the crop (Bensch *et al.*, 2003).

Steckel & Sprague (2004) reported that season-long interference of *A. tuberculatus* at 270 plants/m² can reduce maize yield by 74% (Illinois/United States). Jones *et al.* (1998) reported that *A. tuberculatus* emerging with soybean caused yield losses of 5% and 18% at densities of 7.9 and 31.5 plants/m², respectively. A study from Hager *et al.* (2002) reported that *A. tuberculatus* allowed to compete with soybean up to 10 weeks after soybean unifoliate expansion at a density up to 362 plants/m² reduced soybean yield by 43% (Illinois/United States).

In Canada, interference of *A. tuberculatus* resulted in soybean yield losses of up to 73% in weedy versus weed-free controls (Vyn *et al.*, 2007). A study by Cordes *et al.* (2004) reported a maize yield loss of 36% occurred, with *A. tuberculatus* density ranging from 369 to 445 plants/m² full-season interference (Missouri/United States).

Bensch *et al.* (2003) described the effect of the density of *A. tuberculatus* on soybean yield loss using a rectangular hyperbola model (Kansas/United States). Soybean yield loss varied depending on year and location from 27% to 63%. Maximum soybean yield loss occurred at eight plants/m of row length and was 56% for *A. tuberculatus* as determined by the model. Even the competitive impact of late emerging individuals can result in a 10% reduction in soybean yield (Bensch *et al.*, 2003).

An important problem is also the evolution of herbicide-resistant *A. tuberculatus* biotypes (Sarangi *et al.*, 2019). Resistant biotypes have been confirmed in populations of the species to seven different herbicide mechanisms of action: ALS-inhibiting herbicides (e.g. imazethapyr), auxins (e.g. 2,4-D), EPSPS (e.g. glyphosate), HPPD inhibitors (e.g. mesotrione), protoporphyrinogen oxidase (PPO, e.g. acifluorfen), photosystem II (PSII, e.g. atrazine) and VLCFA (e.g. metolachlor) (Oliveira *et al.*, 2018, HEAP, 2019; Sarangi *et al.*, 2019). Many populations of *A. tuberculatus* contain more than one of these resistances and thus severely limit the options for effective herbicide control. According to Sarangi *et al.* (2019), the dioecious nature of *A. tuberculatus* promotes the spread of herbicide-resistant traits through pollen-mediated gene flow. Furthermore, an individual *A. tuberculatus* female plant can produce over a million seeds (Hartzler *et al.*, 2004). Thus, herbicide resistance may evolve and spread faster in *A. tuberculatus* than in monoecious weedy *Amaranthus* spp. The species is classified among the worst herbicide-resistant weeds (HEAP, 2019).

The potential economic impact of *A. tuberculatus* in the EPPO region for farmers could be significant if the species spreads and establishes in further areas and therefore effective weed control is essential in *A. tuberculatus*-infested fields.

Environmental and social impact

There is potential for impacts on biodiversity in meso-hygrosopic environments (riverbanks, wet grasslands). There is no evidence that *A. tuberculatus* invades natural areas with high conservation value in the EPPO region.

A. tuberculatus can hybridize with other *Amaranthus* species, thus adversely affecting the gene pools of other species. Hybridization is also a route by which herbicide resistance can be moved between different *Amaranthus* spp. (Costea *et al.*, 2005). However, native European *Amaranthus* species are monoecious (Steckel, 2007) and are not expected to hybridize in field conditions with *A. tuberculatus* when present in limited numbers.

Amaranthus spp. are prolific pollen producers and should be considered as 'hay fever plants' in areas where they are abundant (Oh, 2018). If significant *A. tuberculatus* populations become established in the PRA area, the substantial

pollen production may contribute to allergic rhinitis caused by its pollen. However, allergy impacts specific to *A. tuberculatus* have not been recorded in the EPPO region to date and such an impact is not foreseen to be as important as for other invasive alien plants (e.g. *Ambrosia* species).

CONTROL

In general, *A. tuberculatus* can be managed in crops in the same way as other weeds by herbicide use, mechanical control and integrated pest management. However, *A. tuberculatus* has a prolonged emergence pattern throughout the crop growing season and thus evades weed control attempts. The species will most likely show the same behaviour in the EPPO region. Seedlings will likely establish after initial post-emergence herbicide applications and mechanical weed control tactics, therefore requiring additional weed management actions throughout the crop's life span and this could raise control costs. The introduction of herbicide-resistant genotypes of *A. tuberculatus* appears high and such an introduction may indeed severely limit the options for effective herbicide control and would result in an increase in control costs due to the adoption of specific herbicide programs (e.g. Meyer *et al.*, 2015).

Without the implementation of integrated control against this species – effective chemical weed control, rotation including winter crops and appropriate tillage – the negative effects of *A. tuberculatus* will probably increase. Effective chemical control options (e.g. post-emergence herbicides in soyabean in the EU) may be limited within the EPPO region due to the decrease of the number of herbicides available in the context of legislation, and due to the species being resistant to a number of active ingredients.

A proactive and integrated weed management strategy will be required to effectively manage *A. tuberculatus* in agricultural systems. Heavy tillage, as opposed to light soil disturbance, at the beginning of the season will prepare a proper seedbed for crop planting and eliminate all weeds that have emerged up to this point. Following planting, interrow cultivation can assist to eliminate small seedlings from establishment. In general, significant soil disturbance from heavy tillage discourages small-seeded dicots such as *A. tuberculatus*.

It should be noted that in natural environments, management practices should be tailored to the habitat invaded.

REGULATORY STATUS

In the United States, Wisconsin law prohibits the sale of agricultural seed containing *A. tuberculatus* seed (USDA, 2019a; <https://www.ams.usda.gov/rules?regulations/fsa>). In Canada, *A. tuberculatus* is listed as a Primary Noxious Weed Seed under the Weed Seeds Order of the Seeds Act (<http://www.gazette.gc.ca/rp/pr/p2/2016/2016?05?18/html/sor?dors93?eng.html>). In Argentina, *A. tuberculatus* is included on the A1 (absent) List at 2019 (EPPO, 2020a). In Australia, *A. tuberculatus* (listed as *A. rudis*) is listed as a quarantine pest. The genus *Amaranthus* is regulated in China.

PHYTOSANITARY MEASURES

EPPO (2020b) recommends phytosanitary measures for grains and seeds for relevant crops. Grains of *Glycine max*, *Phaseolus vulgaris*, *Sorghum bicolor* and *Zea mays* should be produced in a pest-free area, or found free from *A. tuberculatus* after inspection for and testing of *Amaranthus* seeds, or should have been devitalized according to an appropriate method. Measures for grains should apply to all commodities that contain the species specified, i.e. irrespective of whether they are intended for animal feed (including bird seeds), human consumption or processing.

Seeds of *Beta vulgaris*, *Glycine max*, *Gossypium hirsutum*, *Medicago sativa*, *Phaseolus vulgaris*, *Sorghum bicolor* and *Zea mays* should be produced in a pest-free area or found to be free from *A. tuberculatus* after inspection for and testing of *Amaranthus* seeds.

Seed mixtures and native seeds should have been produced in a pest-free area found to be free from *A. tuberculatus* after inspection for and testing of *Amaranthus* seeds.

New associated crops should be added if *A. tuberculatus* is shown to develop in these crops and if their seeds or grains may present a risk of contamination with *A. tuberculatus* seeds.

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Datasheet history

This datasheet was first published in the EPPO Bulletin in 2020 and is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity' and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

EPPO (2020) *Amaranthus tuberculatus* (Moq) J.D. Sauer. Data sheets on pests recommended for regulation. *EPPO Bulletin* **50**(3), 543-548. <https://doi.org/10.1111/epp.12716>