

The paradox of the alien plant *Leucaena leucocephala* subsp. *glabrata* (Rose) S. Zárate in Sicily: another threat for the native flora or a valuable resource?

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Abstract

With this contribution, an updated picture of the rapid expansion of *Leucaena leucocephala* subsp. *glabrata* in Sicily is provided. On the one hand, this is a quite worrying sign, as this woody species figures among the world's worst invasive alien species. On the other hand, the species shows interesting potential for production purposes (for wood, biomass and for feeding livestock), also considering its nitrogen fixation ability. Consequently, the two opposite options to cope with this species, *i.e.* cultivation and control/eradication, should accurately take into account the possible uses as well as its invasive behaviour.

Introduction

Leucaena leucocephala (Lam.) de Wit (fam. *Fabaceae*, subfam. *Mimosoideae*) is a woody species native to Mexico and probably to Central America and Caribbean countries.¹ Two main subspecies have been described, mainly differing in the habit, *i.e.* the shrub-like 'common leucaena' *Leucaena leucocephala* (Lam.) de Wit subsp. *leucocephala* and the tree-like 'giant leucaena' *Leucaena leucocephala* subsp. *glabrata* (Rose) S. Zárate.² Henceforth *Leucaena leucocephala* subsp. *glabrata* will be abbreviated as *Leucaena*. Also owing to its wide climatic plasticity, *Leucaena* was introduced in many tropical and sub-tropical countries with average annual rainfall between 750 and 1,800 mm

(but even up to 3,000 mm) and a dry season of 3-6 months.¹ As most legumes, *Leucaena* hosts nitrogen-fixing rhizobia and it is considered as a promiscuous host, being nodulated by both fast- and slow-growing rhizobia belonging to the genera *Ensifer*, *Rhizobium*, and *Mesorhizobium*.³ The amount of nitrogen fixed by *Leucaena* is similar to or higher than that of crop legumes such as peanut and soybean, and most of the fixed N is returned to the soil via leaf litter.⁴ Moreover, *Leucaena* benefits from the mycorrhizal symbiosis for increased nutrient and water uptake, reduced susceptibility to diseases, and increased biomass and growth. Positive effects of arbuscular mycorrhizal fungi inoculation on its growth have been reported under different conditions.^{5,6} Due to its high nutritional value and protein content,² fast-growing traits and rapid life-cycle, *Leucaena* is a multipurpose tree which has been successfully employed for ornamental purposes, as livestock fodder, to obtain biomass and firewood, as well as to improve soil fertility, to control erosion, and for the reforestation of marginal lands.^{7,8}

However, *Leucaena* has also showed an invasive behaviour, rapidly spreading both in anthropogenic and ruderal habitats, as a typical light-demanding pioneer plant, and in semi-natural and forest habitats, especially if subject to frequent disturbance.⁹ Accordingly, it figures among the most dangerous alien species in the world.¹⁰ *Leucaena* has currently showed a marked preference for the often fragile oceanic island ecosystems,¹ where it threatens native vegetation and biodiversity, due to its ability to establish dense monospecific stands which prevent the regeneration of native tree species, also altering the nitrogen cycle.^{11,12} Furthermore, its great drought resistance, and the ability to withstand rather low annual rainfall (250-350 mm),¹³ has recently allowed *Leucaena* to survive in Mediterranean-climate areas like Spain,¹⁴ where it is considered invasive.

The high symbiotic promiscuity has allowed *Leucaena* to establish symbiosis with rhizobia native to different continents, including Europe, thus increasing its invasive potential. The ability to establish symbiosis with strains of *Bradyrhizobium canariense* sv *genistearum* has been recently reported in Portugal for the first time.¹⁵ Sicily has been the only Italian region affected by the naturalization of *Leucaena* until recently.¹⁶ Just last year *Leucaena* has been observed growing wild in Sardinia, too.¹⁷ Moreover, *Leucaena* holds many of the biological traits most commonly found in invasive plant species of Mediterranean islands,¹⁸ such as anemochory, summer and

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prolonged flowering, and abundant seed production. Like for other tree legumes, the invasive potential of *Leucaena* is exclusively linked to the characteristics of sexual reproduction. This monoecious and autogamous species can produce fertile offspring in a very short time, being able to reach sexual maturity within the first year of life.⁹ Then, as early as two to three years of age, seed production begins to be almost continuous throughout the year,¹ even reaching 5,500 seeds m⁻² year⁻¹.¹⁹ *Leucaena* was introduced to Europe almost two centuries ago in the gardens of France and England,²⁰ but the first signs of naturalization in Europe date back only to the end of the last century.¹³

Leucaena leucocephala in Sicily as an emblematic case for the Mediterranean region

Leucaena is probably one of the best examples of alien species which could be properly used under some circumstances but should not be used in others due to its invasive behaviour. Similar is the history of eucalypts in Mediterranean habitats: suitable trees for providing high wood production in some contexts²¹ but increasingly invasive in riparian habitats.²² Hence, before choosing the most appropriate management option, it is necessary to take into account the current situation and the most likely future trends of the species in Sicily and in the whole Mediterranean area.

Leucaena was introduced to Sicily, through the Botanical Garden of Palermo, in 1793.¹⁶ Although it began to produce fertile seeds very soon,²³ it has not escaped from cultivation until recently. The first ascertained cases of naturalization concerned both the southern (Agrigento) and northern (Campofelice di Roccella and Cefalù) coasts of the island.¹⁶ About a decade later, we provide additional naturalization reports in more than 10 sites (Table 1), preferentially coastal areas, from 4 to about 120 m a.s.l., with about 70% of sites located at less than 50 m a.s.l. Its recent spread in circum-Sicilian islands is of great concern. *Leucaena* has been introduced for ornamental purposes, and more rarely in reforestation, to Pantelleria²⁴ (already cultivated there in spring 1992, T. La Mantia, P. Quatrini and S. Pasta, pers. obs.), Ustica, Linosa and Lampedusa.²⁵ More recently, it behaves as a casual alien species in Linosa²⁶

and Favignana,²⁷ and it is nearly fully established in Lampedusa (Table 1), where it has been observed growing wild since 2012. Hence, *Leucaena* should be added to other exotic woody species that are rapidly spreading in Sicily, like *Acacia cyclops* A.Cunn. ex G.Don²⁸ and *Melia azedarach* L.²⁹ In Sicily, *Leucaena* is currently able to establish exclusively within disturbed and anthropogenic habitats such as roadsides and brownfields of suburban areas, irrigated woody and herbaceous crops, and public or private green areas.

Conversely, some biotic and/or abiotic barriers seem to prevent its establishment into semi-natural and natural environments. In support of this, we report an emblematic field observation from a mature *Leucaena* individual cultivated in the boundary of a countryside in Palermo Province (municipality of Trappeto). Here, the species has shown high reproductive fitness, and a number of seedlings, saplings or young trees enjoy regular irrigation and tillage (Figure 1). Conversely, *Leucaena* appears unable to



Figure 1. Massive natural regeneration of *Leucaena* underneath a mature individual cultivated in a coastal area (Trappeto, province of Palermo) (photo by E. Badalamenti).

Table 1. Historical and new records of naturalization events by *Leucaena leucocephala* subsp. *glabrata* in Sicily.

Year	Location (Municipality, Province)	Altitude (m a.s.l.)	Habitat	Reference or observer/s
2007	Agrigento (AG)	n.s.	Abandoned lands, roadside along the highway SS 118	R & D
	Campofelice di Roccella (PA)	n.s.	Citrus orchard, near the rail station	
	Cefalù (PA)	n.s.	Roadside	
2007	Ribera (AG), at the crossroads for "Piana Grande"	90	Roadside (together with <i>Asclepias fruticosa</i> L.)	LS
2009	Trappeto (PA)	65	Irrigated fields	EB
2011-2015	Palermo (PA)	35-94	Urban and suburban environments (gardens, irrigated pots, road borders and trees, the Botanical Garden, citrus groves)	EB
2011	Service area of the Highway SS 115 (Ribera, AG)	25	Small escarpment on abandoned land	EB & TLM
2011	Isola delle Femmine (PA)	33	Roadsides	EB
2012-2020	Lampedusa (Porto Vecchio) (AG)	4-10	Palm grove in harbour area and sandy soils, and small escarpment	EB & TLM
2012	Ribera (Secca Grande) (AG)	23	Roadside	EB
2013	Villagrazia di Palermo (PA)	118	Irrigated fields	EB
2014	Cefalù (PA)	47	Urban areas	EB
2014	Balestrate (PA)	5	Afforestation and roadside	EB
2014	Favignana (TP)	10	Base of a sidewalk	LM
2015	Linosa (AG)	13	Private garden	P & al
2019	Pantelleria (TP)	15	Abandoned lands	EB & TLM

EB = E. Badalamenti, TLM = T. La Mantia, LM=L. Maggioni²⁷, P&al = Pasta *et al*²⁸, R&D = Raimondo & Domina¹⁶, LS = L. Scuderi; n.s.: not specified.

overcome the competition of the native species of the adjacent perennial grassland dominated by *Hyparrhenia hirta* (L.) Stapf, even if this plant community is very disturbed, as indicated by local abundance of *Dittrichia viscosa* (L.) Greuter, and with no doubt is easily reachable by *Leucaena* seeds.

Such evidence, together with the current distribution, suggests a low competitive ability against native flora. However, it is worth highlighting its early achievement of sexual maturity and its ability to rapidly spread even at medium to long distances, a key factor for invasive plants.³⁰ Although the majority of naturalized *Leucaena* individuals were observed growing near the mother plants, some of them have been detected more than 500 meters far from them. Furthermore, the Sicilian nuclei promptly resprout after fire passage and/or mechanical damages caused by periodic road maintenance interventions. A remarkable plasticity in terms of light requirements was also observed, although *Leucaena* is a typical pioneer and light-demanding species. In the Campus of the SAAF Department of the University of Palermo, numerous seedlings and saplings were found under the canopy of large exotic fig trees such as *Ficus microcarpa* L. and *Ficus macrophylla* f. *columnaris* (C. Moore) D.J. Dixon (Figure 2). Both species are widely known for the high shading, one of the reasons why *Ficus microcarpa* is considered an excellent species for urban streets. This is further confirmed by the occurrence under their canopies of *Hedera helix* L., a shade-tolerant species (Figure 2). The adaptation to a wide range of soil conditions has been also pointed out. In the port of Lampedusa Island, *Leucaena* was found invading a date Palm (*Phoenix dactylifera* L.) grove just a few steps from the sea, on purely sandy and brackish soil (Figure 3). The species has been observed in similar environments in Israel.¹⁶

Future perspectives: to use or not to use *Leucaena*?

One constraining factor for the future spread of *Leucaena* in Sicily is its use, currently limited to public and private green areas. On the other hand, the growing number of reports and the characteristics of *Leucaena* would suggest to be cautious when assessing its invasive potential in Mediterranean-climate habitats.¹³ The expected climatic trends could favour the success of the species and the speed of its future invasion.³¹ It is therefore of great

importance to carry out regular monitoring of known nuclei, especially those close to protected areas, natural and semi-natural environments and island ecosystems, which are particularly vulnerable to the proliferation of invasive alien species. In this sense, it is of great concern the recent spread of *Leucaena* in Pantelleria National Park, a Mediterranean island with a high biodiversity heritage. As a precautionary measure, *Leucaena* should be excluded from afforestation interventions in similar sites, in order to prevent fast spreading like that recently performed by *Acacia* spp.³²

Contrariwise, several experiments have been recently carried out to verify the potential of *Leucaena* for productive purposes. Particularly, *Rhizobium* spp. strains isolated from *Acacia saligna* (Labill.) H.L. Wendl. and *Prosopis* spp. root nodules were

found to promote the growth and establishment of *Leucaena* individuals (P. Quatrini pers. obs.). The subsequent naturalization of the species has proved its plasticity and ability to find in Mediterranean soils the necessary symbiont microorganisms. Other field experiments proved that *Leucaena* is able to produce a high amount of wood even under stressful climatic conditions such as limited water availability.⁷ A preliminary test of the productive potential of the species was carried out, and the first experimental data are below reported. In a small area with homogeneous soil conditions and uniform plant growth, seven woody disks from seven trunks of *Leucaena* plants, cut at the base, were sampled. The age of the sampled plants ranged from 2 to 7 years. The mean annual diameter increment was 1.20 cm year⁻¹, with the younger trees (2-4



Figure 2. *Leucaena* saplings growing under the shady canopy of *Ficus macrophylla* f. *columnaris* at the Campus of SAAF Department (University of Palermo). Please remark the lack of other plant species except for *Hedera helix* (photo by E. Badalamenti).



Figure 3. Naturalized young *Leucaena* individual growing at the Port of Lampedusa.

years) showing the highest increment rate (1.77 cm year⁻¹). Regarding fuel properties of *Leucaena* biomass, Feria *et al.* (2011)³³ reported calorific values equal to 18.95 MJ kg⁻¹, *i.e.* higher than those obtained from the residues of food plants and agricultural crops. In our wood samples, the ash content varied from 1.41 to 3.73% of dry weight in plants with diameter from 2.2 to 4.3 cm. The young plants showed the highest content. The values of ash content reported in our work are similar to those obtained in other countries.³³ According to the ruling ISO 17225-1:2014, defining fuel quality classes and specifications for solid biofuels, the analyzed wood samples of *Leucaena* would be classified as A1.5 ($\leq 1.5\%$). These preliminary results suggest a good potential of *Leucaena* either for fodder or for wood/biomass. In both cases, it is important to let *Leucaena* being browsed before the pods harden, thus preventing them from dispersing their seeds through grazing and cutting. Indeed, *Leucaena* is worldwide a well-appreciated leguminous plant for fodder and animal nutrition due to a very high nutritional value of its leaves, even comparable to that of *Medicago sativa* L. (alfalfa).³⁴ For instance, this species was found to increase milk production and forage crude protein content compared to traditional forage in cows.³⁵ Other promising uses of *Leucaena* are linked to traditional medicine, especially in south-east Asian countries³⁶ but also in South Africa.³⁷ For instance, in Malaysia this species is included among the most popular plants for the antidiabetic properties of seed extracts, having a strong inhibitory effect against α -glucosidase. Differently, in the Indonesian Archipelago seeds are used as anthelmintic,³⁸ whereas in South Africa *Leucaena* is employed to alleviate pains and inflammations, and an antioxidant effect of leaves extract was also proved in *in vitro* experiments.³⁷

In conclusion, *Leucaena* could be employed in agricultural areas or in agroforestry systems where the presence of man is constant. The species appears particularly promising to supply forage in semi-arid Mediterranean countries where fodder availability for livestock is a crucial issue, exacerbated by global warming. As *Leucaena* needs very low energy inputs, its cultivation could represent a sustainable alternative in these nutrient- and water-limited environments. To reduce the chance to spread in nearby areas where it could be noxious, regular monitoring activities are required in order to keep it under control. We think it is possible to distinguish areas where *Leucaena* cultivation is suitable and useful, and it does not harm the neighbour-

ing vegetation and biodiversity, and areas where *Leucaena* should be cleared at all to prevent its invasion. As a precautionary measure, the introduction of *Leucaena* within protected areas (e.g. those belonging to Natura2000 network) should be strictly forbidden.

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