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Purslane: A Review of its Potential for Health and Agricultural Aspects

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ABSTRACT

Purslane (*Portulaca oleracea* L.) is a common weed that grows all over the world and is one of the most widespread weed species in summer crops. However, it has great potential to become a new crop since its identification as one of the best plant sources of ω-3 fatty acid, α-linolenic acid, as well as some antioxidants (α-tocopherol, β-carotene, ascorbic acid, and glutathione). Several other features distinguish this species: high content of crude protein, water-soluble polysaccharides useful as gums, and good tolerance to salinity. This review summarizes purslane's origin, botanical, and physiological features while its nutritional and medical properties are reported in reference to several studies carried out on its chemical properties. Finally, its cultivation potential is discussed and future uses are proposed for this species, mainly as a component in ready-to-use vegetables (especially in mixed packaging) but also for other cultivation purposes.

Keywords: ω-3 fatty acids, nitrate, oxalate
Abbreviations: ALA, α-linolenic acid; **DHA**, docosahexanoic acid; **EPA**, eicosapentaenoic acid; **FA**, fatty acids; **LA**, linoleic acid; **NO$_3^-$**, nitrate; **OA**, oxalic acid

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INTRODUCTION

Purslane is a weed commonly found on all continents. It has an enormous potential for infestation mainly due to the large number of seeds produced per plant: up to 500 seeds kg^{-1} of soil were found, but severe infestations depend largely on the amount and frequency of rainfall in summer (Unger *et al*. 1999). In addition, it has a particular ability to re-root after cultivation or hoeing, because the fleshy stems remain moist and viable for several days and have a great potential to form roots (Cudney and Elmore 1999). It forms a dense mat covering the soil and preventing the emergence of other seedlings. Its aggressive and prostrate growth has suggested that purslane can be used as a living mulch intercropped with a row crop, for example broccoli, whose yield was not reduced when compared to conventional methods of weed control, such as black plastic mulch, mechanical or chemical control (Ellis *et al*. 2000).

Purslane has received renewed interest since the identification of some of its nutritional and medicinal properties, so much so that it has been described as a "power food of the future" (Levey 1993) and been proposed as a "new crop" (Kumamoto *et al*. 1990).

HISTORICAL, AGRICULTURAL AND PHYSIOLOGICAL ASPECTS OF PURSLANE

The botanical name is *Portulaca oleracea* L., belonging to the *Portulacaceae* family. Seven subspecies belong to this species, but the subspecies *oleracea* and *sativa* are the most common. *P. grandiflora* is also widespread as a flower species. The Latin name seems to have two meanings: a) '*little door*', deriving from the latin '*portula*', because of the way its capsule opens, and b) 'porto' (which means carry) plus 'lac' (which means milk), referring to the succulent consistence of stems and leaves (Simopoulos 1987). In the Middle Ages the Arabs called it '*baqla hamqa*', which means 'mad' or 'crazy vegetable', because its branches spread over the ground without control. Purslane seems to have an Asian origin (Iran, India, Russian southern regions) (Nuez and Hernández Bermejo 1994). De Candolle (1884) supposed that it was cultivated more than 4,000 years ago. In Ancient Egypt it was already used as a medicinal plant. There is evidence of its cultivation in Arabia and in the Mediterranean Basin since the Middle Ages.

The species has a cosmopolitan distribution, but it is more present in the Mediterranean area, mainly in the arid and semi-arid lands of northern Africa and southern Europe. In particular, in Saudi Arabia, the United Arab Emirates,

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and Yemen, *P. oleracea* subsp. *sativa* is largely cultivated and available in many vegetable shops and used as salad. In the USA purslane is considered a minor crop because of its use in ethnic cooking (Cudney and Elmore 1999). Wild purslane was sold by street-vendors in southern Italy during the 1950s and 60s.

'Purslane is a summer herbaceous plant, with branched, decumbent or fairly ascending stems' (Nuez and Hernández Bermejo 1994). Cultivated forms are more upright and vigorous than wild forms. Plants are succulent, glabrous, with reddish cylindrical stems, up to 50 cm long, with dicotomic growth. Leaves are opposite, oval and glabrous, fleshy, spoon-shaped, up to 3 cm long. Root is a taproot. Flowers are yellow, small, with 5 petals, frequently solitary at the end of the branches, where secondary stems grow. Flowering occurs from July to September. Fruits are capsules containing a lot of black seeds. The germinating capacity lasts eight to ten years if the seeds are stored dry at a low temperature (Nuez and Hernández Bermejo 1994; Stephens 1994; Mitich 1997). The weight of 1,000 seeds is about 0.13 g.

Purslane is well adapted to poor soils, requiring a minimum of water during germination and emergence. Purslane has been rated as moderately salt tolerant, with a threshold value of 6.3 dS m^{-1}; yield is halved when the electrical conductivity of saturated-soil extract reaches 11.5 dS m^{-1} (Kumomoto *et al.* 1990). In another study the threshold of salinity was similar (6.8 dS m^{-1}) but there was a lesser decrease in yield (in plants exposed to irrigation solutions with EC value of 24.2 dS m^{-1}, the yield reduction was around 30% only) (Teixeira and Carvalho 2009). Due to its salt tolerance, purslane has been proposed as a prospective halophytic species for desalinating saline soils and for drainage water reuse systems (Grieve and Suarez 1997). The halophytic nature of purslane, when used as a companion plant, could be useful to increase the yield of the main crop. This is due to purslane's ability to take up large amounts of Na$^+$ and Cl$^-$ from the cultivation medium under saline conditions. It was observed that Na$^+$ concentration in tomato leaves was reduced by 36% when grown with purslane, while fruit yield increased by 33%. This is explained by the fact that tomato plants are able to use more energy to elaborate substances for fruit development, instead of building up mechanisms of salt tolerance (Graifenberg *et al.* 2003). Purslane removed 210 kg/ha of Cl and 65 kg/ha of Na when cultivated at 6.5 dS m^{-1} as an intercrop in fruit orchards during one growing season (Kiliç *et al.* 2008). Searching for the physiological and biochemical mechanisms at the base of their salt tolerance, a recent study found that purslane plants responded to NaCl stress through increased antioxidant activities (catalase, ascorbate peroxidise, glutathione reductase) and the accumulation of osmoprotectant proline (Yazici *et al.* 2007).

Purslane is a C$_4$ succulent plant that under drought stress changes its metabolism to a Crassulacean acid like metabolism (CAM), as evidenced by changes in its CO$_2$ exchange pattern, malic acid content, titratable acidity, specific changes of leaf structure and activity of phosphoenolpyruvate carboxylase, responsible for the diurnal fixation of CO$_2$ in C$_4$ plants and nocturnal in CAM plants (Lara *et al.* 2004).

NUTRITIONAL AND MEDICINAL CHARACTERISTICS AND USES

Leaves and stems of purslane can be eaten cooked in soups and several dishes. But the most frequent use of purslane is raw in mixed salads, particularly appreciated for its succulence and slightly sourish taste, which is similar to watercress or spinach.

In the Middle East, the plant is used as a febrifuge, antiscorbutic (for high content of vitamin C), antiseptic, antispasmodic, diuretic, vermifuge, refrigerant, and as a therapeutic herb against skin inflammations and mouth ulcers (Chan *et al.* 2000). Plant extracts are used as bactericidal in bacillary dysentery; the whole plant is considered an aphrodisiac. Analgesic and anti-inflammatory properties have been demonstrated (Chan *et al.* 2000; Sanja *et al.* 2009), while the examination of the anti-fungal activity of purslane extracts has revealed specific and marked activity against dermatophytic fungi of the genera *Trichophyton* (Oh *et al.* 2000). Purslane extracts have shown none or slight cytotoxic or mutagenic effects, and even a weak inhibition of tested mutagenic agents (Yen *et al.* 2001). Purslane extracts have been demonstrated to have a skeletal muscle relaxant effect that was associated with their high potassium concentration (Parry *et al.* 1993). Purslane leaves and stems have shown a high content of potassium (46,000 and 68,600 mg kg^{-1} dry weight, dw, respectively for leaves and stems) together with magnesium (46,400 mg kg^{-1} dw, on average for two plant portions) and calcium (60,000 and 25,400 mg kg^{-1} dw, respectively for leaves and stems), even if potassium and calcium levels were reduced by high salinity exposure (Teixeira and Carvalho 2009). The consideration of purslane as antidiabetic in the Chinese folk medicine can be supported by the fact that crude polysaccharide extracted from purslane has been assessed to control blood glucose and the metabolism of glucose and blood lipids in diabetes mellitus mice. The dose of 400 mg kg^{-1} body weight was the optimal level (Gong *et al.* 2009). Purslane polysaccharides have also showed free radicals scavenging activities and protective effects against oxidative damage of rats with ovarian cancer (Chen *et al.* 2009).

Some studies indicate that consumption of purslane may help to reduce the occurrence of cancer and heart disease (Simopoulos 1991). This may explain the definition as a 'vegetable for long life' that purslane has in Chinese folklore. These properties may be related to its high content of catecholamines (noradrenaline and dopamine, 0.15 and 0.25%, respectively) (Zhang *et al.* 2002). In particular, noradrenaline has been shown to be a modulator of the immune system and have anti-cancer properties. The highest content of catecholamines has been found in leaves (0.074 and 0.69% for noradrenaline and dopamine, respectively) compared to stems (0.029 and 0.18%) and seeds (0.054 and 0.59%) (Chen *et al.* 2003). It has been reported that green leaves of wild and cultivated plants of *P. oleracea* have a very high content of phenols, such as epigallocatechin (111 and 76 μg g^{-1} dw) and luteolin (43 and 10 μg g^{-1} dw, respectively for leaves of wild and cultivated plants), though higher amounts of these compounds have been found in the root extracts. Roots of wild and cultivated plants have shown a higher Total Phenolic Content (486 and 311 mg GAE/100 g dw, respectively) than leaves (214 and 171 mg GAE/100 g dw, respectively), higher in wild plants than in cultivated ones (Spina *et al.* 2008). In a DPPH assay estimating the free radical scavenging activity, purslane has revealed an IC$_{50}$ of 54.33 μg mL^{-1}, much higher than that found for other antioxidant agents used as control (Erclisi *et al.* 2008). The same authors reported a very high value of equivalent of phenolic compounds (17.88 μg GAE mg^{-1} dw) in purslane leaf extracts and high ascorbic acid content (77.25 mg/100 g fw) in fresh leaves. Another bioactive compound found in purslane at levels remarkably higher than other vegetables is melatonin, noted to have multiple functions as free radical scavenging and antioxidant activity, synergic activity with other compounds, like ω-3 fatty acids (Simopoulos *et al.* 2005). The main nutrient properties of purslane are summerized in **Table 1**. It appears as an excellent source of several bioactive constituents, including antioxidants (α-tocopherol, β-carotene, ascorbic acid, and glutathione) and ω-3 fatty acids (FA), among which α-linolenic acid (ALA) is particularly abundant. In 1986 it was first stated that 'purslane is the richest source of omega-3 fatty acids of any vegetables yet examined' (Simopoulos and Salem, 1986). Hence the Authors suggested that 'purslane could be cultivated as a source of omega-3 fatty acids for human consumption, fish feed or animal feed'. FAs are important lipid components (Trautwein 2001). The ω-3 and ω-6 FAs are defined as essential because mammals are not able to introduce a double bond beyond position 6. Hence, they must be

Table 1 Nutritional characteristics of purslane (values per kg of fresh mass).

Compound	Content	References
Water (g)	940[a]	USDA 2007
Protein (g)	13[a]	USDA 2007
Total lipid (g)	1[a]	USDA 2007
Ash (g)	12.5[a]	USDA 2007
Carbohydrate (g)	34.3[a]	USDA 2007
Calcium (mg)	650[a]	USDA 2007
Iron (mg)	19.9[a]	USDA 2007
Magnesium (mg)	680[a]	USDA 2007
Phosphorus (mg)	440[a]	USDA 2007
Potassium (mg)	4,940[a]	USDA 2007
Sodium (mg)	450[a]	USDA 2007
Vitamin C (mg)	210[a]	USDA 2007
	266[b]	Simopoulos *et al.* 1992
	840[b]	Guil *et al.* 1997
Vitamin A (μg)	660[a]	USDA 2007
Folate, total (μg)	120[a]	USDA 2007
α-tocopherol (mg)	122[b]	Simopoulos *et al.* 1992
β-carotene (mg)	21-30[b]	Liu *et al.* 2000
	19[b]	Simopoulos *et al.* 1992
	3.6-6.5[c]	Liu *et al.* 2000
Glutathione (mg)	148[b]	Simopoulos *et al.* 1992
Total fatty acids (mg)	856[a]	Cros *et al.* 2007
	1,620-2,560[b]	Liu *et al.* 2000
	590-870[c]	Liu *et al.* 2000
	81,800-177,000[d]	Liu *et al.* 2000
α-linolenic acid (mg)	481[a]	Cros *et al.* 2007
	970-1,600[b]	Liu *et al.* 2000
	3,000-4,000[b]	Simopoulos *et al.* 1992
	100-290[b]	Omara-Alwara *et al.* 1991
	700-1,330[b]	Palaniswami *et al.* 2001
	70-210[c]	Liu *et al.* 2000
	35,300-68,800[d]	Liu *et al.* 2000

[a]: Whole plant; [b]: Leaves; [c]: Stems; [d]: Seeds

Table 2 Lipidic content and main fatty acid percentage contents in edible portions of purslane (only values higher than 1% are reported) (adapted from Guil *et al.* 1996).

Fatty acids	Composition (%)
Lipids (g kg^{-1} fm)	3.9
α-linolenic acid - 18:3ω3	32.60
Palmitoleic acid - 16:1ω7	20.96
Palmitic acid - 16:0	17.40
Linoleic acid - 18:2ω6	16.82
Oleic acid - 18:1ω9	5.89
Stearic acid - 18:0	3.46
Behenic acid - 22:0	3.33
Saturated acids/ω3	0.80
ω3/ω6	2.00

provided by the diet. Linoleic acid (LA) and ALA are the most important FAs in the ω-6 and ω-3 series, respectively. The relationship between ω-3 and human health was defined for the first time in the early 1970s when epidemiological findings revealed that Greenland Eskimos had a lower incidence of coronary heart diseases, despite a traditional diet rich in fat and cholesterol, but rich also in long-chain FAs coming from fish products (Bang *et al.* 1971). Since then the ability of ω-3 to reduce the incidence of cardiovascular diseases, together with the anticancer and anti-inflammatory functions, has been well documented through many epidemiological studies (Simopoulos 1999; Ruxton *et al.* 2004). Nevertheless, these functions are especially associated to the long-chain ω-3 FAs, eicosapentaenoic acid (EPA, C20:5) and docosahexanoic acid (DHA, C22:6), but unfortunately, there is no known terrestrial plant source of these compounds except for mosses. Fatty fish (tuna, sardine, salmon, mackerel) provide a great amount of EPA and DHA (Trautwein 2001). In addition to oil-rich fish, meat and eggs can also make a contribution to the dietary intake with long-chain ω-3 FAs (Givens and Gibbs 2005). The long-chain ω-3 FAs EPA and DHA are also synthesized in the human body from ALA provided by plants in the diet (Burdge and Calder 2005). ALA is found in the chloroplasts of green leafy vegetables (such as spinach, kale, cress, containing 89, 350, 290 mg 100 g^{-1} fw, respectively) but it is more abundant in seeds such as linseed, rapeseed and soybean, as well as in their oils (54.2 and 7.7 g 100 g^{-1} in linseed and soybean oil, respectively), and nuts (6.8 g 100 g^{-1} fw in walnuts) (Simopoulos 1991; Trautwein 2001). The problem is that in most plants LA is present in greater amounts and competes with ALA for their conversion to longer chain FAs, by sharing the same metabolic pathway and hence competing for the same enzymes (Trautwein 2001). In purslane, not only is ALA present in high amounts, but it also prevails over LA (Simopoulos *et al.* 1992; Fontana *et al.* 2006; Ercisli *et al.* 2008; Oliveira *et al.* 2009) (**Table 2**).

Purslane is widely consumed in Mediterranean countries such as Greece, where the incidence of cardiovascular diseases and cancer is very low (Simopoulos 2001). The ALA content in purslane leaves is several times higher than in spinach, mustard, and lettuce (Simopoulos *et al.* 1992; Simopoulos 2001). One hundred grams of fresh purslane leaves can provide 300-400 mg of ALA, 12.2 mg of α-tocopherol, 26.6 mg of ascorbic acid, 14.8 mg of glutathione and 1.9 mg of β-carotene (Simopoulos *et al.* 1992). In wild and cultivated Australian varieties, a level of FAs was found in leaves ranging from 1.5 to 2.5 g kg^{-1} fresh mass (fm) where ALA accounted for 60% (Liu *et al.* 2000). In stems the total FA content was lower (Omara-Alwala *et al.* 1991); but it was higher in seeds, from 80 to 170 g kg^{-1} fm, with 30-40% accounted for by ALA (Liu *et al.* 2000). The difference in ALA concentrations reported by various authors in leaves (**Table 1**) may be due to differences in cultivars, sample material, sampling procedure, time of growth and analytical methods. When considering a mean ALA concentration in leaves of 1,000 mg kg^{-1} fm, it may be estimated that a 100 g portion of purslane might supply around 10% of average intake of approximately 1 g/day of ALA. This fraction appears limited if compared with the amount of EPA and DHA directly provided by other foods, especially oil-rich fish, but some considerations are useful. A low percentage of the population eat fish, for example only 27% of the UK population (Givens and Gibbs 2005). In general the ω-3 FA intake is limited by patterns of food choice and by the low availability of fish stocks to sustain the supply of both oil-rich fish and fish oil for human diet (Burdge and Calder 2005). Moreover, the continued and increasing use of fish oils in animals' diet to enrich meat, eggs, and milk in ω-3 FAs is not sustainable, taking into account that the efficiency of incorporation of ω-3 FAs into edible tissues or products is low (Givens and Gibbs 2005). In this respect, any alternative and sustainable source of fatty acids should be considered. In a specific study purslane was able to increase the polyunsaturated FAs and to reduce the saturated FAs content in egg yolk, when dried purslane was supplemented to hens diet by 20% (Dalle Zotte *et al.* 2005).

Studying the influence of planting date on different purslane accessions from Greece, Egypt, and the USA, purslane was confirmed as the most abundant terrestrial vegetable source of essential ω-3 FAs, regardless of its genetic diversity, while the total lipid content was higher in the first planting date (Ezekwe *et al.* 1999). Plants not differing in total FA content were obtained at the 14-true-leaf stage compared with the 6-true-leaf stage, but with a higher ω-3/ω-6 ratio and lower levels of saturated FAs at the 14-true-leaf stage (Palaniswamy *et al.* 2001). On the other hand, fatty acid concentration in chamber-grown purslane plants, harvested at different stages of growth, showed the highest ALA content in leaves at 30 days after planting, compared with 49 and 59 days (Omara-Alwala *et al.* 1991).

Since ALA is a critical constituent in chloroplasts (representing two thirds of the total FAs in photosynthetic tissues), it is assumed that nitrogen nutrition can affect its content. In fact, the synthesis of ALA increases when chlorophyll increases (Tremolieres *et al.* 1979), and chlorophyll synthesis can in turn be influenced by nitrogen level and form (Blanke *et al.* 1996; Osorio *et al.* 2003). In some species total FA synthesis is increased by supplying more nitrogen, while ammoniacal nitrogen causes an increase in chlorophyll (Raab and Terry 1994; Flores *et al.* 2001). In purslane, nitrogen form has a pronounced effect on the concentration of FAs but does not affect FA composition and modestly increases chlorophyll and thylakoid protein content. Probably the effect on chlorophyll content results from an increased chloroplast volume, while total FA accumulation is associated with FA storage in osmophilic lipid globules in purslane chloroplasts (Palaniswamy *et al.* 2000).

A moderate salinity exposure (6.8-12.8 dS m^{-1}) induced a singular increase in total lipid content (up to 20% on a dw basis), but a detailed fatty acid profile of lipid fraction was not reported in this paper (Teixeira and Carvalho 2009). In another paper, the applied saline treatments (from 0 to 120 mM NaCl) did not significantly changed the total amount of fatty acids (which slightly increased until 40 mM NaCl), while the ratio ω6 to ω3 remained unchanged, approximately at 0.3 (Carvalho *et al.* 2009).

Despite the nutritive value of purslane, its introduction and acceptance into the human diet is limited by large contents of oxalic acid [OA, $(COO^-)_2$], which is formed in plants as a metabolism end product. After intake, it can cause the formation of kidney stones and disorders mainly due to reduced bio-availability of cations (Ca^{2+}, Mg^{2+}, Fe^{2+}, K^+). Noonan and Savage (1999) placed purslane in the Group 1 of species containing the highest levels of oxalate, ranging from 9.1 to 16.8 g kg^{-1} fm, often higher than spinach (3.2-12.6 g kg^{-1} fm). Recently, oxalate levels for raw purslane leaves have been found much higher than the previously reported range (23.4 g kg^{-1} fm of total oxalate) (Poeydomenge and Savage 2007). OA concentration can be reduced in plants grown in soilless systems. In hydroponics, the highest OA content (6.2 g kg^{-1} fm) was found in leaves at the 8 true-leaf stage (Palaniswamy *et al.* 2004), whereas in floating systems the highest value was 5.0 g kg^{-1} fm (Charfeddine 2004). OA accumulation in vegetables can be limited by ammoniacal N nutrition (Elia *et al.* 1998). Increasing NH_4^+ in the nutrient solution from 0% to 75% of total N, the OA content in leaves decreased (from 6.2 to 3.8 g kg^{-1} fm) (Palaniswamy *et al.* 2004). Similar result was found by Fontana *et al.* (2006). Explanation is that ammonium assimilation avoids the synthesis of organic acids, such as OA, that, on the contrary, are synthesized during nitrate assimilation to neutralize OH^- ions. It has also been proposed that nitrate ions inhibit the OA oxidase activity, resulting in the accumulation of OA in leaves and stems (Libert and Franceschi 1987). A combination of NH_4^+ 65% in the nutrient solution with harvest at the 16-true leaf stage would optimise the nutritional value of leaves (lower OA and higher ω-3 FA concentrations) (Palaniswamy *et al.* 2004). A sharp decrease in total oxalic acid content was found at increasing salt concentration in the hydroponic nutrient solution after 30 days of saline stress (Carvalho *et al.* 2009). Leaves harvested from plants grown in shaded light contained more total and insoluble oxalates than those grown in full light, while the soluble oxalate contents were similar (Moreau and Savage 2009). The addition of yoghurt to raw purslane leaves (as it is often consumed in some countries, like Turkey) reduced the total oxalate content, but in particular the soluble oxalate from 53.0 to 10.7% of the total oxalate content. Maybe the soluble oxalate is converted in insoluble oxalate by calcium coming from milk products (Moreau and Savage 2009). Brief cooking (5 min) in boiling water did not changed the content of soluble or insoluble oxalate (Moreau and Savage 2009), in contrast to the earlier study by Poeydomenge and Savage (2007) who found a reduction up to 33.5% of soluble oxalate in the leaves and 18% in the stems by boiling purslane for the same time. A greater loss (66.7%) of soluble oxalate was caused by pickling in vinegar (Poeydomenge and Savage 2007).

Purslane is classified as a species rich in nitrate (NO_3^- >2,500 mg kg^{-1} fresh matter, fm) (Corré and Breimer 1979). However, NO_3-N fed purslane shoots harvested in July showed a NO_3^- content around 1,000 mg kg^{-1} fm, that was greatly reduced by supplying ammoniacal nitrogen alone or with nitrate (Charfeddine 2004). Much higher values (3,200 mg kg^{-1} fm) were found in purslane leaves picked from wild plants in Spain (Guil *et al.* 1997). Wild plants picked in southern Italy showed an average nitrate content of 520 mg kg^{-1} fm (Bianco *et al.* 1998), ranging from 360 to 2,100 mg kg^{-1} fm in a further survey (Bianco 2002).

OTHER USES

A protein level of up to 22-25%, comparable to other forage or vegetable food crops traditionally used as protein sources, also suggests an alternative use of purslane for both animal and human consumption (Ezekwe *et al.* 1999). However, symptoms such as weakness, diarrhoea, colic and hepatonephropathy (probably due to the high content of free oxalate or the presence of anthraquinone and coumarin) may be associated with daily and abundant doses of purslane as fodder (Obied *et al.* 2003). These symptoms have not been reported for the Sudanese people who consume purslane as a common vegetable dish (Obied *et al.* 2003).

Purslane has been proposed as an effective 'biomonitoring tool' of fresh water environments and as an aluminium toxicity testing plant. Aluminium toxicity symptoms are concentration dependent and expressed through the inhibition of root growth and increased decay of leaves and stems. The aluminium toxicity in purslane can be fixed next to Cu (Cd > Cu > Al > Zn > Hg > Se > Pb) (Anandi *et al.* 2002). At sites contaminated with multiple metals of industrial origin where purslane naturally grows, it produces high biomass thanks to its high regeneration power, fast growth and short life cycle, showing also a good potentiality to hyperaccumulate Cd, Cr and As, especially in roots. Hence purslane may be successful employed for phytoremediation aims (Tiwari *et al.* 2008).

Purslane leaves are a good new source of gum useful as a food emulsifier (Garti *et al.* 1999).

CULTIVATION

Cultivation does not present technical difficulties. In experiments carried out on the south-eastern coast of Spain, uniform production of 6-8 cm seedlings was obtainable after a month during winter and spring in an unheated polyethylene greenhouse (Nuez and Hernández Bermejo 1994). In southern Italy it was grown in floating system in unheated greenhouse giving a total yield of tender shoots from 9 to 15 kg m^{-2} in several mowings during three months (**Table 3**). In soil it yielded about 16 kg m^{-2} after four months (**Table 3**).

The species seems very suitable for floating system cultivation. It provides a completely edible product, characterized by high juiciness and optimal nutritional properties. The cultivation cycle can be protracted *ad libitum*, through successive mowings, allowed by purslane's high capacity for budding again and by the late growth of seedlings after mowing (Charfeddine 2004). In two greenhouse experiments, purslane produced up to 15.1 and 9.2 kg m^{-2} of shoots, 6-8 cm long, with a dry matter content of 60 g kg^{-1} fm (**Table 3**). The cultivation cycle lasted almost 3 months, from sowing to the last harvest. Both trials were closed in the first decade of July, but plants could still produce shoots, in spite of high air temperature and high salinity in the nutrient solution. Water consumption was quite high (220 and 275 l m^{-2}, respectively in the two cycles), due to high evaporation from substrate when polystyrene boards were left bare after shoot mowing (Charfeddine 2004). In three experiments carried out in floating system comparing different substrates, Cros *et al.* (2007) obtained higher yields of young shoots with five leaf pairs when grown on peat alone (1.8 kg m^{-2} and 2.2

Table 3 Details of some greenhouse experiments carried out on purslane.

Cultivation system	Cycle length (sowing ÷ harvest) (days)	Yield ($kg\ m^{-2}$)	Dry matter content ($g\ kg^{-1}$ fm)	References
Floating system[a]	69	15.1	60	Charfeddine 2004
Floating system[b]	89	9.2	60	Charfeddine 2004
Soil[c]	124	15.6	63	Graifenberg *et al.* 2003
Soil[d]	124	17.7	60	Graifenberg *et al.* 2003

[a] 2002 trial; [b] 2003 trial; [c] plants treated with EC_{water}=1.3 dS m^{-1}; [d] plants treated with EC_{water}=6.5 dS m^{-1}

kg m^{-2}, respectively, in the first two experiments and in the third) or with perlite (3 peat: 1 perlite mixture) (1.8 kg m^{-2}) and on vermiculite only in two of the three experiments (1.9 kg m^{-2}). These yields were obtained in a brief time, between 13 and 18 days after sowing (Cros *et al.* 2007). The same authors rejected purslane soil growing due to the rapid formation of mucilage in leaves and stems and the difficulty of harvesting (Cros *et al.* 2007). In other experiments purslane, grown in floating system on peat, yielded at maximum 1.8 kg m^{-2} of leaves plus 1.2 kg m^{-2} of stems with N supplied with a 40/60 NO_3^-/NH_4^+ ratio (Fontana *et al.* 2005).

This technique allows the grower to obtain shoots free of cultural residues (soil or substrate particles) that, appropriately packaged (e.g. in trays closed by plastic film), might be introduced in ready-to-use vegetable production. Under these conditions, it keeps well at low temperatures for up to two weeks. Tender shoots have a milder flavour and texture which make them more appetizing compared to the whole plant (Nuez and Hernández Bermejo 1994). Further investigations are needed to verify both the agronomic profitability and the maintenance of the nutritional properties in relation to the cultivation system and storage of this potentially valuable healthy food source.

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