Neglected and underutilized species for food and income security in marginal environments

ARTICLE *in* ACTA HORTICULTURAE · SEPTEMBER 2014

DOI: 10.17660/ActaHortic.2014.1051.8

Kameswara Rao Nanduri

International Centre for Biosaline Agriculture

Mohammad Shahid

International Centre for Biosaline Agriculture

Neglected and Underutilized Species for Food and Income Security in Marginal Environments

N.K. Rao, M. Shahid, A. Al Shankiti and I. Elouafi
International Centre for Biosaline Agriculture
P.O. Box 14660, Dubai
UAE

Keywords leafy vegetables, nutrition, salinity, productivity, heat stress, water scarcity

Abstract

Several neglected and underutilized species, because of their resilience and natural adaptation to harsh growing conditions, can provide alternatives to the staple crops to sustain farm productivity in environments constrained by water scarcity, poor soil fertility and other such yield-limiting factors. Among the species native to or naturalized in the Middle East, Christ's thorn jujube, purslane, rocket, jute mallow and safflower have considerable value because of their tolerance to salinity and harsh climatic conditions. These species have significant potential for future food and income security in the region. Similarly, salt- and drought-tolerant non-native species such as leaf mustard, quinoa, salicornia, guar, amaranth and New Zealand spinach, which showed good adaptation in field trials under harsh conditions in the United Arab Emirates, are likely to be of value in providing cost-effective and long-term solutions to problems of water shortage and increasing salinity of soil and water resources in the region. Besides their tolerance to abiotic stresses, all these species are nutritionally rich and can thus play a crucial role in combating vitamin and micronutrient deficiencies frequently experienced by inhabitants of marginal environments. Research to improve the productivity and value of these crops, and to encourage them to be more widely cultivated, would contribute to food, income and nutritional security in the Middle East, especially for smallholders living in marginal environments.

INTRODUCTION

Availability of productive agricultural land per capita is declining in many countries, even as projections for world population growth over the next 20 years show the need to increase food production by at least 50%. Water scarcity and salinity are becoming major threats to irrigated agriculture in arid and semi-arid regions. Estimates show that some 50% of all irrigated lands are salt affected (Pitman and Lauchli, 2002) and the cost of salinity to agriculture is expected to be about US$12 billion a year (Ghassemi et al., 1995). With major staple food crops such as rice, maize and to some extent wheat, being sensitive to salinity, some neglected and underutilized crop species (NUS) are key resources to meet the challenge to improve agricultural production. In general, NUS are known to be more resilient and better adapted than staple crops to grow in marginal environments constrained by water scarcity, poor soil fertility and other such yield-limiting factors.

The Middle East is one of the world's most water-scarce regions, with a high dependency on climate-sensitive agriculture. Yet, it has surprisingly diverse climatic conditions and ecological niches with edaphic conditions supporting a wide range of agrobiodiversity (De Pauw, 2002). Until recently, rural communities in the Arabian Peninsula depended on it for food, fodder, medicines, perfumes and dyes. However, with globalization and changes in lifestyle, many of these species have fallen into disuse, becoming neglected or underutilized. In the context of global climate change, these species because of their natural adaptation to the harsh climatic conditions could be very important to local as well as global food and nutritional security. The aim of this paper is to review some of the important but neglected or underutilized species which have horticultural value and which can be very important resources for food and nutrition security and income generation, especially for the smallholder farmers in marginal and harsh environments.

MATERIALS AND METHODS

Species discussed in this paper include those featured on the list of NUS compiled by the Malaysia-based Crops for the Future (CFF) as well as species which have shown their potential as alternative crops in challenging environments in worldwide studies. Unless otherwise specified, the field trials to assess the effect of salinity were conducted at the International Centre for Biosaline Agriculture (ICBA) in Dubai, United Arab Emirates (UAE), in sandy soils and irrigated with water of low (5 dS m^{-1}), moderate (10 dS m^{-1}) and high salinity (15 dS m^{-1}) in three replicates. Information on nutritional content was compiled from various sources, including those published in print and on the web.

RESULTS AND DISCUSSION

The list of NUS compiled by CFF includes some 900 species (see www.cropsforthefuture.org), of which 40-50 are known to be distributed in the Middle East region. Among these, species native to or naturalized in the Middle East with significant potential as horticultural crops for marginal areas include Christ's thorn jujube (*Ziziphus spina-christi* L.), purslane (*Portulaca oleracea* L.), jute mallow (*Corchorus olitorius* L.), rocket (*Eurica sativa* Mill. and *Diplotaxis tenuifolia* (L.) DC.), safflower (*Carthamus tinctorius* L.) and wild drumstick tree (*Moringa peregrina* (Forssk.) Fiori). Non-native species of horticultural importance which showed good adaptation in field studies and therefore are perceived to have potential to sustain agricultural productivity in extreme environments included leaf mustard (*Brassica juncea* (L.) Czernj & Cosson), quinoa (*Chenopodium quinoa* Willd.), salicornia (*Salicornia begelovii* Torr.), guar (*Cyamposis tetragonoloba* (L.) Taub.), amaranth (*Amaranthus cruentus* L.) and New Zealand spinach (*Tetragonia tetragonioides* (Pall.) Kuntze).

NUS Native to the Middle East

1. Christ's Thorn Jujube. Christ's thorn jujube, also known as Sidr (Arabic), belongs to the family *Rhamnaceae*. It is a tree growing up to 20 m and native to the regions of Africa stretching from Mauritania through the Sahara and Sahelian zones of West Africa to the Red Sea. It is also common to the eastern Mediterranean, Iran, eastern Turkey and the Arabian Peninsula. Christ's thorn jujube has a number of uses. Fresh and dried fruit are edible and highly valued locally by Arabs and the Bedouins. Rural populations in the central and western parts of Sudan rely on it to meet their food and energy needs (Saied et al., 2008).

Fruit have a very high energy value, estimated to be 122.4 Kcal per 100 g (Feyssa et al., 2011). Only a few other dried fruits such as dates, figs and raisins have values higher than this (Eden Foundation, 1992). The fruit are rich in carbohydrates, notably sucrose, glucose and fructose, and in iron (Nour et al., 1987; Osman and Ahmed, 2009). Fruit pulp is also rich in protein, potassium, calcium, sulphur and magnesium. Ascorbic acid content in the mesocarp (98 mg 100 g^{-1} of dried pulp) is higher than that of orange, grape and strawberry (Saied et al., 2008).

Christ's thorn jujube leaves provide valuable forage to animals under open grazing conditions. All parts of the plant have folk medicinal use, especially for treatment of wounds and skin care. Recent studies have confirmed the antimicrobial properties of leaf extracts (Motamedi et al., 2009). The wood is termite resistant and used for shafts, posts, roofing beams and cabinet making. It also yields an excellent charcoal. Because of the very deep taproot and spreading lateral roots, Christ's thorn jujube is used for stabilizing sand dunes and other unstable soils (ICRAF, 1998; Saied et al., 2008).

Christ's thorn jujube is heat tolerant and drought hardy, commonly found surviving in the hyper-arid desert areas with little annual rainfall. Its adaptation to dry, hot climates owing to the exceptionally deep tap root and unusually high regenerative power makes it suitable for cultivation in environments characterized by increasing degradation of land and water resources. Christ's thorn jujube has low to moderate tolerance to salinity and has been suggested for revegetation of moderately degraded saline lands (Sohail et al., 2009). Despite its many uses, lack of adequate research, especially on genetic variability and agronomic requirements, hinders its promotion and full exploitation of its potential.

2. Purslane. Purslane, known as Alverwha (Arabic), is an annual green leafy vegetable belonging to the family *Portulacaceae*. It is a succulent herb growing to a height of 40 cm. It is native to North Africa, the Middle East and the Indian subcontinent, but is now naturalized in most parts of the world and even considered a weed in some countries. In many countries, leaves are commonly eaten as a fresh or cooked vegetable. The seeds are also edible. It is sometimes used as fodder for livestock and fed to poultry to reduce egg cholesterol (Mahr, 2011).

Purslane is very low in calories and fats, but rich in dietary fibre. It is an excellent source of vitamin A, being one of the highest among green leafy vegetables. It is also a rich source of vitamin C and some B-complex vitamins like riboflavin, niacin, pyridoxine and carotenoids, as well as dietary minerals such as iron, magnesium, calcium, potassium and manganese (Table 1). Purslane contains betalain alkaloid pigments, which are potent antioxidants with anti-mutagenic properties (Chowdhary et al., 2013). Fresh leaves contain more omega-3 fatty acids (α-linolenic acid) than any other leafy vegetable. For instance, 100 g of fresh purslane leaves provide about 350 mg of α-linolenic acid (Simopoulos et al., 1992). Studies show that consumption of foods rich in omega-3 fatty acids reduce the risk of coronary heart disease and stroke, and help prevent developmental disorders in children (Simopoulos, 2008).

Purslane is a halophyte with adaptation to both dry and saline conditions. Grieve and Suarez (1997) found that biomass from plants irrigated with 15.2 dS m^{-1} water was nearly double that from the 2 dS m^{-1} treatment and recommended it for saline drainage water reuse systems. In hot and dry conditions, purslane's photosynthesis mechanism switches to Crassulacean acid metabolism (CAM) as a mean of conserving moisture, which makes the plant tolerant to environmental stresses (Mahr, 2011). Despite its nutritional value and potential for cultivation in highly saline areas, purslane remains a largely underexploited crop.

3. Jute Mallow. Jute mallow, also known as Jews' mallow and Molukhiyah (Arabic), is a nutritious leafy vegetable with a long history of cultivation in Africa, the Middle East and a few Asian countries. It is an annual erect herb growing to a height of 2 m and belongs to the family *Tiliaceae*. Young leaves of jute mallow are added to salads, and older leaves are cooked as a potherb. Dried leaves can be used as a thickener in soups. A tea is also made from the dried leaves. Immature fruit are added to salads or used as a potherb (Facciola, 1990; Fondio and Grubben, 2004).

Jute mallow leaves are high in protein and energy value (58 Kcal per 100 g), making it a high quality leafy vegetable. Leaves are also a good source of potassium, iron, phosphorus, manganese and calcium (Ndlovu and Afolayan, 2008). Jute mallow also contains considerable amounts of fibre and vitamins, especially ascorbic acid and β-carotene (Table 1). Folic acid content is substantially higher than that of other folacin-rich vegetables (Chen and Saad, 1981). Leaves contain an abundance of antioxidants that have been associated with protection from chronic diseases such as heart disease, cancer, diabetes and hypertension, as well as other medical conditions (Mibei et al., 2012).

Jute mallow can grow readily in saline soils. Considering its tolerance especially to chlorine salinity, it has been suggested as a promising candidate for planting in wetlands and saline soils in China (Ma et al., 2011). In Africa, the crop is grown in rural subsistence farming systems more easily than cabbage and spinach (Schippers, 2000), which makes this vegetable very important to poor communities in combating hunger and malnutrition (van Rensburg et al., 2004).

Jute mallow is more than just a vegetable. Its fibre is strong and waterproof, and is used for making burlap sacks, furnishings and even clothing. Although jute mallow is a valuable and versatile vegetable, it has not received due research attention, leading to a lack of availability of quality seed, as well as knowledge on best cultivation practices to maximize productivity.

4. Rocket. Rocket is the common name used for some species in the family *Brassicaceae* that have a pungent aroma and a sharp taste. There are two common forms of rocket that are cultivated, an annual species known as annual garden rocket (*Eruca sativa* L.) and a perennial species known as perennial wall rocket (*Diplotaxis tenuifolia* (L.) DC.) (Hall et al., 2012).

Annual garden rocket, also known as arugula, is a quick-growing, cool-season leafy vegetable growing to a height of 40 cm. It is often found growing in arid and semi-arid regions and on severely salt-affected soils (Deo and Lal, 1982; Ashraf and Noor, 1993). Leaves are used in mixed salads, adding a unique flavour to these dishes. It is grown throughout the Mediterranean, central Europe, the Arabian Peninsula, Afghanistan, continental America, South Africa and Australia. It is also cultivated in Pakistan and India as an industrial oil crop. Rocket can be easily grown on marginal and barren land as well as in areas where rainfall and soil fertility are low. It is also known to be drought resistant and has some degree of salt tolerance (Shannon and Grieve, 1999).

Perennial wall rocket is native to the Mediterranean region, but also found in Yemen and a few other countries of the Middle East. It is an erect herbaceous plant with elongated leaves and a deep taproot. Under natural conditions, the mature plant can grow to a height of 80 cm. The leaves are fleshy, oblong and deeply lobed, with pointed apexes (Hall et al., 2012).

Like other leafy greens, rocket is a very low calorie vegetable and has many vital nutrients of immense benefit to health (Table 1). Vitamin C concentration in leaves is high compared to that of other leafy crops, showing its immense potential as a natural antioxidant in the human diet (Bennett et al., 2006; Martinez-Sanchez et al., 2008). Rocket is also an excellent source of vitamin A, especially β-carotene, and vitamin K. Rocket leaves contain adequate levels of minerals, especially copper and iron, and phytochemicals such as indoles, thiocyanates, sulforaphane and isothiocyanates, which provide protection against carcinogens (Balch and Balch, 2000; Ward, 2002). Rocket seeds can yield up to 35% oil. However, because of its pungent smell, the oil is not used in the food industry, though it would be ideal for biofuel production (Yadava et al., 1998).

Perennial wall rocket is unique in having C3-C4 intermediate photosynthesis, which minimizes photorespiration and helps it grow better under hot, dry conditions than C3 plants (Hall et al., 2012). It is also a promising species for saline agriculture, as it lives naturally in saline and dry habitats. Ladeiro (2012) found that Diplotaxis plants survived, grew and reproduced in salinity up to 300 mM NaCl with no loss of nutritional value, which suggests the high potential of the species for large-scale production in salt-affected areas.

5. Safflower. Safflower is an annual multipurpose crop, believed to have originated in the Eastern Mediterranean and Greater Syria. It is an annual crop of the family *Asteraceae* and most suited to hot, dry climates (Knowles and Ashri, 1995). Historically safflower was grown for the red and yellow dyes obtained from the petals, which are excellent for dyeing silk, linen and cotton. The introduction of cheap synthetic dyes resulted in disuse of safflower dyes, but the growing demand for vegetable dyes internationally, not only for dyeing cloth but also for food colouring, is likely to provide safflower a significant niche for exploitation.

Safflower grows to a height of 75 cm and produces attractive flowers of various colours that give its ornamental value. Though most safflower-growing countries cultivate it for oil, it has huge scope to be used for fresh-cut and dried flowers. In Europe, where it is grown for ornamental purposes, cut flowers worth millions of dollars are sold every year. Some work in China, India and the United States of America has been done to select spineless cultivars, which are necessary for floriculture. Safflower flowers are also used for various other purposes. For instance, the petals are an inexpensive alternative to saffron (Oyen and Umali, 2007).

Safflower seeds contain 24-36% oil, which is nutritionally close to sunflower oil. Two types of safflower cultivars are known based on the fatty acid composition of the oil polyunsaturated oil, with about 80% linoleic acid and 15% oleic acid, used as salad oil and for soft margarine production; and the monounsaturated oil, containing around 80% oleic acid and 15% lenoleic acid, comparable to olive oil and suitable for cooking (Oelke et al., 1992). The polyunsaturated oil is also used by cosmetic, paint, varnish, drug and lubricant industries, as well as in biodiesel production (Ekin, 2005).

The main advantage of safflower over other agricultural crops is its drought tolerance and ability to adapt to hot, dry climates. Safflower has an extensive root system capable of extracting subsoil water at greater depths than other crops. Safflower is also considered to be a moderately salt-tolerant crop that makes it better than wheat and equal to barley for planting in saline soils; therefore, cultivation on salt-affected land can prove beneficial to farmers. An evaluation of the world collection of 640 accessions for tolerance to salinity in sandy soils of the UAE showed that at higher salinity (15 dS m^{-1}), flower number was reduced by 25% and seed yield decreased by 75% (B. Fraj, pers. commun.).

6. Wild Drumstick Tree. Wild drumstick tree, known as Al Ben (Arabic), is a desert tree of the monogeneric family *Moringaceae*. It is a rare species distributed in the semi-arid to hyper-arid regions of northeast Africa and the Middle East (Boulos, 1999).

Several studies have indicated the importance of the species as a food, medicine and income generator. In particular, wild drumstick tree seeds have great potential as a food or feed due to the high content of oil, protein, amino acids, sterols and polyunsaturated fatty acids. Immature seeds are eaten like peas, and the mature seeds are fried or roasted like groundnuts. In the southern Arabian Peninsula, the tubers of saplings are roasted and eaten (Hegazy et al., 2008; Al-Dabbas et al., 2010).

Recently, Osman and Abohassan (2012) found that both culms and leaves of the wild drumstick tree are good sources of protein and essential minerals comparable to those recorded from the cultivated species *M. oleifera*. Leaves contain high levels of calcium (2390 mg 100 g^{-1}), phosphorus (190 mg 100 g^{-1}), magnesium (530 mg 100 g^{-1}), potassium (3500 mg 100 g^{-1}), sodium (1090 mg 100 g^{-1}) and sulphur (630 mg 100 g^{-1}). Among the micro-minerals, iron recorded the highest value (844.6 mg kg^{-1}), followed by manganese (177.9 mg kg^{-1}). The seeds contain 54-57% oil, with high levels of monounsaturated fatty acids (83.5%) in particular, oleic acid (74.8%), to be an acceptable substitute for olive oil in diets (Tsaknis, 1998).

The wild drumstick tree could be one of the most valuable plants of arid lands due to its various economic uses. In spite of the importance of the species, it is not paid enough attention by researchers and conservationists, and the species is now threatened by severe drought and the over-exploitation of seeds for oil extraction and tree cutting for firewood and fodder.

Non-Native NUS of Value to the Middle East

1. Leaf Mustard. Leaf mustard, also known as mustard greens, belongs to the family *Brassicaceae* and is native to Himalayan region of India. It is a winter crop cultivated for its tender green leaves, used as a vegetable, and edible seeds, used as a condiment. The plant usually grows to a height of 1.6 m (Schippers and Mnzava, 2007), though some cultivars grow to lower heights.

Leaf mustard is nutrient rich, with a very good amount of fibre, and is very low in calories and fats. It is high in vitamins K, A and C and in iron, a 100 g serving providing an adult with approximately 500% of vitamin K, 350% of vitamin A, and all of the vitamin C daily requirements (Table 1). Fresh leaves are also a very good source of folic acid and an excellent source of several essential minerals, including calcium, iron, magnesium, potassium, zinc, selenium and manganese (Schippers and Mnzava, 2007). Leaf mustard has been the direct focus of some health-oriented research studies, since it ranks high among vegetables for total glucosinolate content, which has cancer-preventive properties (Mateljan, 2006).

Salt tolerance of mustard has been reported by numerous investigators (Shannon and Grieve, 1999). Leaf mustard is moderately tolerant to salinity, with a threshold value similar to Swiss chard and spinach. With late salinization, 50% reduction in yield was reported at 15 dS m^{-1}. Early salinity, however, effectively reduced the C50 point to about 10 dS m^{-1} (Shannon et al., 2000).

In field trials at ICBA, average green biomass of six accessions (selected for leafiness from a collection of 100 accessions) was 3.0 g m^{-2} at 5 dS m^{-1}, which decreased to 2.8 kg m^2 (i.e., by 33%) and to 1.5 kg m^2 (i.e., by 50%) with an increase in salinity to 10 and 15 dS m^{-1}, respectively. The water requirement under the UAE conditions was estimated to be around 250 mm, which is very similar to lettuce and spinach, but leaf mustard has the advantage of being more salt-tolerant than these commonly grown leafy greens, and hence of great potential for the Middle East.

2. Quinoa. Quinoa is a pseudocereal that has been cultivated in the Andes region for thousands of years for its highly nutritive grain. It belongs to the family *Chenopodiaceae*. Quinoa is known to grow well under extreme ecological conditions including drought and soil salinity, making it important for diversification of future agricultural systems in marginal environments (Rao and Shahid, 2012).

Quinoa grows up to a height of 1 m, depending on the cultivar. Leaves are eaten as a leaf vegetable, much like spinach, but the commercial availability of quinoa greens is limited. Quinoa grain is actually more like a vegetable than a grain. The protein content ranges between 11 and 19% and is of very high quality, containing all eight amino acids essential for human health. Quinoa is also a good source of dietary fibre and phosphorus and is high in magnesium and iron. Because of its high nutritional value and medicinal use, quinoa is recognized as a 'super crop' with the most complete nutritional composition (Vega-Galvez et al., 2010).

In a recent study conducted in the UAE on five accessions of quinoa using low-salinity water (2-3 dS m^{-1}), the average dry matter yield of five accessions was 1464 g m^{-2} and the average grain yield was 456.6 g m^{-2} both these being much higher than the average yields reported from the traditional growing areas in the Andes (Rao and Shahid, 2012). The study showed that quinoa can perform well under ecologically extreme desert conditions and holds great promise as a food, feed and forage crop for diversification of the agricultural production systems in salt-affected areas within the Middle East as well as other regions with similar climatic conditions.

The performance of selected cultivars of quinoa was also studied in the model farms in the western region of Abu Dhabi, where the salinity of irrigation water was in the range of 13-18 dS m^{-1}, and the data obtained of biomass and seed yield corroborated earlier findings that quinoa holds promise as a multipurpose crop for salt-affected areas in the Middle East. Earlier research at the International Potato Center (CIP) in Peru showed that quinoa's salt tolerance is very high, being able to grow and produce in salt concentrations close to sea water (Jacobsen et al., 2003; Koyro et al., 2008). Another attractive feature of quinoa is its low water requirement, and recent studies in the South Sinai desert demonstrated the value of quinoa as a crop suitable for arid climates (Shams, 2011). Its high levels of salinity tolerance, low-water demand and exceptionally high nutritional quality place quinoa in an enviable position as an alternative crop for marginal environments.

3. Salicornia. Salicornia, also known as dwarf saltwort, is a halophyte that grows in the coastal areas of Mexico and the United States of America. It is an annual plant of the family *Chenopodiaceae* with erect succulent stems, growing to a height of 30 cm. Salicornia is a delicacy salad vegetable and grown on a commercial scale for its tips in some countries (Glenn et al., 1991, 1998). It is an excellent source of vitamins, particularly vitamin A (Table 1). It is also a good source of the minerals calcium, iodine and iron (Lu et al., 2010). Seeds contain 28% oil and 31% protein, similar in quality to soybean. Salicornia oil has high levels of linoleic acid, similar to that of safflower oil (Anwar et al., 2002).

The species has significant potential in saline agriculture and coastal greening in the Middle East region (Shahid et al., 2013). Grattan et al. (2008) showed that hyper-saline drainage water can be used to irrigate Salicornia and more recently, Jaradat and Shahid (2012) carried out a detailed evaluation in sandy soils with sea water irrigation and identified genotypes with favourable combinations of traits that can be used by farmers in small-scale vegetable production, in large-scale biomass and oilseed renewable bioenergy production, or for reclamation of saline lands. Despite its potential as a crop with multiple uses, salicornia improvement receives very little attention.

4. Guar. Guar, also known as cluster bean, is a leguminous crop grown in Asia as a vegetable for human consumption, as forage for cattle, and as a green manure. The origin of guar is unknown, though it is believed to have developed from the African species *C. senegalesis*, but domesticated in India and Pakistan, where it has been cultivated for many centuries (Wong and Parmer, 1997; Mudgil et al., 2011).

Guar pods, used as a vegetable, are a good source of dietary fibre (3 g 100 g^{-1}) and minerals such as potassium (310 mg 100 g^{-1}), calcium (130 mg 100 g^{-1}) and the amino acid folate. The pods are also rich in protein and a good source of vitamins C, K and A (Wong and Parmer, 1997). The endosperm of guar seed contains galactomannan gum, which is gaining importance as a food and non-food item. Highly refined guar gum is used as a stiffener in soft ice cream, instant puddings and whipped cream substitutes. It is a common ingredient in fibre-rich drinks marketed as health drinks and weight-loss drinks. Lower grade guar gum is used in the textile, paper, petroleum, mining, pharmaceutical and cosmetic industries (Undersander et al., 1991).

In a field trial conducted in sandy soils at ICBA, the mean number of pods per plant of 10 accessions varied from 164.4 to 113.4, with a mean of 149.4, amounting to about 12 t/ha. Seed yield varied between 2.5 and 1.4 t ha^{-1} with a mean of 2.2 t ha^{-1} over accessions (Rao and Shahid, 2011). Both pod and seed yields obtained in the UAE were higher than the average yields reported from the traditional growing areas, indicating its potential as a multipurpose crop for the Middle East region.

Guar is more salt tolerant than many other grain legumes, with a high salinity threshold of 8 dS m^{-1} (Francois et al., 1990). It is also known for its drought tolerance and grows without irrigation even in areas with as little as 250 mm of annual rainfall (Undersander et al., 1991). The water requirement for guar in the UAE was estimated to be 354 mm, similar to other vegetables such as cucumber and cabbage. However, the higher salt tolerance of guar and its multiple uses as a forage and source of industrial gum make guar superior to other vegetable crops.

5. Amaranth. Amaranth, which belongs to the family *Amaranthaceae*, is an ancient food of the Aztecs and Mayans of Central America, and is now grown in many temperate and tropical regions. All parts of the amaranth plant are edible. In India and the Americas, amaranth is most often grown for its seeds, while in Southeast Asia and Africa, amaranth is grown as a leafy vegetable. Cooked greens (leaves) are used as a side dish, in soups and as an ingredient in baby food, pasta, pie, and so forth. Amaranth greens are a good source of vitamins and minerals (see Table 1). In comparison, amaranth leaves contain three times more vitamin A, calcium and niacin (vitamin B3) than spinach, and 18 times more vitamin A, 13 times more vitamin C, 20 times more calcium and seven times more iron than lettuce (Guillet, 2004).

There has been growing interest in amaranth worldwide in recent years due to its highly nutritious gluten-free grain. Amaranth grain contains 12 to 17% protein, and it is an excellent source of lysine, which sets it apart from other grain crops. The grain is high in fibre and low in saturated fats, contributing to its use by the health food market. Recent studies have linked amaranth to reduction in cholesterol in laboratory animals (Mendona et al., 2009).

Amaranth is moderately salt tolerant and compares well with other vegetable crops such as cowpea and mustard (Omami, 2005). Amaranth is one of the few C4 crops that are not grasses and once established, it can withstand acute drought conditions (NRC, 1984; Mnkeni et al., 2007).

6. New Zealand Spinach. New Zealand spinach is a member of the family *Tetragoniaceae*. It is a leafy vegetable native to New Zealand and occurs naturally in coastal areas of Australia and the Pacific Islands. It was introduced in Europe and America in the late 18th century, where it is a fairly common summer vegetable, grown as a substitute for ordinary spinach in home gardens (Grubben, 2004). New Zealand spinach leaves are edible and may be eaten fresh in salads or cooked. They can be used in many dishes, like amaranth, spinach or other leafy vegetables, with flavour similar to lettuce. The plant can also be used as a ground cover ornamental (Yensen, 2009).

New Zealand spinach is an excellent source of vitamins (especially vitamin A) and minerals such as calcium, phosphorus and iron (USDA, 2011). Leaves contain antioxidants such as carotenoids. Whole plants showed distinct anti-ulcerogenic activity in tests with mice and the active principles were determined to be sterylglucosides and cerebrosides (Grubben, 2004). New Zealand spinach is a halophyte, and studies show that its growth is promoted under saline conditions (Yousif et al., 2010). The main strategy of salt tolerance seems to be an increase of osmotic adjustment through the accumulation of Na^+ in leaves. New Zealand spinach is also characterized as a xerophyte, capable of enduring long periods of drought (Grubben, 2004).

CONCLUSIONS

Water scarcity and salinity are major constraints to agricultural production in the Middle East. Furthermore, climate change projections for the region indicate considerable negative impact on farm-level productivity due to the area's high dependency on climate-sensitive agriculture. Neglected and underutilized crops, being more resilient and better adapted to grow in marginal environments than current staple crops, offer cost-effective and viable solutions for food production. Native and non-native NUS identified in this paper offer robust alternatives to sustain agricultural productivity in the Middle East. Many of the NUS are also nutritionally rich and have a real potential to contribute to combating vitamin and micronutrient deficiencies, particularly in rural communities dependent on agriculture.

However, there are major gaps in our knowledge and capacity to make the best out of these NUS because agricultural research has so far paid little attention to these species. Research to increase the value of these crops and encourage them to be more widely cultivated would broaden the resource base and increase the livelihood options especially for smallholder farmers in marginal areas. In particular, efforts to improve NUS production through yield improvement and better postharvest management should be accelerated. The growing demand from consumers for diversity and novelty in foods is creating new market niches for NUS. Designer foods with balanced amino acid and micronutrient profiles can be developed using appropriate blends of major crops and NUS to meet demand and encourage farmers to grow these crops.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Ahmed Al Sharif for helpful discussions on the indigenous species.

Literature Cited

Al-Dabbas, M.M., Ahmad, R., Ajo, R.Y., Abulaila, K., Akash, M. and Al-Ismail, K. 2010. Chemical composition and oil components in seeds of *Moringa peregrina* (Forssk) Fiori. Crop Res. 40:161-167.

Anwar, F., Bhanger, M.I., Nasir, M.K. and Ismail, S. 2002. Analytical characterization of Salicornia bigelovii seed oil cultivated in Pakistan. J Agric Food Chem. 50:4210-4214.

Ashraf, M. and Noor, R. 1993. Growth and pattern of ion uptake in *Eruca sativa* Mill. under salt stress. Angew. Bot. 67:17-21.

Balch, J.F. and Balch, P.A. 2000. Prescription for Nutritional Healing. Penguin Putnam Inc., Avery, New York.

Bennett, R.N., Rosa, E.A.S., Mellon, F.A. and Kroon, P.A. 2006. Ontogenic profiling of glucosinolates, flavonoids, and other secondary metabolites in *Eruca sativa* (salad rocket), *Diplotaxis erucoides* (wall rocket), *Diplotaxis tenuifolia* (wild rocket) and *Bunias orientalis* (Turkish rocket). J. Agric. Food. Chem. 54:4005-4015.

Boulos, L. 1999. Flora of Egypt. Al Hadara Publishing, Cairo.

Chen, T.S. and Saad, S. 1981. Folic acid in Egyptian vegetables. The effect of drying method as storage on the folacin content of mulukhiyah (*Corchorus olitorius*). Ecol. Food Nutr. 10:249-255.

Chowdhary, C.V., Anusha, M., Naresh, K. and Kumar, A.E.R. 2013. A review of phytochemical and pharmacological profile of *Portulaca oleracea* Linn (Purslane). Intl. J. Res. Ayur. Pharm. 4:34-37.

De Pauw, E. 2002. An Agroecological Exploration of the Arabian Peninsula. ICARDA, Aleppo.

Deo, C. and Lal, P. 1982. Effect of water quality and moisture regime on soil properties and yield of mustard and taramira (*Eruca sativa*). J. Indian Soc. Soil Sci. 30 411-414.

Eden Foundation. 1992. Nutritional study on *Ziziphus spina-christi*. http://www.eden-foundation.org/index.html

Ekin, Z. 2005. Resurgence of safflower (*Carthamus tinctorius* L.) utilization. A global view. J. Agron. 4 83-87.

Facciola, S. 1990. Cornucopia. A Source Book of Edible Plants. Kampong Publications, Vista, California.

Feyssa, D.H., Njoka, J.T., Asfaw, Z. and Nyangito, M.M. 2011. Wild edible fruits of importance for human nutrition in semiarid parts of East Shewa Zone. Pak. J. Nutr. 10:40-50.

Fondio, L. and Grubben, G.J.H. 2004. *Corchorus olitorius* L. In: G.J.H. Grubben and O.A. Denton (eds.), PROTA (Plant Resources of Tropical Africa/Resources Vegetales de l'Afrique Tropicale). 2 Vegetables/Legumes. PROTA, Wageningen.

Francois, L.E., Donovon, T.J. and Maas, E.V. 1990. Salinity effects on emergence, vegetative growth and seed yield of guar. Agron. J. 82:587-592.

Ghassemi, F., Jakerman, A.J. and Nix, H.A. 1995. Salinization of Land and Water Resources. CAB International, Wallingford.

Glenn, E.P., Brown J.J. and O'Leary, J.W. 1998. Irrigating crops with seawater. Sci. Am. 279:76-81.

Glenn, E.P., O'Leary, J.W., Watson, M.C., Thompson, T.L. and Kuehl, R.O. 1991. *Salicornia bigelovii* Torn An oilseed halophyte for seawater irrigation. Science 25:1065-1067.

Grattan, S.R., Benes, S.E., Peters, D.W. and Diaz, F. 2008. Feasibility of irrigating pickleweed (*Salicornia bigelovii* Torr) with hyper-saline drainage water. J. Environ. Qual. 37:149-156.

Grieve, C.M. and Suarez, D.L. 1997. Purslane (*Portulaca oleracea* L.) A halophytic crop for drainage water use systems. Plant Soil 192:277-283.

Grubben, G.J.H. 2004. Tetragonia tetragonioides (Pall.) Kuntze. In: G.J.H. Grubben and O.A. Denton (eds.), PROTA (Plant Resources of Tropical Africa/Resources Vegetales de l'Afrique Tropicale), Wageningen. http //www.prota4u.org/search.asp

Guillet, D. 2004. Grain Amaranthus, History and Nutrition. Kokopelli Seed Foundation. http://www.kokopelli-seed-foundation.com/amaranths.htm

Hall, M.K.D., Jobling, J.J. and Roger, G.S. 2012. Perspectives on rocket as vegetable crop A review. Veg. Crops Res. Bull. 76:21-41.

Hegazy, A.K., Hammouda, O., Lovett-Doust, J. and Gomaa, N.H. 2008. Population dynamics of *Moringa peregrina* along altitudinal gradient in the north-western sector of the Red Sea. J. Arid Environ. 72:1537-1551.

ICRAF. 1998. http://www.worldagroforestrycentre.org/Sea/Products/AFDbases/AF/

Jacobsen, S.E., Mujica, A. and Jensen, C.R. 2003. The resistance of quinoa (*Chenopodium quinoa* Willd.) to adverse abiotic factors. Food Rev. Intl. 19:167-177.

Jaradat, A.A. and Shahid, M. 2012. The dwarf saltwort (*Salicornia bigelovii* Torr.)

Evaluation of breeding populations. SRN Agron. doi 10.5402/2012/151537
Knowles, P.F. and Ashri, A. 1995. Safflower *Carthamus tinctorius* (*Compositae*). In: J. Smartt and N.W. Simmonds (eds.), Evolution of Crop Plants, Longman Scientific & Technical, Harlow.
Koyro, H.W., Lieth, H. and Eisa, S.S. 2008. Salt tolerance of *Chenopodium quinoa* Willd. p.133-145. In: H. Leith, M.G. Surce and B. Herzog (eds.), Mangroves and Halophytes Restoration and Utilisation. Springer, Dordrecht.
Ladeiro, B. 2012. Saline agriculture in the 21st century. Using salt contaminated resources to cope food requirements. J. Bot. doi 10.1155/2012/310705
Lu, D., Zhang, M., Wang, S., Cai, J., Zhou, X. and Zhu, C. 2010. Nutritional characterization and changes in quality of *Salicornia bigelovii* Torr. during storage. LWT - Food Sci. Technol. 43:519-524.
Ma, H., Yang, R., Wang, Z., Yu, T., Jia, Y., Gu, H., Wang, X. and Ma, H. 2011. Screening of salinity tolerant jute (*Corchorus capsularis* & *C. olitorius*) genotypes via phenotypic and physiology-assisted procedures. Pak. J. Bot. 43 2655-2660.
Mahr, S. 2011. Common Purslane, *Portulaca oleracea*. University of Wisconsin, Madison. http://wimastergardener.org/?q=Portulaca_oleracea
Martinez-Sanchez, A., Gillzquierdo A., Gil, M.I. and Ferreres, F. 2008. A comparative study of flavonoid compounds, vitamin C, and antioxidant properties of baby leaf *Brassicaceae* species. J. Agri. Food Chem. 56:2330-2340.
Mateljan, G. 2006. Mustard greens. In: World's Healthiest Foods Essential Guide for the Healthiest Way of Eating. The George Mateljan Foundation, California. www.whfoods.com/genpage.php?tname=foodspice&dbid=93
Mendona, S., Saldiva, P.H., Cruz, R.J. and and Arêas, J.A.G. 2009. Amaranth protein presents cholesterol-lowering effect. Food Chemistry 116:738-742.
Mibei, E.K., Ojijo, N.K., Karanja1, S.M. and Kinyua1, J.K. 2012. Phytochemical and antioxidant analysis of methonolic extracts of four African indigenous leafy vegetables. Ann. Food Sci. Technol. 13:37-42.
Mnkeni, A.P., Masika, P. and Maphaha, M. 2007. Nutritional quality of vegetable and seed from different accessions of Amaranthus in South Africa. Water SA 33:377-380.
Motamedi, H., Safary, A., Maleki, S. and Seyyednejad, S.M. 2009. *Ziziphus spina-christi*, a native plant from Khuzestan, Iran, as a potential source for discovery new antimicrobial agents. Asian J. Plant Sci. 8:187-190.
Mudgil, D., Barak, S. and Khatkar, B.S. 2011. Guar gum processing, properties and food applications: a review. J. Food Sci. Technol. doi 10.1007/s13197-011-0522-x
National Research Council. 1984. Amaranth Modern Prospects for an Ancient Crop. National Academy Press, Washington, D.C.
Ndlovu, J. and Afolayan, A.J. 2008. Nutritional analysis of the South African wild vegetable *Corchorus olitorius* L. Asian J. Agri. Sci. 7:615-618.
Nour, A., Ali, A.O. and Ahmed, A.H.R. 1987. A chemical study of *Ziziphus spina-christi* (Nabag) fruits grown in Sudan. Trop. Sci. 27:271-273.
Oelke, E.A., Oplinger, E.S., Teynor, T.M., Putnam, D.H., Doll, J.D., Kelling, K.A., Durgan, B.R. and Noetzel, D.M. 1992. Safflower. Alternative Crops Field Manual. Universities of Wisconsin Cooperative Extension Service, University of Minnesota Centre for Alternative Plant and Animal Products & Minnesota Extension Service. http://www.hort.purdue.edu/newcrop/afcm/saffl ower.html
Osman, H.E. and Abohassan, A.A. 2012. Morphological and analytical characterization of *Moringa peregrina* populations in Western Saudi Arabia. Intl. J. Theor. Appl. Sci. 4:174-184.
Osman, M.A. and Ahmed, M.A. 2009. Chemical and proximate composition of (*Ziziphus spina-christi*) nabag fruit. Nutr. Food Sci. 39:70-75.
Oyen, L.P.A. and Umali, B.E. 2007. *Carthamus tinctorius* L. In: H.A.M. van der Vossen and G.S. Mkamilo (eds.), PROTA (Plant Resources of Tropical Africa/Resources Vegetales de l'Afrique Tropicale). 14 Vegetable oils/Oléagineux. PROTA, Wageningen.

Pitman, M.G. and Läuchli, A. 2002. Global impact of salinity and agricultural ecostems. p.3-10. In: A. Läuchli and U. Lüttge (eds.), Salinity Environment - Plants - Molecules. Kluwer Academic Publishers, Dordrecht.
Rao, N.K. and Shahid, M. 2011. Potential of cowpea (*Vigna unguiculata* L.) Walp.] and guar (*Cyamopsis tetragonoloba* L.) Taub.] as alternative forage legumes for the United Arab Emirates. Emir. J. Food Agric. 23:110-119.
Rao, N.K. and Shahid, M. 2012. Quinoa- A promising new crop for the Arabian Peninsula. American-Eurasian J. Agric. Environ. Sci. 12:1350-1355.
Saied, A.S., Gebauer, J., Hammer, K. and Buerkert, A. 2008. *Ziziphus spina-christi* (L.) Willd.: a multipurpose fruit tree. Genet. Resour. Crop Evol. 55:929-937.
Schippers, R.R. 2000. African Indigenous Vegetables: an Overview of the Cultivated Species. Natural Resource Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation, Chatham.
Schippers, R.R. and Mnzava, N.A. 2007. *Brassica juncea* (L.) Czern. In: H.A.M. van der Vossen and G.S. Manila (eds.), PROTA (Plant Resources of Tropical Africa/Resources Vegetales de l'Afrique Tropicale), Wageningen. http: //www.prota4u.org/search.asp
Shahid, M., Jaradat, A. and Rao, N.K. 2013. Use of marginal water for *Salicornia bigelovii* Torr. planting in the United Arab Emirates. p.451-461. In: S.A. Shahid et al. (eds.), Developments in Soil Salinity Assessment and Reclamation Innovative Thinking and Use of Marginal Soil and Water Resources in Irrigated Agriculture. Springer Science+Business Media, Dordrecht.
Shams, A. 2011. Combat degradation in rain-fed areas by introducing new drought tolerant crops in Egypt. Intl. J. Water Resour. Arid Environ. 1:318-325.
Shannon, M.C. and Grieve, C.M. 1999. Tolerance of vegetable crops to salinity. Sci. Hort. 78:5-36.
Shannon, M.C., Grieve, C.M., Lesch, S.M. and Draper, J.H. 2000. Analysis of salt tolerance in nine leafy vegetables irrigated with saline drainage water. J. Amer. Soc. Hort. Sci. 125:658-664.
Simopoulos, A.P., Norman, H.A., Gillaspy, J.E. and Duke, J.A. 1992. Common purslane a source of omega-3 fatty acids and antioxidants. J. Am. Coll. Nutr. 11:374-382.
Simopoulos, A.P. 2008. The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. Exp. Biol. Med. 233:674-688.
Sohail, M., Saied, A.S., Gebauer, J. and Buerkert, A. 2009. Effect of NaCl salinity on growth and mineral composition of *Ziziphus spina-christi* (L.) Willd. J. Agr. Rural Dev. Trop. 110:107-114.
Tsaknis, J. 1998. Characterisation of *Moringa peregrina* Arabia seed oil. Grasas Aceites 49:170-176.
Undersander, D.J., Putnam, D.H., Kaminski, A.R., Kelling, K.A., Doll, J.D., Oplinger, E.S. and Gunsolus, J.L. 1991. Guar. In Alternative Field Crop Manual. University of Wisconsin Cooperative Extension Service, University of Minnesota Extension Service, Centre for Alternative Plant & Animal Products. http: //www.hort.purdue.edu/newcrop/afcm/cowpea.html
USDA. 2011. USDA nutrient database for standard reference, release 25. USDA Nutrient Data Laboratory, Beltsville Human Nutrition Research Centre, Beltsville, Maryland. http://ndb.nal.usda.gov/ndb/foods/show/3009?fg=&man=&lfacet=&format=&count=&max=25&offset=&sort=&qlookup=new+zealand+spinach
van Rensburg, J.W.S., Ventel, S.L., Netshiluvhi, T.R., Van Den Heever, E., Voster, H.J. and De Ronde, J.A. 2004. The role of indigenous leafy vegetables in combating hunger and malnutrition. S. Afr. J. Bot. 70:52-59.
Vega-Galvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L. and Martinez, E.A. 2010. Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* Willd.), an ancient Andean grain a review. J. Sci. Food Aric. 90:2541-2547.
Ward, R. 2002. Traditional herbal medicine directive. Nutraceut. World 5:74-77.
Wong, L.J. and Parmar, C. 1997. *Cyamopsis tetragonoloba* (L.) Taubert. p.109-113. In: I.

F. Hanum and L.J.G. van der Maesen (eds.), PROSEA (Plant Resources of South-East Asia) Foundation, Bogor. http //www.proseanet.org
Yadava, T.P., Friedt, D.W. and Gupta, S.K. 1998. Oil content and fatty acid composition of Taramira (*Eruca sativa* L.) genotype. J. Food Sci. Technol. 35:557-558.
Yensen, N.P. 2009. Halophyte Database salt tolerant plants and their uses. USDA-ARS U.S. Salinity Laboratory and NyPa International. http://www.ussl.ars.usda.gov/pls/caliche/halophyte.query?k=Species&q=tetragonoides
Yousif, B.S., Nguyen, N.T., Fukuda, Y., Hakata, H., Okamoto, Y., Masaoka, Y. and Saneoka, H. 2010. Effect of salinity on growth, mineral composition, photosynthesis and water relations of two vegetable crops; New Zealand spinach (*Tetragonia tetragonioides*) and water spinach (*Ipomoea aquatica*). Intl. J. Agric. Biol. 12:211-216.

Tables

Table 1. Nutritional composition (per 100 g) of some neglected and underutilized leafy vegetables with potential for marginal environments.

	Purslane[1]	Jute mallow[1]	Rocket[1]	Mustard greens[1]	Salicornia[2]	Amaranth[1]	New Zealand spinach[1]	Recommended daily allowance (RDA)
Energy (Kcal)	16	34	25	26	4.48	23	14	2500
Carbohydrate (g)	3.4	5.8	3.56	4.9	1.54	4.02	2.5	130
Protein (g)	1.3	4.6	2.58	2.68		2.46	1.5	50
Fat (g)	0.1	0.25	0.66	0.18	0.37	0.33	0.2	65
Fibber (g)	0.9	0.25	1.6	3.3	0.83			25
Calcium (mg)	65	208	160	103	62	215	58	1000
Phosphorus (mg)	44	83	52		18	50	28	700
Potassium (mg)	494	559	369	354	176	611	130	4700
Magnesium (mg)	68	64	47	32	118	55	39	400
Sodium (mg)	45	8	27	25	998	20	130	1500
Iron (mg)	1.99	4.7	1.46	1.46	1	2.32	0.8	8
Manganese (mg)	0.30	0.12	0.32	0.48				2.3
Zinc (mg)	0.17	0.79	0.47	0.2	0.4	0.9	0.38	11
Copper (mg)	0.113	0.25	0.076	0.15	0.009			0.9
Vitamin C (mg)	21	37	15	70	40.7	43.3	30	90
Vitamin A (IU)	1320	5559	2373	10500	15.9	2917	4400	3000
Vitamin K (µg)		640	108.6	497.3		1140	337	120
Vitamin E (mg)		6.5	0.43	2.01			1.42	15
Folate (µg)	12	250	97	187		85	15	400

[1]USDA National Nutrient Database for Standard Reference (http //ndb.nal.usda.gov).
[2]Lu et al., 2010.