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International Cooperators' Guide



Vegetable amaranth (Amaranthus L.)

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Introduction

Vegetable amaranth is widely grown in the tropics and is one of the most important leafy vegetables in the lowlands of Africa and Asia. Amaranth is an annual, fast growing herb that can be cultivated easily in home gardens and at commercial scale (Fig. 1). This highly nutritious vegetable is rich in protein, calcium, iron, vitamins A, C and K, riboflavin (B2), niacin (B3), vitamin B6, and folate (B9).



Fig. 1. Commercial amaranth production under nylon-mesh netting in Taiwan.

Biodiversity, origin, geographic distribution and use

The genus *Amaranthus* comprises about 70 species, 40 of which are native to the Americas. Among the 70 species, 17 are vegetable amaranths with edible leaves, and three are grain amaranths with edible seeds (*A. caudatus* – Inca wheat, love-lies-bleeding; *A. cruentus* – purple amaranth; *A. hypochondriacus* – Prince's feather).

Popular vegetable amaranth species

- ***Amaranthus blitum***

Common names: livid amaranth, slender amaranth (En.); amarante livide (Fr.); blede (Sp.).

The probable origin of *A. blitum* is the Mediterranean region; it is found worldwide from the tropics to temperate climates (Fig. 2). It is a popular cultivated vegetable in India and is also cultivated in East and Central Africa. It is grown in home gardens in southeastern Europe (Greece), where it is used as a spinach substitute during the hot and dry summer months. It is not suitable for fresh consumption due to relatively high levels of hydrocyanic acid and oxalic acid. It is also a cosmopolitan weed.



Fig. 2. Plants of *A. blitum* with emerging inflorescences.

● *A. cruentus*

Common names: purple amaranth, red amaranth, red shank, bush greens, African spinach, Indian spinach (En.); amarante étalée, queue de renard (Fr.); achita, blede (Sp.)

This amaranth species was domesticated as a grain in Mesoamerica and found its way to the tropics and subtropics of the Old World during colonial times. It is used for grain production (pseudocereal), as a leafy vegetable, and for ornamental purposes. In tropical Africa it is a traditional, highly productive, nutritious and economically important leafy vegetable. It is also widely grown as a leafy vegetable throughout Southeast Asia and South Asia (Fig. 3). In Indonesia it is mostly grown in mountainous areas where it is too cold for the popular amaranth species *A. tricolor*. The leaves and tender stems are cut and cooked or fried in oil and served as a side dish. The high calcium oxalate content limits its use as fodder.



Fig. 3. Plants of *A. cruentus* with red inflorescences and partially red-colored leaves.

Grain amaranth types of *A. cruentus* are common in Central America and northern South America. Grain amaranth is also popular in India and Nepal and is commercially grown in hot and dry areas of the United States, Argentina, and China.

Ornamental types of *A. cruentus* have large bright-red inflorescences and are often found in the tropics and subtropics. The inflorescences can be used to produce a red dye.

● *A. dubius*

Common names: spleen amaranth (En.); brède de Malabar (Fr.); blede, bledos malezas, pira (Sp.)

Cultivated types of *A. dubius* (Fig. 4) may have been derived from the weedy ancestor in tropical Asia (Indonesia, India) and may have been introduced to Africa and Central America by immigrants. It is usually grown from sea level to 1200 m elevation and reaches a yield of 25 t/ha in eight weeks. The plants are used as a cooked leafy vegetable. *A. dubius* is more susceptible to drought than *A. cruentus*.

● *A. spinosus*

Common names: spiny amaranth, thorny pigweed (En.); épinard cochon, épinard malabre (Fr.); blede espinoso, espinaca de Malabar (Sp.); katemath (Ind.)

This species probably originated from the lowland tropics in South and Central America. It is now found in most tropical and subtropical regions, including Africa, but is rarely cultivated due to the spines and the poor taste (Fig. 5a, b). It is usually collected for home consumption and eaten cooked, steamed or fried; it can help bridge periods of drought. To some extent, it is also used as forage. The species has multiple medicinal uses. The root has diuretic effects; the plant sap is used as an eye wash. The plant is also used as an expectorant and to relieve breathing of patients suffering from acute bronchitis.



Fig. 4. *A. dubius* plants with inflorescences, on raised beds with drip irrigation.

● *A. tricolor*

Common names: Chinese amaranth, Chinese spinach, Joseph's coat (En.); amarante comestible, amarante tricolore (Fr.); amaranto, moco de pavo (Sp.); tampala, math, (Ind.); aupa (Indon.); hageito, hiyu (Jap.)

The probable origin of this amaranth species is tropical Asia (Fig. 6a, b). In South and Southeast Asia, *A. tricolor* is a major leafy vegetable species and is the dominant cultivated amaranth species, followed by *A. dubius* and *A. cruentus*. It is occasionally cultivated in East, West, and southern Africa. It is generally used as a cooked vegetable, but occasionally also eaten raw in salads. In India, the soft stems are eaten like asparagus. Leaves and stems contain the antinutrients nitrate (mostly in stems) and oxalate, but adverse nutritional effects are unlikely if consumption does not exceed 200 g per day. Cooking in ample water removes the toxic components. Types with red, yellow and green leaves are widely cultivated as ornamentals. *A. tricolor* is also used as a diuretic and to treat inflammations. *A. tricolor* is an easy-to-grow, productive, tasty, and nutritious leafy vegetable. Seed companies are offering commercial varieties of this species in South and Southeast Asia. The cultivar 'Lal Sag' is popular in India, while the cultivar 'Tampala' is well-adapted for cultivation in the southern United States.

● *A. viridis*

Common names: green amaranth, pigweed, slender amaranth (En.); bleado (Sp.); cararu (Port.)

A. viridis is possibly of Asian origin (Fig. 7). It is considered a pan-tropical weed and has penetrated into warm temperate regions worldwide. It is also a widespread and common weed

in Africa and occasionally cultivated. Although mostly growing as a weed, its nutritional value is high. Leaves and young plants are eaten as a cooked vegetable. The plant also serves as fodder for cattle and green manure. The leaves have diuretic and purgative properties and are used in traditional medicine to cure many different ailments.

Local names of amaranth:

- Cambodia: Phtii
- Indonesia & Malaysia: Bayam
- Laos: Hôrn
- Papua New Guinea: Aopa
- Philippines: Kulitis
- Thailand: Phakkhom-suan
- Vietnam: Rau d[ee]f[n]



Fig. 6a. Young plants of *A. tricolor* with some leaf damage caused by insects, ready for harvesting.



Fig. 5a. *A. spinosus* plants with inflorescences on raised beds with plastic mulch; insert: clearly visible spines on main stem.



Fig. 6b. *A. tricolor* plants with typically colored leaves.



Fig. 5b. *A. spinosus* - clearly visible spines on main stem.



Fig. 7. Mature *A. viridis* plants with inflorescences.

Ecology

Amaranth uses the C₄-cycle photosynthetic pathway. It has a high rate of photosynthesis and excellent water use efficiency at high temperatures and high radiation intensity. Other C₄ crop plants are maize, sugarcane and spider plant (*Cleome gynandra*). Vegetable amaranth grows well in both hot humid and hot dry climates and requires day temperatures above 25 °C.

Vegetable amaranth can tolerate day temperatures up to 40 °C, while night temperatures should not be lower than 15 °C. Temperatures below 10 °C may cause chilling injury resulting in fibrous, non-straight plants. After seedling emergence, many amaranth cultivars are tolerant to drought and highly wet conditions, but sensitive to complete flooding. Amaranth is photoperiod-sensitive and most species will flower when day lengths are shorter than 12 hours.

Amaranth grows best in a fertile loam or silty-loam soil with good water-holding capacity, but depending on the species, also adapts to poor soil conditions and low soil moisture levels (*A. blitum*, *A. cruentus*, *A. hypochondriacus*). The mineral uptake from the soil is high. Some amaranth types (*A. blitum*, *A. spinosus*) are known to be drought-tolerant.

Cultivation

Amaranth requires thorough land preparation and raised beds for good growth. Beds may be 90 cm wide and 20 cm high during the dry season and 30 cm or higher during the rainy season. Amaranth is planted either by direct seeding (*A. tricolor*) or by transplanting (*A. cruentus*, *A. dubius*). **Direct seeding.** Direct seeding is recommended for *A. tricolor*. Seeds are either broadcast or sown in rows, 10-20 cm apart, on well-prepared seed beds. Because amaranth seed is very small, it is recommended to mix seed with sand at a ratio of 1 g seed to 100 g sand to facilitate the sowing process and to obtain a uniform stand. The seed rate ranges from 1 to 1.5 g per m² resulting in a plant density of 100-400 per m², without thinning. The amount of seeds per gram varies depending on the species. *A. blitum* has relatively large seeds (1000 seeds/g), followed with decreasing seed size by *A. tricolor* (1200-2900 seeds/g), *A. cruentus* (2500-3500 seeds/g), and *A. dubius* (4000-6000 seeds/g). After broadcasting, the seeds are covered with a thin layer of compost or rice hulls as germination is stimulated by darkness.

Raising seedlings for transplanting. To shorten the cropping period in the field and to assure a better and more uniform stand, especially during the wet season, raising seedlings in a nursery followed by transplanting to the field is recommended over direct seeding (except *A. tricolor*).

Seedling production. Seedlings can be sown in a nursery on seedbeds. The soil should be partially sterilized by burning a 3-5 cm thick layer of rice straw or other dry organic matter on the bed. This adds minor amounts of P and K to the soil facilitating the establishment of the seedlings. The seeds are broadcast at a seed rate of 3-10 g/m² and lightly covered (1 cm deep). This results in 1000-1500 plantlets per m² for transplanting.

It is recommended to cover the seedbeds with an insect-proof net, or sow the seeds inside a screenhouse.

This provides shade and protects the seedlings from heavy rains and pests. Regular watering with a fine-mist sprinkler is required to keep the seedlings moist, but not wet. Raising seedlings in shade requires a hardening step before seedlings can be transplanted to the field. Seedlings are gradually exposed to direct sunlight starting with an exposure of 3-4 hours on the first day. During the following days exposure is gradually increased until the seedlings receive full sunlight on the fourth day. After 2-3 weeks, the plantlets are pulled and transplanted bare-rooted to the field.

Another option is to grow the seedlings in plug trays with cells 3-4 cm wide and deep (size 100-128). The seedling trays are filled with a potting mix of good water-holding capacity and drainage such as peat moss, commercial potting soil, or a self-made potting mix prepared from soil, compost, rice hulls, vermiculite, and/or sand. A mixture of 66% peat moss and 34% coarse vermiculite is recommended. If non-sterile components are used, it is preferable to sterilize the potting mix by autoclaving or baking at 150 °C for 2 hours.

Two to three seeds are sown per cell at 0.5-1 cm depth and thinning to one seedling occurs at the 2-3 true leaf stage. The trays are kept inside a screenhouse. This provides shade and protects the seedlings from heavy rains and pests. Regular watering with a fine-mist sprinkler is required to keep the seedlings moist, but not wet.

Hardening of seedlings is required as described previously before transplanting to the field. Seedlings are ready for transplanting at about 3 weeks after sowing or when transplants have five or six leaves (Fig. 8a, b).

Field transplanting. Spacing varies depending on variety/species used and frequency of harvests. Wider spacing is used for tall varieties with broad leaves and multiple harvests while narrower spacing is used for short varieties with narrow leaves and single harvest. A plant density of 100-400 plants/m² can be used for a single harvest while 20-100 plants/m² are appropriate for repeated cuttings (*A. blitum* in India). Low plant densities of 100 plants/m² result in good yields and significantly reduce the labor costs for transplanting. Higher plant densities of up to 400 plants/m² often result in self-thinning without noticeable yield increase. During the rainy season denser plantings are applied to compensate for plant losses caused by *Choanephora cucurbitarum* stem rot. Rows may be spaced 10-20 cm apart and plants 5-10 cm apart within rows.



Fig. 8a. Amaranth seedlings ready for transplanting.

Fertilizer application

Although amaranth can grow in poor soils, yields are notably enhanced with fertilizer. An amaranth yield of 25 t/ha is extracting 125 kg N, 25 kg P, 250 kg K, 75 kg Ca and 40 kg Mg from the soil. Amaranth responds well to organic fertilizer, which can be applied at a rate of 25 t/ha. On poor soils, a complementary mineral fertilizer application of 250 up to 400 kg/ha of NPK 10-10-20 is often recommended. A split application of NPK is advisable to avoid nutrient leaching, especially during the rainy season. Amaranth responds better to nitrate-N than to ammonium-N. Ideally, a soil test should be undertaken to determine pH, organic matter content and the levels of available N, P, K, Ca, and Mg. This would allow an informed decision concerning the fertilizer needs of the crop.

Irrigation

Although some amaranth species are relatively drought-tolerant, lack of water will lead to early flowering, a decrease in yield and market quality. Watering is very important after sowing or transplanting to ensure a good stand. At AVRDC, fields are furrow-irrigated every 10 days during the cool-dry season, and weekly during the hot-dry season. As a rule, the plants should be irrigated if wilting occurs at around noontime. Drip irrigation or micro-sprinklers are recommended in areas with limited water supply. Late evening sprinkler irrigation should be avoided as this may favor the outbreak of diseases.

During the rainy season, drainage is essential for plant survival and growth. Raised beds, clean furrows and large drainage canals facilitate quick drainage of excess water after heavy rain.

Weed control

Due to the weedy nature and rather strong growth of many amaranth species, weeds, in general, are not a major problem. Nevertheless, early weed control is important

as amaranth seeds are small in size and relatively slow to germinate. Thorough land preparation is essential for effective initial weed control. A clean seedbed gives amaranth seedlings a head start on weeds and the plantlets may then establish a dense canopy that suppresses the emergence of weed seedlings. Mulching is recommended to reduce soil compaction and erosion, to conserve soil moisture, and to suppress weed competition. Organic mulching materials should be free of weed seeds. Herbicides should only be used if absolutely necessary.

Control of diseases and insect pests

Damping-off caused by *Phytophthora blight* and *Rhizoctonia* can be a serious problem in seedbeds. To control it, avoid over-dense sowing and provide good drainage. Wet rot or stem rot caused by *Choanephora cucurbitarum* is a major fungal disease on *A. cruentus*, while *A. tricolor* and *A. dubius* are much less susceptible. Wet conditions, poor soil fertility and high nitrogen levels favor the disease.

In Taiwan and other countries, white rust (*Albugo bliti* (Biv.) Kuntze) and amaranth anthracnose (*Colletotrichum erumpens* Sacc. var. *amaranthi* Teng.) may turn into serious diseases, which can be addressed in the long run through genetic resistance. Until resistant lines become available, chemical sprays with (a) 80% WG Fosetyl-Aluminum at a rate of 2-3 kg/ha diluted in 1000 or 1500 l of water, respectively, or (b) 64% WP Propineb (56%) + Oxadixyl (8%) at a rate of 2-3 kg/ha diluted in 800 or 1200 l of water, respectively are recommended in Taiwan. The chemical should be applied once four green leaves have developed. A minimum time of 12 days (Fosetyl-Aluminum) or 15 days (Propineb + Oxadixyl) must elapse between spraying and harvesting. These products are toxic to aquatic organisms and must not be applied in water catchment areas that are sources for drinking water.

Leaf and stem blight caused by *Phomopsis amaranthophila* has been reported in Brazil. Alternaria leaf spot occurs on *A. cruentus* in Tanzania. Fungicide sprays help to control these diseases, but are rarely used.

Insect pests are a major problem for amaranth growers. Damage caused by caterpillars (*Spodoptera litura*, *Heliothis armigera*, *Hymenia recurvalis*), the stem weevil (*Lixus truncatulus*), and grasshoppers can be quite severe. Other insect pests of amaranth are aphids, leaf miners, stinkbugs, mole crickets, and mites. The traditional application of wood ash to dispel the insects is now often replaced by frequent applications of insecticides with frequencies of up to twice a week. Due to the short growth cycle of amaranth, special care must be taken to avoid pesticide residues that may harm consumers. Biopesticides based on *Bacillus thuringiensis* (Bt) should be used as the first option. A safe and effective measure to control insect pests is the use of fine screen or nylon mesh netting (32-mesh or finer) to cover the planting beds (Fig. 1).



Fig. 8b. Amaranth seedlings transplanted into net cages in multiplication fields at AVRDC – The World Vegetable Center.

Harvest

Amaranth is ready for harvesting 20-45 days after transplanting or sowing, depending on variety and harvesting method (Fig. 9). Plants may be harvested once or multiple times. Fast-growing and quick-maturing species such as *A. tricolor* are adapted for single harvesting. At 20-30 days after transplanting, whole plants are pulled from the soil with roots, washed and tied in bundles. Some growers harvest by cutting at ground level.

With wider spacing, the preferred harvest method is repeated cutting. The first cutting is done about one month after transplanting, and then repeated every 2-3 weeks. The first cut is done at a height of 10-15 cm, leaving at least two leaves and buds behind for regrowth. Low cutting retards bolting and allows for up to 10 cuttings at 2-week intervals. Eventually, the plants start to flower and produce fewer leaves.

Like other leafy vegetables, amaranth plants have a large surface-to-volume ratio and lose water rapidly. Harvesting during early morning or late afternoon hours is preferred to reduce water loss. In Taiwan, maturity for harvesting is reached 3 weeks from planting (single harvest) during summer, while 40-50 days are required during the winter season. The produce has to be washed and kept in a cool place after harvest to reduce losses.

Nutritional value of amaranth

Amaranth is a highly nutritious leafy vegetable, both in raw and cooked form (Table 1). Its nutritional value is comparable to spinach, but much higher than cabbage and Chinese cabbage (Table 1). Amaranth is well adapted to high temperatures in the tropics, while spinach lacks heat tolerance and is not an option for tropical climates.

Amaranth is low in saturated fats and sodium; cholesterol is absent. It is a good source of calcium, iron, magnesium, phosphorus, potassium, zinc, copper and manganese. It is a very good source of high quality protein with well-balanced amino acids. Many vitamins are found in high levels in both raw and cooked amaranth leaves and stems: vitamin A, vitamin C, riboflavin (vitamin B2), vitamin B6, folate (vitamin B9) and niacin (vitamin B3).



Fig. 9. Different amaranth cultivars on display at the Fongshan Tropical Horticultural Experiment Station, ready for first harvesting.

Amaranth also contains betacyanines—amaranthine and iso-amaranthine—responsible for the red-violet colors of leaves, stems, flowers and seeds. These pigments dissolve in cooking water, which is poured off. Leaves and stems contain the antinutrients nitrate (mostly in stems) and oxalate at a level similar to other leafy vegetables such as spinach and spinach beet. Consumption of 100-200 g of fresh produce per day is safe. Cooking in water removes the toxic components.

Utilization

- Leaves and tender stems are eaten fresh, boiled, steamed, stir-fried, as soup, stewed or pureed.
- Seeds are popped, ground to thicken stews, or used as flour.
- Amaranth seeds have an excellent protein quality characterized by a high lysine content of 3-18% and are therefore increasingly popular among health-conscious consumers.
- Amaranth oil has antioxidant properties and is used in the cosmetic industry.
- Forms with bright red inflorescences are grown as ornamentals.
- Amaranth has many medicinal properties (diuretic, laxative, fever, anemia, wound dressing, and stomachache).

Other ways of food preparation

- In India, amaranth greens are steamed and mashed, with a light seasoning of salt, red chili and cumin. Amaranth is also used to prepare curries like Hulee, Palya, and Majjigay-hulee. In Kerala, amaranth leaves are stir-fried and eaten with spices and red chilis, called Cheera Thoran.
- The white root of mature amaranth is an excellent vegetable. It is cooked with tomatoes or tamarind gravy. It has a milky taste and is alkaline.
- In the Caribbean, amaranth leaves are stewed with onions, garlic and tomatoes, or sometimes used in a soup.

Table 1. Nutritional value of raw and cooked (boiled, drained, without salt) amaranth leaves, compared with raw cabbage, raw Chinese cabbage and raw spinach

Nutrients\Leafy vegetable	Cabbage, raw	Chinese cabbage, raw	Spinach, raw	Amaranth, raw	Amaranth, cooked
	Value per 100 g	Value per 100 g	Value per 100 g	Value per 100 g	Value per 100 g
Protein (g)	1.28	1.20	2.86	2.46	2.11
Minerals					
Calcium (Ca; mg)	40	77	99	215	209
Iron (Fe; mg)	0.47	0.31	2.71	2.32	2.26
Magnesium (Mg; mg)	12	13	79	55	55
Phosphorus (P; mg)	26	29	49	50	72
Potassium (K; mg)	170	238	558	611	641
Sodium (Na; mg)	18	9	79	20	21
Zinc (Zn; mg)	0.18	0.23	0.53	0.90	0.88
Copper (Cu; mg)	0.019	0.036	0.130	0.162	0.158
Manganese (Mn; mg)	0.160	0.190	0.897	0.885	0.861
Vitamins					
Vitamin C (mg)	36.6	27.0	28.1	43.3	41.1
Riboflavin (mg)	0.040	0.050	0.189	0.158	0.134
Niacin (mg)	0.234	0.400	0.724	0.658	0.559
Vitamin B-6 (mg)	0.124	0.232	0.195	0.192	0.177
Folate (total; mcg)	43	79	194	85	57
Vitamin A, RAE ¹ (mcg)	5	16	469	146	139
Vitamin K (mcg)	76	42.9	482.9	1140	-
Lipids					
Fatty acids (total saturated; g)	0.034	0.043	0.063	0.091	0.050
Cholesterol (mg)	0	0	0	0	0

Source: USDA National Nutrient Database for Standard Reference, Release 23 (2010)

<http://www.nal.usda.gov/fnic/foodcomp/search/>

¹The recommended dietary allowance (RDA) for vitamin A is measured in retinol activity equivalents (RAE). The body obtains vitamin A from retinol and carotenoids. One RAE is equal to 1 mcg of retinol; 12 mcg of beta-carotene; 24 mcg of other vitamin-A precursor carotenoids.

Amaranth recipes

Fried Amaranth

Ingredients

- Amaranth leaves 300 g
- Chopped garlic 3 tablespoon
- Sliced bacon 1/4 cup
- Vegetable oil few teaspoons
- Sliced chili pepper to taste
- Salt to taste

Procedure

1. Heat vegetable oil in a pan and add garlic.
2. Stir-fry garlic and bacon until golden color shows.
3. Add the amaranth leaves and season with salt.
4. Add red chili pepper for decoration.
5. Serve while hot.

Source: Sylvia Hsu, AVRDC Food and Dormitory Services



Fig. 10. Fried amaranth.

Amaranth Soup with Larval Fish

Ingredients

- Vegetable oil 1 teaspoon
- Chopped garlic 2 teaspoons
- Chicken stock 6 cups
- Amaranth leaves 300 g
- Larval fish 150 g
- Corn starch 3 teaspoons
- Water 1/2 cup
- Salt 1-2 teaspoons
- Sesame oil 1 teaspoon

Procedure

1. Heat vegetable oil in a pan and add garlic.
2. Stir-fry garlic until golden color shows.
3. Add chicken stock and cook until it boils, then add the amaranth leaves.
4. After boiling for 3 minutes, add larval fish.
5. Mix water and corn starch.
6. Stir the soup while adding the mixture of water and corn starch.
7. Bring to a boil, add sesame oil, and serve.



Fig. 11. Amaranth soup with larval fish.

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