HERBS AND LEAF CROPS: CILANTRO, BROADLEAF ILANTRO, AND VEGETABLE AMARANTH

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Contents

Summary

Herbs and leafy crops are important components of the diet of millions of human beings around the world. Cilantro (leafy coriander, Chinese parsley) and broadleaf cilantro (shado benee, spiritweed, fitweed, Mexican cilantro, Thai cilantro) are very popular seasoning herbs and medicinal plants in the tropics and subtropics, particularly in the Caribbean, Latin American, Asian, and part of the Mediterranean cuisine and lore. These plants contain significant amounts of essential oils, which impart them their particular flavor and aroma, as well as their capacity to repel undesirable organisms in intercropping situations.

Vegetable amaranth (green leaf amaranth, Chinese spinach, or callaloo) is used for traditional dishes in China, India, Indonesia, Malaysia, Greece, Vietnam, as well in

Africa and the Caribbean. The vegetable amaranth is valued as a good source of vitamins A, B6, C, K, riboflavin, and folic acid, as wells as the minerals calcium, copper, iron, magnesium, manganese, phosphorus, potassium, and zinc. Generally produced by small-scale growers, these short-term herbs and leafy crops can generate important income to them. This is particularly true for the organic segment, which can command selling price of 33 to 400% above conventionally-grown herbs. This paper presents an overview of the economic importance, history, plant description, breeding aspects, production practices, and uses of the leafy crop vegetable amaranth and the herbs cilantro and broadleaf cilantro.

1. Introduction

Herbs and leafy green "salad" crops are a good source of various minerals, vitamins, antioxidants and other medicinal compounds. They are very important for the distinct flavor, aroma, and appearance of the local cuisine, each country or region having its own preferred herb or group of herbs and leafy salads. These are usually high value crops, which can be grown throughout the year in large, medium, or small scale production units. These crops can be grown with low inputs or with high technology, depending on the resources available to growers, and may contribute significantly to the farmer's income. High value markets such as the organic, natural, and export markets may be especially profitable. Herbs such as cilantro (leaf coriander) (*Coriandrum sativum*) and broadleaf cilantro (fitweed, spirit weed, shado benee; *Eryngium foetidum*) are essential for the preparation of many plates in several regions in Asia, Africa, Oceania, Europe, and America.

Cilantro and broadleaf cilantro are classified in the botanical family Apiaceae (formerly known as Umbelliferae), which includes around 455 genera and nearly 3600 species, among them other well known plants such as carrot (*Daucus carota*), celery (*Apium graveolens*), arracacha (*Arracacia xanthorriza*), parsley (*Petroselinum* spp), anise (*Pimpinella anisum*), dill (*Anethum graveolens*), fennel (*Foeniculum vulgare*) and cumin (*Cuminum cyminum*). Vegetable amaranth or calaloo (*Amaranthus* spp, Amaranthaceae) is a favorite leafy vegetable in many English- and French-speaking Caribbean nations, parts of Asia, Africa, and in other regions with Caribbean and Asian immigrant populations.

2. Cilantro

Cilantro (*Coriandrum sativum* L.) is one of many economically important species in the Apiaceae family, and probably the most important in the family as an Apiaceae culinary herb in many tropical and subtropical cuisines. For some people, the many common names of this plant can be confusing, but the confusion may be dispelled if one understands that the same plant can be considered both a herb (by definition, part of the aromatic plant is consumed fresh) and a spice (part of the aromatic plant is consumed dried). When consumed fresh, *Coriandrum sativum* is called *cilantro*, *green coriander*, and *Chinese parsley*, among other names in English. When the same species is used as a spice (generally the dry seeds), it is called *coriander*. The global economic relevance of cilantro has been increasing with the expanding acceptance and distribution of 'ethnic' restaurants and dishes such as the Mexican and Thai, which use fresh cilantro abundantly. A newer niche for this crop is the organic market, in which it may command high premiums as compared to conventionally-grown cilantro.

2.1. History and Economic Importance

Cilantro originated in the coastal regions north and east of the Mediterranean Sea, and from there the plant spread to Asia, Africa and Europe in ancient times. There is evidence that cilantro was grown in Assyria (belonging to modern-day Iraq) around 9,000 years ago, and remains of cilantro seeds were found in tombs in Israel dated 8,000 years old. In India cilantro has been grown for the last 5,000 years. It was used as a medicinal plant and as a condiment by the Egyptians since at least 4,500 years ago. It is also documented that other old Mediterranean societies, such as the Classic Greeks, the Carthaginians, and the Imperial Romans were cilantro consumers (Diederichsen, 1996).

The Roman Empire is largely responsible for the spread of cilantro, for it brought and grew the plant to its provinces, and from there the crop further spread as merchants brought seeds beyond the Roman frontiers. Hence, cilantro was grown in England as far back as the 1st century A.D. (introduced by the Romans), and was known as a vegetable in China in the 5th century A.D. (introduced through Persia). The crop was brought to Hispaniola (currently the Dominican Republic and Haiti) by Spanish conquerors late in the 15th century, and then to other European colonies in the American continent, Australia and the Philippines.

Nowadays cilantro is grown commercially, either at small or large scale, in almost every country in the world, but most of the production is consumed in the local markets. The cilantro herb is important in the culinary of many Asian countries (such as India, Thailand, Vietnam, Bangladesh, China, and Yemen), most of Latin America and the Caribbean, and in Mediterranean countries. The largest cilantro production areas are in India, China, the former Soviet Union, Mexico, Central America, South America, and the Caribbean. In 2008, Mexico was the largest cilantro exporter in the world, producing 42 million kg of cilantro in 5250 ha, with a farm gate value of approximately US$ 13.3 million. In the Caribbean, Puerto Rico's 2007 cilantro harvest had a farm gate worth of $4 million, and in the Dominican Republic, in 2007 the crop was grown in 875 ha, producing approximately 2.3 million kg of cilantro, with a farm gate value of US$2.5 million. In the USA, California is the largest producer state, with 25.5 million kg in 2004 valued at US$20.5 million.

Most countries seem to be self-sufficient to satisfy their domestic demand of cilantro. The USA, Canada, and Europe produce cilantro, but not enough to supply all of their internal demand, which results in large importations from Asia, America, Africa, and Australia. The largest importers of cilantro are the USA, Germany, England and The Netherlands. The countries of the Middle East are also important cilantro consumers.

2.2. Taxonomy and Plant Description

Cilantro (*Coriandum sativum* L.) belongs to the family of Apiaceae, formerly named Umbelliferae. It is an annual, fast-growing, short herbaceous plant (Figure 1), propagated by seeds, which usually come in pairs inside the round, small (<5 mm), and dry fruit commonly called coriander. The root system is delicate and not very profuse. The stem is erect and branching, commonly reaching less than 75 cm in height. The leaves are flat, small, indented, commonly green, but purple in some varieties.

Figure 1. Plants of cilantro (*Coriandum sativum*) prior to the flowering stage.

The leaves and stems are the commercial organs of the cilantro herb. The flowers are produced in groups (inflorescences); they are white, pink or purple depending on the variety. Plants may flower as early as the third week after the seed germinates, but may take 5 weeks or longer to flower, depending on the variety and the weather. Flowering triggers the senescence of the plant, shown by yellowing and wilting of the leaves and maturation of the seeds/fruits. The whole plant, even the roots, have specialized cells that produce essential oils that give the plant its peculiar aroma and flavor. The essential oils are inside the cells, and their fragrance is only felt when the tissues are crushed or injured, breaking the cells and releasing the oils. The concentration of essential oils produced by the plant depends on the age of the plant, the environmental conditions in which it grows, and the variety. Generally, cilantro contains between 0.1 and 0.6% of essential oils, and excessive watering and nutrients tend to result in lower oil concentration. The most abundant oils in cilantro are E-2-decen-1-ol and decanal, and the one that contributes the most to its peculiar aroma is beta-ionona (Diederichsen, 1996).

2.3. Breeding and Varieties

There are two accepted species in the genus *Coriandrum*: *C. sativum*, which became a crop, and *C. tordylium*, which is similar to the cilantro grown as a crop but is still a largely undomesticated plant. The chromosome number of cilantro is $2n = 22$. A related genus, *Bifora*, contains several species native to Asia and North America. One of them, *B. radians*, looks very much like the cilantro plant, and has globular fruits without the characteristic cilantro aroma. Crossing cilantro and *B. radians* for breeding new varieties has been unsuccessful. Even embryo-rescue has failed to yield *C. sativum* x *B. radians* hybrids.

Cilantro varieties are generally classified by their sensitivity to ambient heat and photoperiod, two main environmental factors that influence cilantro flowering. Some varieties are very sensitive to weather and flower a few weeks after germination if grown during days with more than 12 hours of daylight and high temperatures. Other varieties called ‘slow bolt’ are less sensitive to heat and day length, and are more appropriate for production of cilantro leaves in the summer. Slow bolt varieties usually have abundant and very aromatic leaves, and most times are descendants of the cilantros that developed in the Asian Caucasus. Cilantro varieties may be further classified by their leaf color, being either green or purplish. In most countries, there are local landraces that developed from either the native populations in the Mediterranean basin or from the seeds brought by merchants and settlers from elsewhere.

Some countries are interested in developing their own varieties from local landraces, often having the advantage of genetic populations with some extent of adaptation to the biotic and abiotic conditions of the region. Other countries base their high-technology production on imported ‘improved’ varieties, such as ‘Long Standing’, ‘Slo-Bolt’, ‘Santo’, ‘Jantar’, ‘Caribe’.

Currently, the main objectives of breeding are slow bolting, high concentration of essential oils, large leave/stem biomass, and disease resistance. Ideal varieties for the fresh market should have low sensitivity to heat and long photoperiod, good aroma and taste, tolerance or resistance to common pests and diseases in the region, rapid above-ground growth, reasonable seed cost, and appealing appearance for the market (plant size, leaf size and color, aroma and taste, stem thickness and branching), the desirability of which may vary from one country to another.

2.4. Crop Husbandry

***Climatic and Soil Requirements* -** Cilantro is an annual plant propagated by seeds. At soil temperatures above 15° C, cilantro seeds germinate within two weeks after being sown. Soil temperatures near 25° C are ideal for faster germination. The crop grows well in many soil types, but prefers deep and fertile soils with good water holding capacity, pH of 6.5 to 7.5, and good drainage. This herb thrives well under direct sunlight, and grows faster and larger at temperatures between 20° and 30° C. Long photoperiods and/or high temperatures promote early flowering as well, which is undesirable for leaf production. Low relative air humidity reduces the incidence of foliar diseases, but prolonged soil drought may drastically reduce leaf yield and induce premature flowering.

***Cropping System* -** Cilantro may be grown in containers with soil or other substrates, in hydroponic systems, or directly in the soil, either in open fields or under protected structures such as greenhouses and tunnels. Most of the production takes place directly in open fields. At a commercial scale, cilantro seedlings do no recover well from transplant. Usually 20-25 kg of seed (100 seeds per linear meter) is adequate for seeding one hectare of cilantro. This herb may be grown in mono-culture or may be intercropped with plants that do not have common pests and diseases with cilantro, that share similar watering needs, and that do not cast dense shade over cilantro. When intercropped with certain plants like tomato, cilantro deters some pests, such as white flies of the genus *Bemisia*, which transmit viruses that affect tomato.

Nutrient Supply - Cilantro is a rapid-growing herb, and thus needs an ample supply of nutrients readily available to be able to accumulate a large amount of biomass in the relatively short period of time between germination and harvesting. Potassium, nitrogen, calcium, and phosphorus, in that order, are the nutrients cilantro usually absorbs in larger amounts from the soil. These elements have several functions in plants, but in simple terms nitrogen promotes fast mass accumulation, phosphorus enhances root growth and physiological energy in the plant, and potassium and calcium contribute to healthy growth and increase the plants defenses against diseases and pests (Filgueira, 2000).

If the soil is deficient, it may be necessary to supply the crop with other nutrients like magnesium, sulfur, copper, iron, zinc, manganese, chloride, boron, and molybdenum, which are essential to the crop, although necessary in smaller amounts than nitrogen, phosphorus, potassium and calcium. The crop may be supplied with nutrients using mineral fertilizers (in conventional production systems) or using organic fertilizers (in organic and conventional systems). When using organic fertilizers or amendments, cilantro responds well to composted manure and vermicompost.

Growth Stimulators - The growth of cilantro can be accelerated and/or its biomass significantly increased by foliar application of bio-stimulants or bio-regulators. Some of the bio-stimulants that have had good results in cilantro are: gibberellic acid, folcyteine, commercial formulations of extracts of marine algae *Ascophyllum nodosum* and *Sargassum vulgare*, as well as commercially available blends of amino-acids and peptides. Premature flowering may be delayed with foliar sprays of auxins and cytokinins.

Water Supply - Irrigation is important to secure a high yield of cilantro foliage, as prolonged watering deficiency may result in yield reductions of 35% of more. Although the crop requires an adequate supply of water throughout its life, the most critical time for irrigation is the germination period and first 2-3 weeks afterwards, in which the crop is getting established. In commercial settings, cilantro may be watered using drip or overhead irrigation; however, overhead irrigation may lead to increased frequency of leaf diseases caused by fungi or bacteria.

Weed Management - From germination through flowering, cilantro plants are very weak competitors with other plants. Thus, undesirable plants (weeds) must be kept away from competing with the cilantro season-long, lest unchecked weed competition may cause total crop loss. Weed management includes practices like soil solarization, repeated soil tilling before planting the crop, avoiding excessive fertilization and watering, using soil mulch or chemical herbicides such as linuron and others, mechanical cultivation, and hand removal (Morales-Payan and Stall, 2005,).

Diseases - Several diseases afflict cilantro, among them the bacterial spot and wilt caused by *Pseudomonas syringae*, the powdery mildew caused by the fungus *Erysiphe*, the leaf spots caused by the fungi *Cercospora* and *Alternaria*, and the root rot and white mold caused by the fungus *Rhizoctonia.* Incidence and severity of diseases vary depending on the environmental conditions of the region, the cilantro variety grown, and the prevalence of pathogen propagules. High temperature and humidity favor the development and spread of these diseases.

Some diseases have become recurrent in certain areas, and growers have learned to live with them. These diseases may be prevented, delayed, or managed by using resistant or tolerant cilantro varieties, proper fertilization and irrigation, and/or treatment with approved pesticides, among other practices. Growers must be well instructed about how to use pesticides and the risks associated with them. Several viruses are known to attack cilantro, among them the *Yellow Motley Mosaic Virus*, the *Clover Yellow Vein Virus*, the *Parsnip Mosaic Virus*, the *Celery Mosaic Virus*, and the *Alfalfa Mosaic Virus* (Diederichsen, 1996).

Pests - Pests are not usually an important problem in small-scale cilantro production. In fact, when pesticides are not overused, cilantro attracts beneficial insects that fight some pests commonly occurring in vegetable gardens. In intensive cilantro production operations, there may be economically important attacks by pests such as the leaf-eating worms *Spodoptera exigua*, *Spodoptera frugiperda*, and *Trichoplusia nii*, mites, scales, thrips, and aphids.

Pests are best handled with integrated pest management (IPM) programs that combine, among other practices, the use of tolerant varieties (if available), adequate supply of nitrogen, potassium and calcium, and (if necessary) proper application of pesticides approved for use in cilantro. There are biological, botanical and synthetic pesticides available for use in herbs (Mohammed and De Chi, 2006; Ramcharan, 2000).

Harvesting - Being a leafy crop, cilantro is harvested when leaves are ready to be used. Some people harvest cilantro a few days after emerging from the soil, but more foliage can be obtained when harvesting plants 10 to 15 cm tall. Other consumers prefer to detach a few leaves at a time and allow the plant to continue producing leaves until flowering. In commercial settings, the general rule for harvesting may be to wait for the herb to attain its maximum biomass before the onset of flowering. That usually occurs around 40 days after the seed germinates.

Depending on the preference of the market, harvesting is done by (1) pulling the whole plant from the soil with the roots, (2) or cutting the stem near the soil level, leaving the roots and the lower part of the stem in the soil, which may re-grow and produce more leaves. In small-scale plots, 6 kg/m^2 harvested 50 days after germination is a reasonable cilantro yield. In large commercial plots, cilantro yield is quite variable, with reports ranging from 7,000 to 34,000 kg per hectare, depending on the location, variety, and intensity of inputs. Yields higher than 30,000 kg of fresh weight per hectare are considered very good.

Market Quality - For most markets, fresh cilantro should be free of blemishes and have strong aroma and green coloration. The postharvest life of cilantro is relatively short, as it dehydrates very quickly. Postharvest deterioration may be delayed keeping cilantro in an ambience with high relative air humidity (90-95%) and low temperature (0-5°C), which allows the leaves to retain marketable quality for 2 to 4 weeks. To extend its shelf life, cilantro is commonly iced after harvesting, and technology exists to package cilantro in modified atmosphere that reduces the rates of dehydration and respiration of the leaves (Yaguang Luo *et al*., 2004).

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Biographical Sketch

J. Pablo Morales-Payan is a researcher and professor at the University of Puerto Rico-Mayagüez Campus. He has a M.Sc. in Horticulture (plant physiology and regulation) from Rutgers University (1989) and a Ph.D. in Horticultural Sciences (weed science and plant pathology) from the University of Florida-Gainesville (1999). His current research and teaching focus is on the use of exogenous substances for physiological regulation, and on practices for sustainable/organic production systems for horticultural crops with emphasis in weed, pest and disease ecology and management.

Dr. Morales-Payan has led many research projects and has been thesis chairman for many graduate and undergraduate plant science students in the Dominican Republic and in Puerto Rico. He has been National Director of the Agricultural Research Department of the Dominican Republic, Chair of the Agronomy Department at UNPHU, President of the Dominican Society of Agriculture and Forestry Researchers, and President of the Caribbean Division of the American Phytopathological Society. He also served as Research Director of the Dominican Team with the Network for Vegetable Research and Development of Central America, Panama, and the Dominican Republic (REDCAHOR). In 2007 he received the *Eugenio de Jesus Marcano Award* for his contributions to research and education in agricultural sciences.