Crop Reports

Watercress: A Salad Crop with Chemopreventive Potential

Usha R. Palaniswamy[1] and Richard J. McAvoy[2]

ADDITIONAL INDEX WORDS. ***Nasturtium officinale*, *Rorippa nasturtium-aquaticum*, Phen(yl)ethyl isothiocyanate, Cruciferae**

Classification, origin, and development

Watercress [*Nasturtium officinale* (also known as *Rorippa nasturtium-aquaticum*)] belongs to the family Brassicaceae (Cruciferae). It is a native of southeast Europe (Habegger et al., 1989), probably Germany (Humphrey, 1984) or England (Howard and Lyon, 1952). Watercress is a perennial herbaceous plant reported widely in several parts of Europe, China, New Zealand, and in North America, both as a wild growing species and a cultivated crop. Although described as a medicinal plant since the first century A.D. (Howard, 1976), and valued as a gift fit for royalty (Howard and Lyon 1952), its large-scale cultivation did not start until 1750 in Germany, 1808 in England, and 1811 in France (Manton, 1935). Two species of watercress, green watercress (*N. officinale*) and brown watercress (*N. microphyllum*), and a sterile hybrid (*N. officinale* x *N. microphyllum*) were introduced in about 1850 to New Zealand from England and both species were reported to be growing in Europe and North America (Michaelis, 1976). The Germans and French only cultivated green watercress while the English grew both green watercress and brown watercress on a large scale during the 19th century. However, brown watercress soon was replaced in commercial cultivation by green watercress because of ease of propagation by seeds, and lower susceptibility to the fungal crook root disease caused by *Spongospora subterranea* sp. *nasturtii* (Howard and Lyon, 1952). Green watercress appears to be the only species currently cultivated and consumed around the world.

Botanical description and cultivars

Watercress is a perennial herb with a creeping habit that branches freely. Numerous exogenous adventitious roots are produced at the axils of the leaves under moist and humid growing conditions. Leaves are glabrous, dark green, pinnate, and form about three to six pairs of well-separated leaflets (Fig. 1). It flowers under long day conditions and the inflorescence is a short raceme with small white or yellow flowers that are about 5 to 7 mm (0.20 to 0.28 inches) in diameter. The flowers have four green sepals, four pale yellow or white petals, six stamens, and a solitary pistil. Flowers are self-pollinated, and fruits, elongated capsules, are borne on pedicels, and seeds are produced plentifully (Bleasdale, 1964).

Green watercress is a diploid (2n = 32) and the brown watercress is an allotetraploid (2n = 64), whose other parent may be *Cardamine* sp. (Howard, 1976). A number of varieties of *N. officinale* have been distinguished in the past including *siifolium* (1831), *microphyllum* (1831), and var. *parvifolium* (1838). However, the two varieties, *siifolium* and *parvifolium*, appear to be merely different growth forms of *N. officinale* resulting from moist conditions and from dry conditions respectively (Howard and Lyon, 1952). Though var. *microphyllum* refers to the tetraploid species (Airy Shaw, 1947), it has been used in the past also to refer to the small-leaved specimens of *N. officinale* as well as to the triploid (2n = 48) hybrid, *N. officinale* x *N. microphyllum*.

A number of commercial strains were isolated and selections made for frost resistance, ability to maintain vegetative growth during summer time when watercress normally tends to flower, and for resistance or tolerance to turnip mosaic virus (Bleasdale, 1964; McHugh et al., 1987). However, there has been very little selective and systematic breeding and no standard commercial cultivars seem to have been developed. Many of the selections and commercial strains appear to be unnamed, and the only named strain recorded to be commercially cultivated is Sylvasprings, which was originally developed in England. However, this strain showed a lot of genetic diversity when grown in the United States and was further selected to obtain a homogenous crop stand in the commercial watercress beds.

Production, uses, and composition

Watercress is a minor crop and the actual area under cultivation is rather difficult to determine, because it is mostly cultivated and marketed locally. Annual consumption of watercress is as low as 110 g (3.9 oz) per head in the United States (Humphrey, 1984), and its cultivation and consumption as a significant salad crop has declined overtime (Howard, 1976). In the United States, watercress is of considerable economic importance in the state of Hawaii where watercress

The cost of publishing this paper was defrayed in part by payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* to indicate this fact.

[1]School of Allied Health/Asian American Studies Institute, U-2101, University of Connecticut, Storrs, CT-06269-2101; to whom reprint requests should be addressed.

[2]Department of Plant Science, University of Connecticut, Storrs, CT 06269.

Fig. 1. Watercress (*Nasturtium officinale*).

was produced on 14.2 ha (35 acres) of land in 1985, yielding 695 t (766 tons) with a total farm value of $1,212,000 (Hawaii Agricultural Reporting Service, 1985).

More recently, the total area under watercress production increased slightly from 204 ha (505 acres) in 1992, to 246 ha (608 acres) in 1997 (USDA, 1997). Currently it is grown in 122 ha (302 acres) in Florida, 48.6 ha (120 acres) in California and in 13.8 ha (34 acres) in Hawaii. Watercress is also grown on private farms in Connecticut, Massachusetts, Virginia and Maryland for which the exact areas under production are withheld to avoid disclosing confidential data.

Watercress has been used as both food and medicine since the first century AD. As a medicinal plant, watercress traditionally has been considered a diuretic, expectorant, purgative, stimulant, stomachic, and tonic. It also has been used as a remedy against anemia, eczema, kidney and liver disorders, tuberculosis, boils, warts, and tumors. The 16th century herbalist Gerarde described watercress soup as a good blood cleanser, and good against scurvy (Humphrey, 1984). Leaf extracts have been used to treat wounds, freckles, and external and internal ulcers. Tender shoots and leaves are used fresh or cooked alone or in mixtures of salad and as a garnish. Though most find the biting peppery taste of watercress leaves rather appealing and its flavor appetizing, some people may find the pungency somewhat objectionable and the flavor too strong.

More recently, with increasing interest in healthy diets, the nutritional value of watercress has attracted the attention of a number of scientific investigators and the health-conscious public. Reportedly, watercress has high concentrations of a recently identified chemopreventive of a number of tobacco specific carcinogens-2-phen(yl)ethyl isothiocyanate (PEITC) [≈2 to 7 mg·g^{-1} (2,000 to 7,000 ppm) leaf dry weight] (Palaniswamy, 1995b, 1997). Watercress is also an excellent source of the antioxidant α-tocopherol [0.34 mg·g^{-1} (340 ppm) fresh weight] (Hadas et al., 1994), and other vitamins and minerals (Table 1) (USDA, 1984).

Watercress possesses glucosinolates and myrosinase, which are characteristic to all crucifers (Kjaer, 1976). Glucosinolate is found in various concentrations throughout the various plant tissues. But the myrosinase enzyme is stored exclusively in special cells that are dispersed throughout the plant. Upon tissue damage, the glucosinolate is hydrolyzed by the myrosinase enzyme to yield isothiocyanates and nitriles (Larsen, 1981; Van Etten and Tookey, 1979). The relative proportion of these two compounds depends on the condition during hydrolysis. In watercress PEITC, and 3-phenylpropionitrile are the predominant hydrolytic products (MacLeod and Islam, 1975; Spence and Tucknott, 1983).

PEITC is the predominant flavor component that imparts the characteristic biting and peppery-hot tastes of watercress (Freeman and Mossadeghi, 1972a). The glucosinolate and the corresponding isothiocyanate in watercress are classic examples of chemical defense (Feeny 1976, 1977). These compounds are deleterious to nonadapted herbivores (Blau et al., 1978) and reduce herbivore damage (Louda and Rodman, 1983) as well as damage by amphipods in water (Newman et al., 1990) during cultivation.

Interest in watercress as a salad vegetable for health promotion and disease prevention has been revived over the past decade because of the many studies that linked the intake of cruciferous vegetables to reduced risk of cancers (Cohen et al., 2000; Joshipura et al., 1999; Osborne, 1999). In particular, the isothiocyanates are reported to be potent inhibitors of carcinogenesis in several animal models (Zhang and Talalay, 1994). Among the crucifer seeds studied, watercress is the most abundant source of gluconasturtin (gluconasturtiin) (the glucosinolate precursor that yields PEITC on hydrolysis), with 5.32 g of gluconasturtin/100 g of defatted seeds (53, 200 ppm) (Daxenbichler et al., 1991). PEITC, inhibited cancers in rats and mice that are caused by several tobacco specific carcinogens including 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone, N-nitrosomethyl benzylamine, benzo(a)pyrene, and N-nitrosobenzylmethyl amine (Siglin et al., 1995; Stoner et al., 1991, 1994; Wattenberg, 1992). PEITC acts as both a blocking agent and an inhibitor of tumor initiation via inhibition of cytochrome P450 enzymes and by induction of phase II enzymes such as glutathione S-transferases (Meyer et al., 1995).

Steam distilled extracts of watercress containing 3-phenylpropionitrile and 3-phenylpropionic acid were reported to exhibit auxin-like activity and stimulate the elongation of wheat (*Triticum aestivum*) coleoptiles and garden cress (*Lepidium sativum*) hypocotyl sections (Wheeler, 1980).

Culture and management

Watercress can be propagated either from seed or by vegetative means using shoot tip cuttings that root very easily. Until 1955 most watercress was propagated vegetatively, but this prac-