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Fig. 1: *Ipomoea aquatica* in its natural habitat

grows rapidly producing dense masses of foliage within a few weeks of planting. It is one of the most popular green leafy vegetable. Its commonly called as aquatica morning glory, Chinese water spinach, kangkong, morning glory, swamp cabbage, swamp morning glory, water convolvulus, water spinach (Anonymous, 1959; Candlish *et al*., 1987; Chen *et al*., 1991; Edie and Ho, 1969; Payne, 1956; Synder *et al*., 1981; Wills *et al*., 1984).

Origin and distribution: *I. aquatica* is supposed to be originated in China (Edie and Ho, 1969). It is distributed through out India, Sri Lanka, Tropical Asia, Africa and Australia (Kritkar and Basu, 1952). The plant is grown wildly as weed in India and USA (Anonymous, 1959; Reed, 1977) while in South East Asia like Malaysia, China, Hong Kong, Singapore and Indonesia, the plant is grown commercially (Candlish *et al*., 1987; Chen *et al*., 1991).

Composition: The leaves of *I. aquatica* contain the following: moisture 90%, protein 3%, fiber 0.9%, fat 0.4%, carbohydrate 4.3%, mineral matter 2%, nicotinic acid: 0.6 mg/100 g; riboflavin: 120 mg/100 g; vitamin C: 137 mg/100 g; vitamin E: 11 mg/100 g and ash: 1.4% (Anonymous, 1959). The young terminal shoots and leaves of *I. aquatica* are eaten as green leafy vegetable and in salads (Ismail *et al*., 2004) and as fodder (Phimmasan *et al*., 2004). *I. aquatica* leaves are also very rich in proteins (Ngamsaeng *et al*., 2004), carotenes (Chen and Chen, 1992), amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, leucine, tyrosine, lysine, histidine and arginine (Rao and Vijay, 2002), minerals like sodium, potassium, calcium, iron, magnesium and zinc (Duc *et al*., 1999), sugars like glucose, fructose, sucrose (Wills *et al*., 1984), fiber, lipids and fats (Imbs and Pham, 1995), organic acids like malic acid, citric acid, oxalic acid (Wills *et al*., 1984), vitamins (Duc *et al*., 1999), starch (Candlish *et al*., 1987), polyphenols like myricetin, quercetin, luteolin, apigenin, kaempferol (Chu *et al*., 2000; Daniel, 1989; Miean and Mohamed, 2001), dihydroquercetin glycoside (Prasad *et al*., 2005a) and ash (Ogle *et al*., 2001) contents.

Nutrition: Moisture, nitrogen, protein and amino acids like aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cysteine, valine, methionine, isoleucine, leucine, tyrosine, lysine, histidine and argenine content of *I. aquatica* by Sutaria and Diego (1982) were estimated using AOAC methods. Alpha-tocopherol content of *I. aquatica* with other leafy vegetables were analysed by Candlish (1983). Wills *et al*. (1984) studied vitamins like vitamin C, thiamin, riboflavin, niacin, protein, fat, sugars like glucose, fructose, sucrose, starch, dietary fiber, organic acids like malic acid, citric acid, oxalic acid, ash and minerals like sodium, potassium, calcium, iron, magnesium and zinc contents for 15 Chinese vegetables including *I. aquatica*. Candlish *et al*. (1987) studied the dietary fiber (non-cellulose polysaccharide, cellulose, lignin) and starch content in vegetables that are extensively grown and consumed in Southeast Asia including *I. aquatica*. Rao *et al*. (1990) estimated the lipid contents like non polar lipids, glycolipids, phospholipids, fatty acids, amino acids like aspartine, threonine, serine, glycine, proline, alanine, leucine, tyrosine, histidine, aspergine, argenine, minerals like calcium, magnesium, iron, zinc and copper of *I. aquatica*.

Imbs and Pham (1995) analyzed total lipids, fatty acid, triglycerides content and phospholipid content of *I. aquatica*. Iron and vitamin C content of *I. aquatica* grown in three sites of Vietnam were investigated by Duc *et al*. (1999). The nutritional value of *I. aquatica* with yielding crops such as rice, sugarcane and maize were compared by Munger (1999). It is urged that investment in crops such as *I. aquatica* may be a suitable and cost-effective way to supplement the caloric and nutritional value of current crop production. Micronutrient composition like ash, calcium, iron, zinc, carotenes like α and β carotenes by Ogle *et al*. (2001) were determined. Iron, calcium, β carotene, ascorbic acid and oxalic acid content of *I. aquatica* consumed by the tribals of Purnia district of Bihar, India were analyzed by Rao and Vijay (2002). The dieting pattern of rabbits fed with water spinach were investigated by Phimmasan *et al*. (2004). Ngamsaeng *et al*. (2004) analyzed water spinach as protein supplements for ducks feed as basal diet.

Carotenes: Ortaliza *et al*. (1969) estimated the carotene contents and its availability of *I. aquatica*. The effects of *I. aquatica* on cholesterol metabolism in rats were studied by Chen *et al*. (1984). Chen *et al*. (1991) characterized the major carotenoids in water convolvulus (*Ipomoea aquatica*) by open-column, thin layer and high performance liquid chromatography. Comparing the absorption spectra and retention time with reference standards the compounds were identified as β-carotene, cryptoxanthin, lutein, lutein epoxide, violoxanthin and neoxanthin. Carotene composition and contents of *I. aquatica* were analyzed by Tee and Lim (1991) by AOAC and HPLC methods. They found that AOAC method gave a falsely elevated result, where as the HPLC method successfully separated the major carotenoids. The carotenoids identified were lutein and β-carotene and were compared to that of reference standards.

Carotenoids and chlorophylls in *I. aquatica* were determined by Chen and Chen (1992) using liquid chromatography. These carotenes and chlorophylls were analyzed by High Performance Liquid Chromatography (HPLC). Fourteen peaks were detected in HPLC, of which 12 pigments were identified. These pigments include neoxanthin, violaxanthin, cryptoxanthin, lutein epoxide, lutein, cis-lutein, chlorophyll b, chlorophyll b^1, chlorophyll a, β-carotene and cis β-carotene. These samples were then compared with standards by thin layer chromatography.

Tee *et al*. (1996) investigated the biological utilization of carotenoids of *Ipomoea aquatica* using rats and found bioavailability of the major carotenoids was high, as evidenced by the accumulation of retinol of the experimental rats in relation to crystalline retinol concentrate. Wills and Rangga (1996) analyzed carotene contents of *I. aquatica* by reverse phase HPLC and gradient elution. The carotenes identified were zeaxanthin (Fig. 2a), lutein (Fig. 2b), anthraxanthin, flavoxanthin, auroxanthin, luteoxanthin, neoxanthin (Fig. 2c), β-carotene (Fig. 2d), violoxanthin (Fig. 2e), cryptoxanthin (Fig. 2f), neoxanthin a and neoxanthin b. These samples were compared to standards and identified. Provitamin A and carotenoids from *I. aquatica* of different maturity and origin were investigated by Hulshof *et al*. (1997). The carotene contents were different when collected from different places. Also, the carotene content of mature plant was high compared to that of young plants. Provitamin A carotenoid content of *I. aquatica* at different maturity and origin was reported by Paul *et al*. (1997).

Flavonoids: Daniel (1989) estimated the polyphenol contents of *I. aquatica* and identified quercetin 3′-methyl ether (Fig. 3a), quercetin 4′-methyl ether (Fig. 3b) and anthocyanins. Flavonoid contents of *I. aquatica* like mycertin, quercetin, luteolin and apigenin content were

Fig. 2: Carotnees from Ipomoea aquatica (a) Zeaxanthin, (b) Lutein, (c) Neoxanthin, (d) β-carotene, (e) Violoxanthin and (f) Cryptoxanthin)

Fig. 3: Flavonoids from Ipomoea aquatica. (a) Quercetin 3′-methyl ether, (b) Quercetin 4′-methyl ether and (c) 7-O-β-D-glucopyranosyl-dihydroquercetin-3-O-α-D-glucopyranoside)

identified by Chu *et al.* (2000). Chlorophylls of *I. aquatica* were investigated by Miean and Mohamed (2001). Prasad *et al.* (2005a) isolated a 7-O-β-D-glucopyranosyl-dihydroquercetin-3-O-α-D-glucopyranoside (Fig. 3c) and it was characterized using UV, MS and NMR data.

Alkaloids: Seven aliphatic pyrrolidine amides with branched and linear saturated C_{15}-C_{19} acyl moieties were detected by Tofern *et al.* (1999) in the vegetative part (stem and leaves) of *I. aquatica*. One of the compounds was isolated and characterized as 1-(14-methylhexadecanoyl) pyrrolidine and compared with synthetic compound. Yajima and Yabuta (2001) investigated the synthesis and configuration of a novel pyrrolidine amide namely 1-(14′-methylhexadecanoyl) pyrrolidine from *I. aquatica*.

Storage studies: Kailasapathy and Koneshan (1986) studied the loss of ascorbate content in eight leafy vegetables including *I. aquatica* due to wilting, from harvest up to a period of 24 h at environmental (24.7-25.8°C) and under refrigeration (4.4°C) temperatures. Quality changes like browning and changes in leaf and stem tissues of *I. aquatica* during storage at various temperatures (1 and 20°C) was analyzed on 5th day by Hirata *et al.* (1987). The structural changes in leaf and stem tissues of *I. aquatica* in relation to chilling injury and browning were investigated by Ose *et al.* (1990).

Processing: Candlish (1983) suggested that steaming of *I. aquatica* had highest carotene content than that of fresh and boiled one. The presence of cis-isomers of β-carotene in *I. aquatica* were examined before and after traditional Indonesian ways of cooking by Van der Pol *et al.* (1988). Yield of carotenoids of *I. aquatica* were analyzed by Chen and Han (1990) under different methods of cooking. Mazrizal *et al.* (1997) reported the retention of vitamin C, iron and β-carotene in *I. aquatica* under different cooking methods. Total carotenoid and β-carotene contents during processing like cooking, sun drying, frying and fermentation were investigated by Speek *et al.* (1988). Van der Pol *et al.* (1988) examined and compared the cis-carotene isomers (α-carotene, β-carotene, neo-β-carotene, neo-U-β-carotene) contents of *I. aquatica* before and after cooking. Mazrizal *et al.* (1997) studied the retention of β-carotene of *I. aquatica* when prepared using different cooking methods like boiling, microwave steaming and frying.

Tissue culture studies of *Ipomoea aquatica:* Effect of light on growth and chlorophyll formation of *I. aquatica* hairy roots were investigated by Masahiro *et al.* (1996). Methods for introducing foreign genes for *I. aquatica* and regenerating the plant by Masanori *et al.* (1997) were developed. The method comprises co-cultivating the nodes of the explant with *Agrobacterium tumefaciens* carrying the target foreign gene. Hirofumi *et al.* (2000) followed the development and characterization of a photoautotrophic cell line of *I. aquatica* hairy roots. The derived photoautotrophic hairy roots had high chlorophyll content and activities of 1,5-ribulose-biphosphate carboxylase content were more than those of the parent plant. Ninomiya *et al.* (2003) investigated the changes in chlorophyll content in phototautotrophic hairy roots of *I. aquatica*. Callus initiation and its antioxidant activity of *I. aquatica* was compared with that of the mother plant and it was found that the antioxidant activity was high in callus cultures (Prasad *et al.* 2006).

Antioxidant studies: Ismail *et al.* (2004) estimated the antioxidant and phenolic contents of *I. aquatica*. Antioxidant activity of leaf extracts and purified compound isolated from *I. aquatica* were determined by Prasad *et al.* (2004, 2005 a) by DPPH, metal chelation and lipid peroxidation methods.

Medicinal importance: In Ayurveda (Indian traditional medicine), the extracts of leaves of *I. aquatica* are orally administered to alleviate the disorders like jaundice and nervous debility. This plant is used medicinally in Southeastern Asia. It is effectively used against nosebleed and high blood pressure (Duke and Ayensu, 1985; Perry, 1980). The juice of *I. aquatica* is used as emetic in cases of opium and arsenic poisoning (Anonymous, 1959; Chopra *et al.*, 1956). Dried juice has purgative properties (Anonymous, 1959; Chopra *et al.*, 1956; Nadkarni, 1954). Leaves and stems are said to be cooling. In Assam, the plant is given for nervous and general debility (Anonymous, 1959; Chopra *et al.*, 1956). It is used also for piles (Anonymous, 1959), as anthelmentic (Anonymous, 1959; Nadkarni, 1954), used in leucoderma, leprosy, jaundice and liver complaints (Nadkarni, 1954)

This plant is supposed to possess an insulin-like principle according to indigenous medicine in Sri Lanka (Jayaweera, 1982). The medicinal uses of hitherto report includes: effect on liver diseases (Badruzzaman and Husain, 1992; Nadkarni, 1954), eye diseases (Jain and Verma, 1981), constipation (Samuelsson *et al.*, 1992) and the inhibition of prostaglandin synthesis (Tseng *et al.*, 1992). Mackeen *et al.* (1997) demonstrated moderate antinematodal activity of *I. aquatica* against pine wood nematode, *Bursaphelenchus xylophilus*. The aqueous extract of this plant also possess hypoglycemic effect (Malalavidhane *et al.*, 2000, 2001, 2003). This plant also possesses antioxidant activity (Prasad *et al.*, 2004, 2005 a). This plant also shows moderate anticancer activity against Vero, Hep-2 and A-549 cancer cell lines (Prasad *et al.*, 2005 b).

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