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Water spinach (*Ipomoea spp.*) and its potential: A review

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ABSTRACT

The problem of malnutrition justifies the need to explore underutilized crops that have the potential to address the food and nutrition insecurity issues. Certain underutilized crops can play a significant role in both food and nutrition security of the vulnerable populations especially children below the age of five and women. Water spinach, a green leafy vegetable, is one of the underutilized crops in Zimbabwe. It is envisaged that exploration, exploitation and full utilization of water spinach would be an appropriate and cost effective strategy to supplement the caloric and nutritional value of the staple crops. The potential of water spinach cannot be overemphasized as far as meeting the nutrition needs of humans is concerned. This review aims at highlighting the inherent potential of water spinach and possibilities of its production to boost food and nutrition security.

Key words: water spinach, *Ipomoea* spp., underutilized crops, food and nutrition security.

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1. INTRODUCTION

Malnutrition, nutrient deficiency disorders, diseases and poverty are associated with the status quo in Sub-Sahara Africa (FAO 2018; UNICEF, 2019). Infant malnutrition in Sub-Sahara Africa is a serious threat and a global health challenge due to its consequential effects on morbidity, mortality, impaired intellectual development and high risk of diseases.

Malnutrition refers to an unhealthy condition that develops when the body does not get enough of the vitamins, minerals, and other nutrients needed for proper functioning. It results from inadequate healthy food (Hopkins, 2023). The World Food Programme (WFP) defines malnutrition as "a state in which the physical function of an individual is impaired to the point where he or she can no longer maintain adequate bodily performance process such as growth, pregnancy, lactation, physical work and resisting and recovering from disease" (WFP, 2015). Malnutrition should be

Corrected by eating nutrient rich foods or ready to use therapeutic foods, and not necessarily just eating more food (Hopkins, 2023). Zimbabwe is currently suffering widespread malnutrition and diseases related to nutrient deficiency (Chinake, 2011). It is estimated that 25% of the population in Africa is malnourished, and Zimbabwe is one of badly affected countries with almost 12,000 children suffering from severe malnutrition (Turner, 2011). This can lead to reduction in efficiency of adults' working capacity (WHO, 2013; Akombi *et al*., 2017) and death of children.

Micronutrient deficiency, also known as hidden hunger is a form of undernutrition that occurs when consumption or absorption of vitamins and minerals is too low to sustain good health and development in

children and normal physical and mental function in adults (FAO, 2013; von Grebmer *et al*., 2013). It is caused by poor diets e.g. consuming a diet composed mostly of starchy staples on a daily basis, disease, or increased micronutrient needs not met during pregnancy and lactation (FAO, 2013; Talla, 2021). Globally, micronutrient deficiencies afflict more than 2 billion people, or one in three people (FAO 2013) and in Zimbabwe, nearly one in five children under the age of five are vitamin A deficient (VAD) (Talla, 2021). According to the 2012 national micronutrient survey, VAD was higher (up to 27%) in children and women in rural than in urban areas, 72% of the children under the age of five were iron deficient while 38% were anaemic, and 61% of women aged 15 to 49 years were iron deficient (Matsungo *et al*., 2020).

Food security exists if at all times, people have a physical and economic access to sufficient, safe and nutritious food that meet their dietary and food preferences, for an active and healthy life (WFP, 2015). Zimbabwe's economy and food security situation remains fragile (USAID, 2022; Care, 2020). Unfavourable weather conditions, including unreliable erratic rainfall and long dry spells, contribute to increased humanitarian needs. The deteriorating economic situation worsens the already rising vulnerability in both rural and urban populace (USAID, 2022; WFP, 2022). The 2018/2019 agricultural season drought in Zimbabwe, resulted in extensive crop failure. It was projected that an estimate of 5.5 million people living in the rural areas were food insecure during the 2019/2020 season. This translated to about 3.8 million people in dire need of food aid (ZIMVAC, 2020). Among urban dwellers, a rise in vulnerability was observed, with an estimate of up to 2.2 million people to be food insecure (Care 2020; USAID, 2022; Global Food Security, 2022). Extensive global economic growth has been experienced recently even in some of the poorest countries in Africa, but despite that, hunger and poverty persist, and millions of people are suffering (Bain *et al*., 2013). Sadly, Zimbabwe is no exception.

The majority of rural farmers in Zimbabwe derive their livelihoods from rain-fed agricultural production (OECD, 2012). The low productivity agricultural practices coupled with lack of access to markets are contributing to food and nutrition insecurity among the people (Dzinotizei, 2019). Under-nutrition rates are high and common especially among households where diets lack diversity. Rural diets in Zimbabwe mainly consist of the produce from the family farm, which is predominantly white maize rich in starch and very low in nutritional value (Phiri, 2023). Hence, results in nutritional challenges.

In response to the nutritional challenges, biofortification efforts have been embarked on in Zimbabwe and Southern Africa countries (Bouis et al., 2011; Talla, 2021; Phiri, 2023). Promotion of vitamin A orange maize (VAM), Orange Fleshed Sweet Potato (OFSP), and zinc- and iron-enriched beans ensured delivery of more micronutrients to children and pregnant women in rural Zimbabwe (Talla, 2021). Although biofortification in Zimbabwe represents a sustainable strategy to enhance the availability of vitamins and minerals for people whose diets are dominated by micronutrient-poor staple food crops, lessons from the Zimbabwe biofortification intervention, have proven that seed availability is a major hindrance to increasing VAM production (Talla, 2021; Phiri, 2023). Hence, many people would still be consuming white maize. It is also argued that biofortified staple foods cannot deliver high levels and a wide range of minerals and vitamins when compared to supplements or industrially fortified foods (Bouis *et al*., 2011; Phiri, 2023), thus despite the biofortification efforts, micronutrient deficiency remains a challenge in Zimbabwe. Therefore, to complement biofortification, exploration and utilization of locally available nutritious crop species would unleash their potential to increase

dietary diversity and help address micronutrient challenges in Zimbabwe.

Full exploration and tapping into these underutilized crop species will go a long way in ensuring food and nutrition security. The nutritional potential of underutilized crop species may influence and improve food and nutrition security among Zimbabweans in order to promote sustainable growth and development in both urban and rural areas. Zimbabwe has a wide diversity of food crops (Mushita, 2018; Crop Trust, 2023). However, most of these crops have not received full attention, exploration and exploitation in terms of research and development in order to promote their effective commercial and industrial utilization. Water spinach is one of such neglected and underutilized crop species (Li *et al.,* 2020).

2. Origin of water spinach

Water spinach belongs to the genus Ipomoea and the family Convolvulaceae, together with sweet potato (*Ipomoea batatas*). It is classified as a vegetable and has been utilized as a medicinal plant in Southeast Asia since 300 AD (Pimentel, 2021; Austin, 2007).

Water spinach, also known as swamp cabbage or water convolvulus (Palada and Chang, 2003) is largely believed to be native to Southeast Asia (Austin, 2007). The crop has various names depending on the country, for example, kangkong in Philippines, Indonesia and Malaysia, kang kung in Vietnam, phak bung in Thailand, and kankon in Japan (Austin, 2007; Keßler, 2020).

Purseglove (1968), Chang (1970) and Van Wyk (2005) cited India or China as possible locations where the plant was domesticated first. These claims, however, have no supporting evidence other than the appearance of the plant's name in historical records (Austin, 2007). There are studies suggesting that water spinach is native to Africa (Rossel, 1998; Mbida *et al*., 2006; Austin, 2007). However, there are debates whether the plant is among the African indigenous flora or was introduced from elsewhere (Austin, 2007).

2.1 Description

Water spinach is a nutrient dense, versatile and fast growing leafy green vegetable. It is a semi-aquatic plant and can grow in and around water, like in swamps or along riverbanks, and can also grow elsewhere (Austin, 2007; Prasad *et al*., 2008). There are basically two types of water spinach i.e. aquatic (*Ipomoea aquatica*) and upland (*Ipomoea reptans*). The latter is adaptable to a variety of growing conditions while the former is mostly cultivated in swampy areas or in moist soils (Austin, 2007; Medenilla, 2021).

According to Keßler (2020) and Masa (2023), the plant has long, thick, white, green or purple hollow stems on which the green or purple leaves grow in an alternating pattern. The leaves can be ovate to lanceolate, and the leaf stalk is arrow or heart shaped that taper at the end of the leaf. The flowers are white to pale purple, and are bee-friendly and attract butterflies. Water spinach is not only highly nutritious but it is also delicious (Ben, 2023). The tender shoot tips and young leaves are mostly preferred, but basically, all above ground parts of the plant are edible (Chitsa *et al*., 2014). Leaves can be cooked whole, or cut into small pieces. It has a sweet, mild taste and can be consumed raw in salads, boiled in soups, in stir-fries, or steamed (Facciola, 1990; Ismail *et al*., 2004; Pimentel, 2021). Water spinach can act as a mild laxative when eaten in large quantities (Van Valkenburgh and Bunyapraphatsara, 2001; Austin, 2007; Chitsa *et al*., 2014).

Traditionally, water spinach is very much appreciated as a leafy vegetable in Southeast Asian countries, as well as in China and India (Prasad *et al*., 2008), having nutritional benefits similar to spinach.

However, in Zimbabwe, this vegetable is not common (Chitsa *et al*., 2014). In Africa, the vegetable is eaten only in Tanzania, Ethiopia and Sudan (Dalziel 1937; Vaino-Mattila, 2000).

Generally, green leafy vegetables have the potential to supply the much-needed vitamins and minerals, and water spinach is one such vegetable (Kala and Prakash, 2004). Water spinach is considered a food with medicinal value (Ogle *et al*., 2001; Etkin, 2006). It is highly recommended in certain nervous conditions with sleeplessness and headache, and for piles (Van Valkenburgh and Bunyapraphatsara, 2001).

However, despite all the substantial uses of water spinach, the vegetable is not common in Zimbabwe and very few researches have been done on water spinach to enable its full exploitation and utilization. With its great potential for enhancing food and nutrition security, it is still categorized as an underutilized crop.

3. Nutritional composition:

Water spinach is a nutrient rich leafy vegetable that can provide a variety of health benefits when incorporated into meals in a balanced diet. It is rich in vitamin A, B6, B12 and D, folates, niacin, pantothenic acid, pyridoxine, thiamin and riboflavin (Duc *et al*., 1999; Kala and Prakash, 2004). Water spinach is also rich in minerals such as iron, magnesium, phosphorus, calcium, potassium, sodium, zinc, copper, manganese and selenium (Duc *et al*., 1999; Kala and Prakash, 2004). Water spinach is considered an abundant source of water, energy, dietary fibres, protein, carbohydrates and antioxidants (Wills *et al*., 1984; Yamaguchi, 1990, Austin, 2007; Be Healthy, 2023) and amino acids such as alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, leucine, lysine, proline, threonine, tyrosine and serine (Rao and Vijay, 2002).

It also contains organic acids such as citric acid, oxalic acid and malic acid (Wills *et al*., 1984) and ash (Ogle *et al*., 2001).

It is estimated that 100 g of water spinach can account for 21% of the daily Ca intake, 18% of Mg, 7.5% of Na and 6.6% of K daily intake (East West Seeds, 2018). Fresh plants contain 1.9 to 4.6% proteins and carbohydrates average calories 4.3% (Wills *et al.,* 1984; Yamaguchi, 1990). The combination of these nutrients makes water spinach a nutritious and versatile ingredient that can be easily incorporated into a wide variety of dishes (Be Healthy, 2023). The nutrient content of water spinach is comparable to milk, banana and orange (National Nutrition Council, 2022). Protein levels are about 2 to 7% and are comparable to legumes, soybeans or full chicken egg (Rao *et al*., 1990; Aletor *et al*., 2002).

A research carried out by Umar *et al*. (2007) analyzed the nutritional composition of water spinach leaves through use of food analysis standard methods to determine proximate composition and minerals (Table 1). The leaves contained adequate amounts of Fe, K and Mn for children, adults and, pregnant and lactating mothers. On the other hand, Mg content was adequate for children. Water spinach leaves therefore, may perhaps be useful for nutritional purposes, due to the diversity and the levels of nutrients contained therein.

Water spinach provides essential vitamins and minerals without adding many calories, supporting overall health. It has a high water content, which can help keep the body hydrated. Water spinach is a high fibre, low glycemic index and low calorie vegetable. The high nutritional value of water spinach contributes to the several therapeutic benefits, making it a leading medicinal plant with great potential. It is evident that this vegetable has potential to contribute immensely to both food and nutrition security.

Table 1: Nutritional composition of water spinach leaves on dry weight basis

Component	Concentration*	Remarks	Recommended dietary allowances**			
			Adult male	Adult female	Children 7-10 years	Pregnant & lactating mothers
moisture content	72.83±0.29%	high				
#	10.83±0.80%					
ash	6.30±0.27%	low				
crude protein	11.00±0.50%	high				
crude lipid #	17.67±0.35%	high				
crude fibre	54.20±0.68%	high				
carbohydrate	300.94±5.31 kcal/100 g	moderate				
calorific value#	5,458.33±954.70 mg/100 g	high	2000	2000	1600	2000
Potassium	135.00±2.50 mg/100 g	moderate	500	500	400	500
Sodium	416.70±5.77 mg/100 g	moderate	800	800	800	1200
calcium	301.64±12.69 mg/100 g	moderate	350	2802	170	375
Magnesium	109.29±0.55 mg/100 g	low	800	800	800	1200
Phosphorus	0.36±0.01 mg/100 g	low	1.5-3	1.5-3	1-3	1.5-3
Copper	210.30±2.47mg/100g	high	10	15	10	13
Iron	2.14±0.22 mg/100 g	high	2-5	2-5	2-3	2-5
Manganese	2.47±0.27 mg/100 g	low	15	12	10	19
Zinc						

Adapted from *Umar et al.* (2007)

* The data is mean value ± standard deviation (SD) of three replicates

** Source: Thangadurai *et al.* (2001).

Value is within range reported in some leafy vegetables in Nigeria and Niger

4. Health benefits of water spinach

4.1 Prevents constipation

The high level of fibre content contained in water spinach plays a significant role in regular bowel movement and supports healthy digestion, thus prevents constipation (Sivaraman and Muralidaran, 2010; National Nutrition Council. 2022). Dietary fibre is essential for maintaining optimal digestive health, and incorporating water spinach into diets can provide various digestive benefits. Fibre adds bulk to the stool, making it easier to pass, thus it helps prevent constipation (Samuelsson *et al*., 1992; Be Healthy, 2023). Fibre acts as a prebiotic, feeding the beneficial bacteria in the gut, which in turn supports overall digestive health and immune function. By promoting regular bowel movements, fibre helps reduce the risk of developing hemorrhoids and other conditions related to straining during bowel movements. Additionally, the soluble fibre can also help lower cholesterol levels by binding to cholesterol and removing it from the body through the digestive system. Water spinach can protect the mucous membrane of the stomach, thereby reducing the occurrence of gastric ulcers. The glycoglycerolipids contained may boost the strength of the digestive tract lining and might also prevent any undesirable inflammation in that part of the body (Pimentel, 2021).

4.2 Anti-diabetic

Regular consumption of water spinach gradually creates some resistance from diabetes within the human body (Craig, 1999; Brandt *et al*., 2004). It has therefore, been recommended to consume the water spinach as a way of treating pregnant women with diabetes. There are indications that its substances take in the excess blood sugar in the human body (Joven, 2017). The high fibre levels in water spinach supports healthy blood sugar levels by slowing down the absorption of sugar into the bloodstream. There is a significant inhibitory effect on glucose absorption (Malalavidhane *et al*., 2000; 2001; 2003), which helps in maintaining stable blood sugar levels, central to people with diabetes or prediabetes (Malalavidhane *et al*., 2000; 2001; 2003; Be Healthy. 2023). Nowonder that in Africa and Sri Lanka, *I. aquatica* is used to treat diabetes (Iwu 1993, Malalavidhane *et al*., 2000).

4.3 Improves eyesight

Water spinach contains high levels of vitamin A, which is essential for eye health by contributing in maintaining good vision and potentially reducing the risk of age-related eye disorders. Vitamin A helps maintain the health of the retina, specifically the rod cells, which are responsible for low-light vision. Its deficiency can lead to night blindness. Vitamin A prevents radical attacks in the cornea and the conjunctiva, the thin outer layer of the eye (Pimentel, 2021). It also reduces eye dryness and irritation (Pimentel, 2021) and other related eye conditions such as Age-Related Macular Degeneration (AMD), a leading cause of vision loss in older adults. Some studies suggest that a diet rich in vitamin A, along with other antioxidants, may help slow down the progression of AMD and lower the risk of development of cataracts (Pimentel, 2021; Be Healthy. 2023). Vitamin A has anti-inflammatory properties that can help protect the eyes from inflammation and infections. Inclusion of water spinach in diets can help in maintaining good eye health and potentially decreases the risk of age related eye disorders (Jain and Verma, 1981; Be Healthy. 2023). Water spinach and carrots are comparable in terms of vitamin A content.

4.4 Reduces risk of anaemia

The high levels of iron in water spinach help increase the blood haemoglobin. Iron is essentially important for the formation of haemoglobin and resolving iron deficiencies of any kind. This is beneficial for pregnant women and those suffering from anaemia. Water spinach contains folic acid, which can play a vital role in supporting a healthy pregnancy. Folic acid, also known as folate or vitamin B9, is an essential nutrient for pregnant women. It helps prevent birth defects and supports the healthy development of the foetus (Pimentel, 2021). Folic acid is crucial during the early stages of pregnancy to prevent neural tube defects (NTDs), which can affect the newly developed baby's brain and spinal cord. It is crucial in the synthesis of DNA and RNA, which are essential for the growth and development of the foetus. Thus it ensures that the baby has sufficient time to develop in the womb, and this has been linked to a reduced risk of preterm birth. It also facilitates the production of red blood cells, which are vital for the transportation of oxygen and nutrients to the developing foetus. Overall folic acid also plays a role in the health of the pregnant women by reducing the risk of anaemia and supporting a healthy nervous system (Pimentel, 2021). Hence, water spinach, which is rich in folic acid has great potential in supporting a healthy pregnancy and ensures nutrition security at large.

4.5 Boosts immunity

The high vitamin C levels in water spinach are ideal for boosting human body immune system. Vitamin C facilitates the production and the functionality of white blood cells, such as lymphocytes and phagocytes, which are essential in protecting the body against infections. As an antioxidant, it helps in preventing free radical damage to immune cells so they can continue to

function effectively. Vitamin C also aids in the production of collagen, which strengthens the skin's barrier, preventing pathogens from entering the body. Adequate vitamin C intake may help reduce the severity and duration of common colds. In addition, it helps in the absorption of non-heme iron from plant based sources, which helps maintain optimal levels of iron needed for a healthy immune system (Be Healthy. 2023). Incorporating water spinach into diets is a great way to support body's natural defense system.

4.5 Improves liver, heart and kidney health

According to Sivaraman and Muralidaran, (2010), water spinach has chemical compounds that give extra protection to the liver). Antioxidants contained in the vegetable like water spinach could be vital in strengthening heart muscles, which continuously pump blood to all parts of the body. It might prevent several cardiovascular diseases such as hyperlipidemia, heart failure, hypertension and coronary heart disease (Pimentel, 2021). Water spinach contains potassium, an essential mineral that plays a key role in maintaining a healthy cardiovascular system. Potassium helps to relax blood vessel walls, which can lower blood pressure and reduce the strain on the heart (Perry and Metzger, 1980; Duke and Ayensu, 1985; Pimentel, 2021). Potassium also helps to counterbalance the negative effects of excessive sodium intake (Pimentel, 2021), which is associated with high blood pressure and an increased risk of heart disease. Studies have shown that a diet rich in potassium may reduce the risk of stroke by helping to prevent the formation of blood clots and promoting overall cardiovascular health. Potassium is a vital electrolyte that helps regulate fluid balance, nerve signals, and muscle contractions. Healthy kidney function is essential for maintaining optimal blood pressure levels. Potassium helps the kidneys filter excess sodium from the body, which in turn supports heart health. Hence, water spinach can contribute to better liver, heart and kidney health.

4.6 Promotes healthy bones

Water spinach contains both calcium and vitamin K, which are essential nutrients for maintaining strong and healthy bones. Calcium is a key building block for bones and teeth, ensuring they remain strong and dense, thus it helps prevent bone loss and the development of osteoporosis. Vitamin K plays a crucial role in bone metabolism by helping the body use calcium effectively. It aids in the production of osteocalcin, a protein which helps bind calcium to the bone matrix, thereby promoting bone mineralization and strength. The fact that water spinach contains both calcium and potassium is of paramount importance considering the synergistic effects of calcium and vitamin K. While calcium provides the necessary building blocks for strong bones, vitamin K ensures that calcium is properly utilized and incorporated into the bone structure. Additionally, water spinach contains magnesium and phosphorus that contribute to bone health through bone formation and maintenance.

4.7 Improves skin health

Water spinach eliminates harmful toxins and skin disorders in the human body and this results in better skin health. The vitamin A and C contained in water spinach can have a positive impact on skin health. Vitamin C is crucial for collagen synthesis, a protein that enhances skin strength and elasticity. Collagen production naturally declines with age, so consuming vitamin C-rich foods like water spinach can help maintain a firm and youthful skin texture. Vitamin A is involved in skin cell regeneration, hence supports skin cell turnover by promoting the growth of new, healthy skin cells and helping to shed old, damaged ones. It also prevents skin dryness and dehydration. Vitamin A has anti-inflammatory properties that can help reduce redness and inflammation, leading to a more even and balanced skin tone. In addition, both vitamins A and C are essential for wound healing, as they support

skin repair and the formation of collagen, scar tissues and new blood vessels (Bechara *et al.,* 2022).

4.8 Anti-ageing effects

Water spinach removes possible free radical damage in the human body, thus it improves the body's capability to resist from any form of damage that may come from the sun. Antioxidants like vitamins A and C shield the skin from free radical damage that can result from exposure to UV rays and pollution in the environment. Free radicals are unstable molecules that can contribute to the development of chronic diseases and aging (Fusco *et al.,* 2007). Hence, this protection can help slow down the aging process and prevent formation of fine lines and wrinkles, and potentially reduce the risk of chronic diseases (Fusco *et al.,* 2007; Cao *et al.,* 2020).

4.9 Improves mental health

Folate content can have a positive impact on mental health through synthesis of neurotransmitters such as serotonin, which are essential for mood regulation and overall mental well-being (Williams *et al.,* 2007). Adequate serotonin levels are important for maintaining a balanced mood and preventing mood disorders. Folate plays a role in the production of other neurotransmitters, such as dopamine and norepinephrine, which are involved in the body's stress response. Hence, adequate folate may help support the body's ability to manage stress effectively. Studies have shown that low folate levels are associated with high risk of depression (Williams *et al.,* 2007). Folate is also essential for proper brain function, and consuming adequate amounts of this nutrient can help support cognitive processes such as memory, learning, and concentration. It also regulates homocysteine levels. Antioxidants in water spinach may help shield brain cells from oxidative stress-related damage, potentially reducing risk of neurodegenerative diseases such as Parkinson's and Alzheimer's (Lee *et al.,* 2020).

Water spinach is reported to have insulin-like activity compounds clinically shown to be effective (Jayaweera, 1982; Austin, 2007). However, there are limited scientific studies that have been conducted on the vegetable's medicinal aspects. There are reports that it reduces liver diseases and constipation. Water spinach is used to treat gastric and intestinal disorders, and is considered a tonic due to the several vitamins including S-methyl-methionine that it contains. Additionally, the vegetable also contains aliphatic pyrrolidine amides, carotenoids, hentriacontane, β-sitosterol and its glycosides (Austin, 2007; Sivaraman and Muralidaran, 2010)

5. Production of water spinach

Water spinach has been grown commercially in Asian cultures for generations (Candlish *et al*., 1987; Chen *et al*., 1991). The vegetable is easy to grow with minimal requirements for land space and maintenance (Prasad *et al*., 2008; National Nutrition Council, 2022; Masa, 2023). It is a crop of choice by many farmers in Asia, possibly due to its relatively cheap and simple farming process (East West Seeds, 2108). The vegetable practically grows anywhere, in ditches, ponds, dry land and even as a potted crop. It requires insignificant amounts of seed, fertilizer, and regular watering (East West Seeds, 2018). Water spinach farming if done correctly is a very profitable agribusiness venture and can be an all-year-round crop in tropical areas if the water supply is sufficient. This fast growing, versatile and nutritious vegetable is easy to grow and has become increasingly popular among farmers in Asia (Masa, 2023).

5.1 Climatic and soil requirements

Water spinach is adapted to a wide range of climate and soil conditions. It is sensitive to frost and thus does well when temperatures are above 24°C. Hence, Subtropical and tropical climates are ideal for the growth of the vegetable (Pandey, 2011). There are reports of plant damage at temperatures of 10°C or below (Palada and Chang, 2003).

Optimum yields are attainable in lowland humid tropics under stable high temperatures and short day lengths (Palada and Chang, 2003). High temperatures i.e. in the range 25 to 30°C are ideal for seed germination and plant growth (Palada and Chang, 2003). Optimum growth is promoted by high soil moisture content. Clay soils and marshy soils rich in organic matter are suitable for water spinach production, but well drained soils are highly recommended. The ideal pH range for growing water spinach ranges from 5.5 to 7.0 (Top and Ashcroft, 2002).

Depending on the variety, water spinach is grown in water or soil. Troughs can be used or raised beds when growing in soil (Keßler, 2020). Irrespective of type, variety choice can be influenced by the local growing conditions, season, and consumer preferences. It is therefore recommended to conduct local testing so as to identify superior varieties.

Reliable water source is critical for growing water spinach to facilitate irrigation. The crop requires full sunshine, (Masa, 2023), but some studies have revealed that production under shading conditions is also possible (Pandey, 2011).

5.6 Land preparation

Land preparation is essential to clear weeds or debris that may hinder water spinach growth. Once the area is cleared, tillage should be done to loosen up the soil and allow better drainage (Masa, 2023). It is advisable to make raised beds when growing water spinach in soil (Keßler, 2020)

5.7 Planting to harvesting

The vegetable can be propagated sexually or vegetatively depending on the availability of seed and labor, growing season, and the type of water spinach. There are several varieties that farmers can choose depending on their preferences and market demand. However, regardless of the farmer's choice, each variety offers unique flavours and textures that make them stand out from each other (Masa, 2023). Either way, the health of the growing media to a large extent determines the success of the crop. Sowing can be done all year round (Keßler, 2020).

Row seeding or broadcasting can be practiced. When row sown, seeds are placed in furrows 1.0 to 1.5 cm deep and 15 to 20 cm apart on well-prepared seedbeds. The seeds are sown 5 cm apart in rows. Thinning is recommended to stand 10 to 15 cm apart at two to three true leaves stage. Commercially, a seed rate of 5 kg/ha can achieve a density of 50,000 plants/ ha (Palada and Chang, 2003). A seed rate of 5 to 10 kg/ha is recommended for intensive production, and thinning may not be necessary (Palada and Chang, 2003).

Seedlings can be raised either in trays or in seedbed nurseries. Trays are more preferred owing to reduced damage to the seedlings when pulled for transplanting, when seedlings have five to six leaves, approximately three weeks after sowing (Palada and Chang, 2003). Soaking the seeds overnight in clear water before sowing may be required (Keßler, 2020).

Transplanting in the late afternoon or on a cloudy day is recommended to minimize wilting (Palada and Chang, 2003). Narrow spacing (10 cm inter-row and 15 cm in-row spacing) is used for once-off harvesting, while wider spacing (20 cm inter-row and 30 cm in-row spacing), is used if plants are allowed to produce long vines and are harvested multiple times (Palada and Chang, 2003).

Stem cuttings of 15 to 25 cm long, with 3 to 4 internodes are normally used in vegetative propagation. In some cases, stem cuttings are soaked in water for a period of 1 to 3 days for them to develop roots before transplanting (Palada and Chang, 2003).

Regular watering is necessary throughout the growing season since water spinach requires adequate water for optimal growth (Masa, 2023; Fothergill, 2023; Palada and

Chang, 2003). Water spinach is responsive to nitrogen fertilizers but it can thrive under low to moderate soil fertility conditions. It is also responsive organic manures. However, combining inorganic and organic fertilizers enhance high yields and maintains high soil fertility (Palada and Chang, 2003). A soil test analysis is recommended to determine the available NPK (Palada and Chang, 2003), and subsequent amounts to apply, which may be influenced by the soil type, soil fertility status, fertilizer type and recovery rate, as well as the soil organic matter content. Two weeks after planting, compost or chicken manure can be applied around the base of each plant to enhance soil fertility and leafy growth. Alternatively, apply vermicompost to the soil or apply vermitea or fermented plant juice twice a week to boost crop growth and resistance to pests and diseases. As a guide, recommended fertilizer rates are shown in Table 2.

Table 2: Recommended fertilizer rates (kg/ha) for water spinach production

	Days after sowing/transplanting			
Nutrient	Pre-plant	10	20	30
Compost	10,000			
Nitrogen (N)	48	30	8	8
Phosphorus (P_2O_5)	64	8	8	0
Potassium (K_2O)	48	15	8	0

Adapted from Palada and Chang (2003)

Harvesting commences six weeks after planting, when leaves reach their desired size (about 8 to 10 centimeters long depending on preference). Contingent with the variety and plant type, water spinach takes about 20 to 60 days from sowing or transplanting to be harvested. The leaves and stems are both edible, so a choice can be made to either cut off some or all of the stems or just pick individual leaves as needed. For good quality produce, the young shoots and leaves are picked before the plant flowers.

In situations where harvesting is done only once, all the plants are uprooted. While for multiple harvests, stems or shoots are cut close to the ground on a weekly basis when they reach 15 to 25 cm in length. The frequent harvesting stimulates growth of side shoots and delays onset of flowers.

According to Masa (2023), a sharp knife or a pair of scissors can be used to harvest water spinach. Care should be taken when harvesting to avoid damage to the crop plants. The harvested produce is washed and tied in bundles. Water spinach has large surface to volume ratio and is susceptible to wilting. To reduce the excessive water loss, it is recommended to harvest early in the morning or late in the afternoon, when temperatures are low (Palada and Chang, 2003). Additionally, the harvested produce should be kept in a cool shaded place. Water spinach is a very perishable vegetable, and it does not store well even in a refrigerator. The produce is characterized with rapid deterioration once harvested, therefore should always be consumed fresh. It can be preserved by blanching or sun drying (Chitsa *et al*., 2014). Blanching, followed by sun drying is advantageous over the straight sun drying, hence whenever necessary, water spinach should be blanched and then sun dried for preservation (Chitsa *et al*., 2014).

6. Pest management

Weed management should be practiced in water spinach production as they compete with the water spinach for light, water, nutrients and space, resulting in reduced yields. As water spinach seeds are slow germinators, early weed control is indispensable for direct seeded crops. Hand

weeding is the most common method used. Mulching is recommended in upland water spinach to reduce weed competition, soil compaction, and soil erosion. Mulching also conserves soil moisture, thereby enhancing crop yield. Organic mulches can be applied as layers above ground level before or after transplanting, or after crop emergence in direct seeded crops. Application of mulch is easier in transplanted crops, but can be used for direct seeded crops once the seedlings reach 10 to 15 cm height (Palada and Chang, 2003). Weeding reduces attack of the crop by pests (Masa, 2023). Leaf-miners, cutworms and mealy bugs are some of the pests that are problematic. A crude mixture of 100g of crushed chili in 16 litres of water can be sprayed as an organic remedy.

Pests and diseases control is important to ensure good yield and marketable quality even though few diseases like white rust (*Albugo ipomoeae-panduratae*) affect water spinach. Disease management can be achieved through crop rotation, field sanitation, wider plant spacing, and using furrow instead of overhead irrigation to reduce the disease incidences. Fungicides are rarely used unless there is a history of fungal diseases infection in the area. Chemical control of pests and diseases should be used only when necessary, and mainly as a corrective measure. Broad spectrum pesticides kill or inhibit growth and development of beneficial organisms, and these should be avoided. Only insects causing the damage should be targeted. In addition, the pesticide effects should have short persistence.

7. Invasiveness

Water spinach is a very invasive and aggressive vegetable. It crowds out native plants and, in some countries, damages have been reported in rice and sugarcane crops. Most herbicides approved for use in aquatic environment are not effective against water spinach (Kipker, 1998). No wonder that water spinach is listed by the USDA as a noxious weed. Water spinach fast growth rate and adaptability have been cited as serious threats to native plants in Florida (Harry and Ho, 1969). However, in Texas the ban on water spinach cultivation was lifted perceiving its importance as a vegetable in many cultures (Langeland and Burks, 1998). In Sri Lanka, there are reports that water spinach can invade wetlands and block the flow of water and interfere with the passage of boats due to its long, floating stems and dense mats (Gunasekera, 2009). However, that poses no economic damage because it is edible and easy to contain. In Southeast Asia it is a cultivated crop, in demand and well-liked by many such that it is even served in fast food outlets. Because of the shining virtues of water spinach, it is possible and practical to produce the crop and contain it, enabling the population to enjoy the benefits associated with the crop.

8. Conclusion

Water spinach is a versatile and nutrient-dense leafy green vegetable that can offer a wide range of nutritional and therapeutic benefits. From supporting eye health and boosting the immune system to aiding in weight management and promoting mental well-being. Water spinach can be a valuable addition to any diet. Packed with essential vitamins, minerals, antioxidants, fibre and folic acid, the vegetable can help improve overall health and potentially reduce the risk of chronic diseases, contribute to better skin health, promotes digestion, and ensure good mental health. It can be used in various dishes, such as salads, stir-fries, and soups to provide a flavourful and nutritious boost to diets. Water spinach is a cheap alternative to medicine that can improve human overall health (Gangopadhyay *et al*., 2021). An added advantage to the nutraceutical and pharmaceutical benefits is the easy to grow, low cost, low maintenance, and versatility nature of this underutilized vegetable. Hence, Water spinach can help households to be food and nutrition secure, as it is a nutritious, healthy and an economically viable underutilized leafy vegetable crop with great potential.

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