



Advancements in Water Spinach Production Technology: Sustainable Practices and Innovations

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Water spinach, scientifically known as *Ipomoea aquatic* Forsk, is a perennial herbaceous plant that belongs to the convolvulaceae family. It is a vascular semi-aquatic plant with a chromosome number of $2n = 30$. Commonly referred to as Karmatta bhaji, Kalmisaag, and Paani palak in the local dialect. Among the two varieties of water spinach, there is a specific type called Lombok water spinach, which is well-known within the community and has the capacity to be grown. Lombok water spinach is characterized by its high quality, including vibrant light green leaves and crisp stems. Lombok water spinach possesses distinctive attributes that distinguish it from other types of kale and might potentially be further enhanced. Visually, Lombok water spinach is plump, green, and vibrant, with a firm texture.

Origin and distribution

As mentioned, water spinach is thought to have originated in China. Water spinach grows naturally and is farmed in Southeast Asia, India, and Southern China. It is a native of the tropics and subtropics. There are two varieties of water spinach grown in Indonesia: aquatic spinach, which is grown in ponds or swamps, and terrestrial kale, which is grown in fields. Due to its fragile branches and leaves, this plant—which grows well in both water and land environments—is grown as a leafy vegetable. The leaves may include protein in addition to being rich in vitamins and minerals. The plant produces fish feed, grilled feed, and nutritious green fodder. Vines have long, flexible, tubular stems that allow them to float on water or move across soil with ease. When nodes come into contact with moist soil or water, adventitious roots sprout. Water spinach reproduces asexually through stem fragmentation, where broken stem fragments establish new plants by developing roots. The green leaves typically have an arrow-head or lanceolate shape. The plant's leaves exhibit alternate phyllotaxy along its stem. The margins can exhibit three different forms: whole, angular, or sub-lobed. The flower peduncles are upright and measure 2.5 to 5.0 cm in length, with 1-2 flowers growing in the leaf axils. They usually bear a resemblance to blooms of the "morning glory" variety. The trumpet-shaped flowers vary in color, ranging from white to pale pink or lilac. They can grow either alone or in tiny clusters. The sepals exhibit a green coloration, possess an oblong shape, and measure approximately 8.0 mm in length. The corolla is characterized by a bell-shaped structure and has a purple coloration. It has dimensions of around 5.0 cm in length and 5 cm in diameter. The limb is predominantly white or pale pinkish-purple, while the tube exhibits a richer shade of purple on its inner surface. The capsules are characterized by their smooth and oval shape, with a length of roughly 1.0 cm.

Fruits are ovoid or globular capsules that become woody when fully mature and have a width of 1.27 cm. The capsule consists of 1-4 seeds that are around 4-5 cm in diameter and have a grayish color. According to Rakesh et. al. (2020), pods and seeds have the ability to float and disperse, allowing them to create new plants.

Importance and uses

It is a prominent vegetable crop in Southeast and South Asia. This vegetable is widely favoured by the general population for its high nutritional content and the convenience of growing it, despite its relatively short lifespan. It is highly nutritious, including essential vitamins such as A and C, as well as minerals like iron, calcium, potassium, and phosphorus. Kale is rich in phytol and palmitic acid, which have advantageous properties (Zeng et al., 2021). Immature sprouts and foliage can be consumed raw in salads or prepared together with other vegetables, seasonings, and meat. Water spinach stir-fried with garlic is a widely enjoyed vegetable dish. Water spinach is commonly prepared in South India by slicing it into thin strips and serving it alongside various types of noodles. It is commonly served in a tangy broth with tomatoes and vegetables. Water spinach is typically eaten in its raw form or partially cooked along with other vegetables in dip preparations. In the Philippines, tender shoots are diced and cooked together with leaves in fish and hog stews. In Singapore and Malaysia, tender shoots and leaves are sautéed with spices such as chili, garlic, and ginger. Kolmishak, a renowned culinary preparation in West Bengal, entails the process of sautéing the leaves.

Health benefits

This method offers an excellent means of effectively reducing weight and decreasing cholesterol levels in a natural manner. Research indicates that the use of water spinach can effectively reduce levels of cholesterol and triglycerides. Water spinach is used in Ayurvedic medicine for the treatment of jaundice and liver problems. It achieves this by regulating detoxifying enzymes and has antioxidant and free radical scavenging properties. Fresh spinach leaves are rich in iron, making them highly beneficial for individuals with anemia and pregnant women who require iron in their dietary intake. Water spinach is rich in dietary fiber, which enhances the digestion process and alleviates gastrointestinal problems. Boiling spinach juice has the potential to alleviate constipation and address intestinal worm infestations. It includes latex, which is a material with purgative properties. Consistently consuming spinach can enhance the body's ability to withstand oxidative damage caused by diabetes. Water spinach is rich in antioxidants that reduce the presence of free radicals and shield cholesterol from oxidation.

Area and distribution

Water spinach thrives in all three agro-climatic zones of Chhattisgarh, including the Northern Hills, Chhattisgarh Plains, and Bastar Plateau. Water spinach is cultivated in multiple districts of Chhattisgarh, such as Dhamtari, Raipur, Ambikapur, Kondagaon, Bastar, Mahasamund, Bilaspur, Gariyaband, Durg, and Kanker. There is currently no improved or upgraded option available in either the government or commercial sector.

Varieties

Light green: Plants in this classification possess stems that are of a pale green color. The sprouts exhibit sensitivity, possess a smooth and hairless texture, and are characterized by the presence of ovate, oblong, and lanceolate leaves that grow in abundance in shallow water.

Green-red: This plant group exhibits stems that are both green and red in color. The shoots are delicate, smooth, and hairless. The leaves are dense and usually shaped like an arrowhead. The plants have elongated and trailing branches during their growth and development.

Red stem: This plant group's stems are dark red, velvety, glabrous, and narrower in diameter than other types.

Kashi Manu Developed by IIVR and suitable for upland cultivation.

Climate and soil

Water spinach flourishes at a temperature range of 20–30 °C. Flowering takes place under short-day photoperiod conditions. It can withstand substantial amounts of water; however, it is not able to survive frost. While it thrives in direct sunlight, it can also be grown as a low-lying plant behind climbing vegetation in regions with high temperatures. Water spinach must be shielded from strong gusts. The optimal pH range for this plant is 5.5 to 7.0, which is conducive to the growth of fertile soil.

Seed sowing and transplanting

Crops in hydric soil cultivation are grown on elevated beds measuring 60–100 cm in width. Either sow seeds directly into the ground or transfer seedlings that have been produced in a nursery. In order to facilitate germination, it is recommended to use seeds that are no more than 2 years old and to soak them for a duration of 24 hours before sowing. Plant the seeds at a depth of 5–10 mm in trays with sufficient potting mix to facilitate optimal root growth. Transplant seedlings once they reach a height of 10–15 cm and have developed four fully formed leaves. The maximum yields are achieved with a plant spacing of 20 × 15 cm. Plants can be arranged with a spacing of 15-20 cm between them in rows. Water spinach can be grown as a crop in highland fields. The weight of 1000 seeds is approximately 50–60 grams. An optimal seed rate for sowing one hectare of land is between 60 and 100 kilograms. The range of plant densities can vary from 3,000,000 to 17,000,000 per hectare. Upland field water spinach has more productivity and commands a higher market value.

Vegetative propagation using cuttings

Water spinach can be cultivated by obtaining stem cuttings that are approximately 30–40 cm in length from the lower part of the plant, namely below a node. These cuttings should then be planted at a depth of approximately 5.0 cm. Aquatic cultivation entails the process of transferring cuttings from cultivars with broad leaves into soil that has been made muddy or saturated with water.

Benefits of upland agriculture: water spinach

It can be grown year-round. This plant exhibits robust growth in elevated areas and does not necessitate being submerged. Produce might be devoid of water impurities. Technology provides the option of cultivating "safe biomass" in the form of "upland water spinach." The objective is to promote the VRWS-1 cultivar in order to enhance the socioeconomic growth of producers.

Crop management

In order to cultivate water spinach of superior quality, it is necessary to provide the crop with sufficient nutrients before transplanting it. Plants require nitrogen for optimal growth; however, excessive nitrogen supply can result in elevated nitrate levels in leaves and stems, which is undesirable. In order to provide nutrients to crops, it is recommended to apply 30 metric tons per hectare of manure containing 50.0 kilograms per hectare of nitrogen, 30.0 kilograms per hectare of phosphorus, and 40.0 kilograms per hectare of potassium prior to sowing or transplanting. Subsequently, every 10 days, three applications of nitrogen (N) are added to the soil at rates of 30, 8, and 8 kg/ha. To enhance the growth of many cuttings in home gardens, it is advisable to apply more top dressing after each cutting. Increasing the application of nitrogen fertilizer to plants enhances productivity, leaf/stem ratio, and nitrate content, but reduces the amount of dry matter. Aquaculture entails increasing the water level

to a specific depth of 15-20 cm to facilitate the cultivation of crops. The application of fertilizers in upland agriculture involves the addition of nitrogen as a top dressing after each cutting.

Harvesting, crop production, and handling after harvest

Water spinach should be harvested before it blooms. The crops are ready for harvesting after a period of 50–60 days after sowing and 35–40 days after planting. By trimming the shoots above ground level in elevated fields, it stimulates the growth of other shoots from the nodes below the cut. This technique enables many harvests to be obtained. The frequency of harvesting varies depending on the rate at which the crops grow. The top section of the main stem, about 30 cm in length, is cut 5 cm above the water surface. A minimum of three cuttings yields around 35–40 tons of fresh vegetation per hectare. In order to mitigate crop damage caused by dehydration and drooping, it is imperative to promptly and cautiously handle crops following their harvest. To mitigate this issue, it is advisable to gather crops during the most frigid period of the day. Following the process of bunching, it is advisable to apply a fine mist of cold water and keep the leaves in a location sheltered from the wind. Markets usually provide bundles of leaves weighing 500 grams, priced at 60–80 per kilogram.

Storage

Water spinach is carefully arranged in 15-cm layers within bamboo crates and stored with crushed ice for the purpose of long-distance shipping and storage. Water spinach that is grown in upland areas has an extended period of time in which it may be stored without spoiling since the fresh shoots have smaller leaves. Water spinach is highly perishable and should be stored at 10-15°C with high humidity. It can be kept fresh for 1-2 days at room temperature and up to a week under refrigerated conditions.

Transport

Transport should be done in the early morning or late evening to avoid heat stress. Use insulated containers or vehicles to maintain a cool temperature during transit.

Key Considerations

Pest and Disease Management: Monitor for pests like aphids and caterpillars, and diseases such as leaf blight and root rot. Use integrated pest management (IPM) strategies.

Market Demand: Ensure there is a demand in local or regional markets. Water spinach is popular in Asian cuisine and markets.

Sustainable Practices: Employ sustainable agricultural practices, such as crop rotation, to maintain soil health and reduce pest buildup.

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Figure 1: Crop field of water spinach



Figure 2: seed of water spinach



Figure 3: leaf of water spinach



Figure 4: Germination of seed (water spinach)



Figure 5: Growing Water Spinach in Aquaponics system