Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 05 (SEP-OCT, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Sustainable Organic Production of Turmeric (*Curcuma longa* L.) in Mid-Hills of Sikkim: Production Technologies and Prospects

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Turmeric (*Curcuma longa* L.) also known as *Haldi* is an important spice and medicinal crop with considerable potential for sustainable organic production in the mid-hills of Sikkim. The region offers favourable agro-climatic conditions, traditional organic farming practices, and abundant locally available organic resources suitable for turmeric cultivation. Sustainable production involves the use of healthy planting material, appropriate varieties, organic nutrient sources, mulching, efficient water and weed management, crop rotation, and intercropping. Eco-friendly approaches for managing major insect pests and diseases are essential for maintaining crop health and productivity. Proper harvesting, curing, drying, and seed rhizome storage further contribute to improved quality and reduced post-harvest losses. Under well-managed organic conditions, turmeric can produce approximately 20–25 t ha^{-1}. Adoption of sustainable production practices can enhance soil health, conserve natural resources, improve rhizome quality, and provide greater livelihood opportunities for farmers in the mid-hills of Sikkim.

Keywords: Sustainable agriculture, Rhizome production, Organic nutrient management; Pest and disease management

Introduction

India is known, from prehistoric times, as the land of spices. Till the seventies, India had a virtual dominance in the international trade even with the emergence of a few countries it continues to be the largest producer, consumer, and exporter of spices in the world. The contribution of Zingiberaceae spices to total spices in area and production in India is 387 thousand ha (15%) and 1136 thousand tonnes (30%) respectively (Choudhary and Rahi, 2018). Turmeric (*Curcuma longa*) is a perennial rhizomatous herb grows up to a height of three to five feet usually with 7 to 12 leaves is one of the world's most important and invaluable medicinal spice crop in India which produces nearly entire whole world's crop and consumes 80% of it. This spice is also sometimes called "*Indian saffron*" because of its yellow colour. It occupies about 6% of the total area under spices and condiments in India which is cultivated extensively in Asia, India, China, and other countries with a tropical climate. Turmeric is considered a minor spice in Western countries but holds considerable importance in Asian countries. In the West, it is valued primarily for its characteristic yellow colour, whereas in Asia, both its colour and distinctive aroma contribute to its culinary and cultural significance. Besides its culinary importance, turmeric has long been valued for its medicinal and therapeutic properties.

India dominates the world production scenario contributing 78 % followed by China (8%), Myanmar (4 %), Nigeria and Bangladesh together contributing to 6 % of the global production (Viraja *et al*., 2018). India is the main producer and exporter of turmeric in the world. More than 70 turmeric types are known to be under cultivation in India (Prasath *et al.,* 2024). Curcuminoids, a group of polyphenolic compounds present in the turmeric rhizome,

are responsible for the yellow colour and its medicinal properties. Turmeric rhizome contains 2–8% curcuminoids, and the variation in phytoconstituents is attributed to differences in genotype, climate, and soil condition of different agroclimatic zones.

Turmeric Production in NEH Region

North eastern hill region, green belt of India which comprises states, namely, Sikkim, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Assam harbour a rich flora on account of its varied topography, climate and altitudes and has great potential or the development of horticultural crops including spices is popular for quality spice production which is used widely since ancient times in different dishes and also in pharmaceuticals due to medicinal properties of curcumin and oleoresin (Devi and Sangamithra, 2011). NEH Region is home to some niche spice crops like Lakadong turmeric, Bird's eye chilli, King chilli and Nadia ginger which has high market demand for their unique features (Momin *et al.,* 2018). Turmeric is an important cash crop in the NEH region and shares about 8.30 per cent of the total production in the country. Mizoram, with a total production of 27.82 thousand MT is the leading state in the region followed by Meghalaya (16.63 thousand MT) and Manipur (15.40 thousand MT). The agro-climatic conditions of the region characterised by warm and humid summers with abundant rainfall and cool winters are favourable for turmeric cultivation (SFAC, 2012). Like other food crops grown in the NE region, turmeric is cultivated using the traditional knowledge of the inhabitants which are generally eco-friendly, less expensive and organic inputs.

Climatic Requirements

Turmeric can be cultivated under rainfed or irrigated circumstances in a variety of tropical climates, from sea level to 1500 meters above sea level, at temperatures between 20 and 35˚C, and with an annual rainfall of at least 1500 mm.

Soil Type

The ideal soil type is sandy or clay loam with a pH range of 4.5–7.5, with good organic matter status, and irrigation capabilities. Alkalinity and water stagnation make soils unsuitable for growing turmeric. For maximum production, turmeric needs extensive manuring and deep soil.

Field Preparation

In Sikkim, farmers start land preparation little early (February-March) immediately after the receipt of early monsoon showers. To prepare the land for good tilth, four thorough ploughings should be made. Conveniently sized beds measuring 1 m in width and 15 cm in height are ready, with 50 cm separating each bed. Rhizomes are sown in small pits atop ridges and furrows made on irrigated ground. Typically, there are 45–60 cm between ridges and 15–20 cm between plants. To reduce the acidity of the soil, dolomite should be used at a rate of 2 t/ha and combined with the soil. In regions with heavy rainfall, appropriate drainage channels should be installed in the spaces between rows to remove standing water.

Varieties

The cultivars most suitable for Sikkim are Lakadang and Megha Turmeric-1. Lakadong variety of turmeric is mostly grown in Meghalaya and this variety is popular for high curcumin content of at least 6%. Dzongu local, Allepey, Sudharshana, Suroma, Roma and Lakadang are grown in Sikkim.

Seed rate

The seed rate varies according to the type of planting material, spacing and weight of rhizomes. Mother Rhizomes: 2,000 to 2,500 kg/ha (800 to 1,000 kg/acre). Finger Rhizomes: 1,500 to 2,000 kg/ha (600 to 800 kg/acre).

Optimal spacing

Plant rhizomes on ridges or raised beds with row-to-row spacing of 45 to 60 cm and plant-to-plant spacing of 25 to 30 cm.

Crop rotation, inter cropping and mixed cropping

In Sikkim turmeric can be grown as an intercrop in agroforestry system, it can be inter cropped with Maize in the ratio 1:1, can also be raised as a mixed crop with chillies,

colocasia, onion, brinjal and cereals like maize, ragi, *etc*. In order to control soil-borne diseases, turmeric crop should be rotated with cereals/legumes after 2-3 years. Crop rotation with legumes such as Black gram (*Pahenlo dal*) French bean and soybean is found to be highly beneficial.

Propagation

Well-developed, healthy and disease-free rhizomes are to be selected for planting. The source of seed should be selected carefully. In the beginning seed material from high yielding local varieties may be used in the absence of organically produced seeds. Thereafter, only carefully preserved healthy seed rhizomes which are collected from organically cultivated farms should be used for planting. Both mother and finger rhizomes are used. Mother rhizomes are planted as such or split into two; each having at least one sound bud whereas, the fingers are cut into 4-5 cm long pieces. 2 to 2.5 tonnes seeds are used for planting one-hectare area. Small pits are made with a hand hoe on the beds with a spacing of 25 cm x30 cm.

Seed treatment

In organic turmeric production use of chemical fungicides for rhizome treatment is strictly prohibited. *Trichoderma viride* slurry @ 5 g/kg of seed is prepared and used for treating the seed materials to control the rot disease. *Acacia* gum may be mixed with the slurry as an adhesive. Before planting, the rhizomes are soaked in the slurry for 30 minutes and then air-dried under shade. Rhizome should be stirred 3-4 times to ensure uniform soaking. Along with *Trichoderma*, rhizome can be treated with bio-fertilizers (*Azospirillum*, *Azotobacter*). Seed rhizomes are placed in shallow pits and then covered with well-decomposed cattle manure or compost mixed with *Trichoderma*.

Organic nutrient management (ONM)

Turmeric is a heavy feeder thus it needs heavy manuring, recommended dose of well decomposed farmyard manure manure (FYM) or compost @ 15-20 t/ha long with 250 kg neem cake and 150 kg/ha rock phosphate or vermicompost @ 10 t/ha through broadcasting and ploughing at the time of land preparation or as basal dressing by spreading over the beds or into the pits at the time of planting (Reza, S. K. 2014. *Pers. Communication*). For sustainable turmeric production integrated application of FYM @ 10 t/ha and vermicompost @ 5 t/ha along with 250 kg neem cake and 150 kg rock phosphate/ha is the best option. Organic manure can also be applied along with bio-fertilizers like *Azospirillum* and *Bacillus* (Phosphate Solubilizing Bacteria) for better nutrition to the crop.

Mulching

It is necessary to enhance the germination of rhizomes and prevent soil erosion during heavy rains. In Sikkim the various mulching materials are paddy straw or green leaves (*Alnus nepalensis*, *Schima wallichii*) or available weed biomass (*Artemisia vulgaris*, *Chromolaena odoratum*), among this the most preferred by farmers is leaves of *Schima wallichii* (*Chilaune*) it also adds organic matter to the soil and conserves moisture during the latter part of the cropping season. The crop has to be mulched immediately after planting with green leaves @ 12-15t/ha. Mulching may be repeated @ 7.5 t/ha at 40 and 90 days after planting after weeding, manuring and earthing up. Cow dung slurry may be poured on the bed after each mulching to enhance microbial activity and nutrient availability.

Water Management

Typically, turmeric is grown as a rain-fed crop. However, when the soil is totally dry, irrigation must be applied. In the case of an irrigated crop, 15 to 23 irrigations should be applied in clayey soils and 40 irrigations in sandy loams, depending on the weather and soil conditions. Appropriate water conservation methods (rainwater harvesting) must be used in water-scarce areas to provide protective irrigation. A water harvesting tank with an HDPE lining is useful in the dry season. For pleasant rhizome excavation, two to three days of light watering are advised during harvest.

Weed Management: Depending on the severity of the weeds, weeding should be done three times at 60, 90, and 120 days following planting. After sixty days, earthing up needs to be done. Mulching makes weeds less of an issue.

Insect and pests

1. Leaf folder (*Udaspes folus*)

It is a specific and serious pest of turmeric pest of turmeric. The larvae of the black-and-white butterfly feed inside the folds of leaves then pupate inside a thick mass of waxy material.

2. Shoot borer (*Conogethes punctiferalis*)

It is a major pest of turmeric. The adult moth has orange-yellow wings with small black spots. The larvae bore into pseudo stems and rhizomes, feeding on the growing shoots and causing yellowing and drying. Pupation occurs inside the affected pseudo stem in a thin silken cocoon. Bore holes with frass extrusion and withered shoots are characteristic symptoms of infestation.

Management of insect and pests

Collection and destruction of larvae and pupae of leaf roller mechanically can reduce infestation. Two sprays of neem formulation 1500 ppm @ 3ml/l at 15 days interval are found to be effective against shoot borer and leaf roller in turmeric.

Diseases

1. Rhizome rot (*Pythium aphanidermatum, P. graminicolum*)

Symptoms

- Leaves start drying from the margins and gradually progresses inward.
- Collar region becomes soft and water-soaked.
- Affected plants eventually collapse.
- Rhizomes undergo decay due to fungal infection.

Disease cycle: Pathogen is soil-borne, therefore primary inoculum comes from soil. Infected rhizomes used for seed purpose may also transmit the disease. Irrigation water from diseased field helps in the spread of the disease.

Management

- Avoid water stagnation in the field. Light soil may be preferred and drainage facility to be ensured.
- Seed material should be selected from disease free areas.
- Drenching the soil with copper oxychloride @ 0.3 per cent or Bordeaux mixture @ 1 per cent. Rhizomes should be dipped in Bordeaux mixture @ 1 per cent solution for 40 minutes before planting.
- Deep summer ploughing, planting is to be done in ridge and furrow method.
- resistant varieties, PCT-13 and PCT-14 should be grown.

2. Leaf blight [*Rhizoctonia solani* (*Thanatephorus cucumeris*)]

Symptoms

- The disease manifests as water-soaked spots of varying sizes and shapes on the lower leaves and blightening of leaves.
- In moist weather fungal growth appears on the under surface of the leaves on the infected portion of the leaf.
- At the end, the infected plant dies.

Management

- Crop rotation.
- Use of disease-free planting material.
- Use *Trichoderma viride* @ 4 g/l for rhizome treatment.
- Soil application of *Trichoderma viride*.

3. **Leaf spot** (*colletrichum capsica capsici*)

Symptoms:

- The disease usually appears in the field during August and September when there is high relative humidity 80% and temperatures of 21 – 23ºC favours the primary infection in the atmosphere.
- Infected leaves turn from normal green to reddishbrown due to spots covering both the su rface and the lamina.

- Severely affected leaves dry and wilt.

Management

- Select seed material from disease free areas.
- The infected and dried leaves should be collected and burnt in order to reduce the inoculum source in the field.
- Crop rotations should be followed whenever possible.
- Cultivate tolerant varieties like Suguna and Sudarshan.

Harvesting

The harvest season typically lasts from January to March, depending on the type of cultivar. After sowing, the crops attend the harvesting time by 9- 11months. Whole plants are removed without damaging the rhizomes during harvest. The rhizomes are collected by hand-picking or by carefully lifting the clumps with a spade after the soil has been ploughed. After being harvested, the rhizomes are thoroughly cleaned to get rid of any dirt or other debris that has stuck to them. Mother rhizomes are separated and used as seeds. Dry turmeric is obtained by curing green turmeric or fingers.

Yield

Turmeric yields approximately 20–25 tonnes per hectare under well-managed organic production systems.

Post harvest practices

Curing

Dry turmeric is made from fresh turmeric that has been cured. Rhizomes are boiled in fresh water during the curing process to soften them and get rid of their raw odour. After curing, the rhizomes are sun-dried. Boiling is done in earthenware, copper, or galvanized iron containers. The fingers or mother rhizomes are softened by boiling them in water. Indian Spice Institute

According to research, rhizomes should be boiled in water for 45 to 60 minutes, or until froth forms on the surface and the characteristic turmeric smell disappears. The softness of the cured rhizomes or a piercing with a blunt piece of wood can be used to determine the ideal curing stage. The color and scent of the finished product are greatly influenced by the point at which boiling is halted. Overcooking ruins the finished product's color, while undercooking makes the dried product brittle. By raising the troughs and pouring the water into the pan, the cooked turmeric is removed. After that, they are drained and sun-dried for 10 - 15 days to make them hard and dry. When the fingers are broken by hand at this point, a metallic sound is produced. After that, they are mechanically cleaned and polished in a drum that is powered or rotated by hand. Alternatively, dry turmeric powder is made by washing, cleaning, chopping, drying, and powdering the rhizomes.

Drying

Following curing, turmeric rhizomes are subjected to sun drying for 10–15 days in 5–7 cm thick layers to achieve uniform drying and desirable colour. At night, the rhizomes are heaped or covered with materials that permit adequate aeration. Mechanical drying using cross-flow hot air at temperatures not exceeding 60°C is an alternative method. Artificial drying is particularly advantageous for sliced turmeric because it minimizes surface bleaching and enhances colour retention. The dry rhizome recovery varies between 10 and 30% according to cultivar and agro-climatic conditions.

Seed Preservation

Seed rhizomes can be stored in pits containing sawdust, which are covered with wooden planks having one or two openings to ensure adequate aeration. Alternatively, seed rhizomes are commonly stored in heaps under well-ventilated sheds or tree shade and covered with turmeric leaves. The heaps are periodically plastered with a mixture of soil and cow dung to protect the rhizomes during storage.

Prospects

Turmeric holds significant scope for sustainable organic production in the mid-hills of Sikkim due to favourable agro-climatic conditions, growing demand for organic and high-

curcumin content products, and availability of local organic resources. Value addition, improved varieties, organic certification, and better processing and marketing can further enhance productivity, quality, and farmer income.

Conclusion

Turmeric (*Curcuma longa* L.) has considerable potential as a sustainable organic spice crop in the mid-hills of Sikkim due to the region's favourable agro-climatic conditions, traditional farming practices, and availability of locally sourced organic inputs. Adoption of healthy seed rhizomes, suitable varieties, organic nutrient management, mulching, crop rotation, intercropping, and eco-friendly pest and disease management can support stable crop productivity. Proper harvesting, curing, drying, and seed rhizome storage are equally important for maintaining rhizome quality and reducing post-harvest losses. With appropriate organic management, turmeric can produce approximately 20–25 t ha^{-1}, making it a promising crop for sustainable agricultural production in the region.

Fig 1: Turmeric cultivation in Mid-Hills of Sikkim

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