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Ecological distribution and commercial exploitation of *Tamarindus Indica* in Kenya: A review

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Abstract

Tamarindus indica L., commonly known as the tamarind tree, is a high-priority fruit species for crop diversification and development in Sub-Saharan Africa. Despite its nutritional, medicinal, and industrial value, limited documentation exists on its processing, utilization, and commercialization in Kenya. This knowledge gap hinders efforts to promote its domestication and conservation. This review paper examines the ecological distribution, morphological characteristics, and commercial potential of Tamarindus indica in Kenya. A desk-based literature review from books, journals, and published reports was conducted. Findings indicate that tamarind is widely utilized, especially in Kenya's coastal region, where its pulp is used to prepare Ukwanju juice and food sauces. However, inefficiencies within the tamarind value chain, including limited value addition, inadequate seedling systems, and weak market linkages, constrain its commercialization. To boost tamarind production and commercialization, coordinated efforts are needed among governments, investors, and researchers. Key priorities include policy support, private sector investment, and research on improved varieties and genetic conservation. Strengthening the value chain through better seedling systems, farmer hubs, processing, and efficient distribution is essential. Additionally, documenting indigenous knowledge will aid its domestication and sustainability.

Keywords: *Tamarindus indica L., geographical distribution, morphology, local and international market, Kenya*

1. Introduction

Tamarindus indica L., commonly known as tamarind, is a tropical evergreen tree native to the dry savannahs of Africa and Madagascar. It has since spread across the tropics and is now cultivated and naturalized in tropical Asia, the Arabian Peninsula, the Americas, the Caribbean, Australia, and various islands in the Pacific and Indian Oceans (PROSEA, 2018; POWO, 2018; USDA-ARS, 2018). The name “tamarind” originates from the Arabic *Tamar Hindi*, meaning "Indian date," while the species name *indica* was assigned by Linnaeus (Kiflie, 2024). Taxonomically, the plant belongs to the Fabaceae family, one of the largest plant families, comprising approximately 766 genera and 19,580 species distributed across diverse climates and habitats (Stevens, 2007). It is classified under the subfamily Caesalpinioideae and is recognized as a monotypic genus, meaning it contains only one species (Kidaha, 2022). The tree's widespread adaptability and economic potential make it an important species for food, medicine, and industry.

The tree grows well over a wide range of soil and climatic conditions. The tree prefers slightly acid deep alluvial, well-drained soils of loamy texture (Von Maydell, 1986). However, it also tolerates, a wide range of physical site characteristics such as high resistance to drought and aerosol salt (wind-borne salt as found in coastal areas) It grows in low-altitude savannah woodland or semi-arid areas. It also thrives along streams and riverbanks. Its extensive root system contributes to its resistance to drought and wind (Orwa et al*.,* 2009).

Globally, nearly every part of tamarind tree (pulp, seed, leaves, flowers, bark and roots) has nutritional, industrial or medicinal value. Tamarind fruit contains substantial levels of carbohydrates, proteins, vitamins, minerals and essential amino acids making it important in addressing malnutrition requirement especially in semi-arid areas. Its anti-oxidant, anti-inflammatory, anti-microbial, anti-fungal and anti-diabetic properties give tamarind wider application in conventional and traditional medicine (Chitra et al*.,* 2023).

The most valuable and widely utilized component of the tamarind tree is its fruit. The pulp is particularly rich in carbohydrates and vitamins, making it nutritionally significant (Toungos, 2019). Characterized by its mildly sweet and notably acidic flavor, the pulp is commonly used as a spice in the preparation of chutneys, sauces, soups, and various beverages. In addition to its culinary applications, it also holds medicinal value in Ayurvedic practice, where it is traditionally used to treat indigestion and gastrointestinal discomfort in India. Tamarind fruit pulp is rich in ascorbic and tartaric acids, which makes it suitable for use as a preservative in the pickling industry (Singh, 2007). In India, the pulp is also consumed raw and is often sweetened with sugar (Bhodoriya et al., 2011). In Ghana, it is mixed with sugar or honey to prepare a sweet beverage. Many tamarind-producing countries manufacture such drinks on a commercial scale, and in some cases, the pulp is fermented into an alcoholic beverage. Tamarind kernel powder (TKP) is used as cattle fodder. Other

commercial products include tamarind pulp powder (TPP) and tamarind juice concentrate (TJC), which can be stored for extended periods. In contrast, fresh tamarind juice is typically produced on a small scale (Van der Stege et al., 2011).

There are two main types of tamarind: the common sour variety and the sweet variety. The sweet tamarind, known as *Makham Waan*, originates from Thailand (Zohrameena et al., 2017), while another sweet variety, *Manila Sweet*, is managed by the United States Department of Agriculture's Subtropical Horticulture Research Unit in Miami (Naeem et al., 2017). The plant has 24 chromosomes with 2n=24 (Purseglove et al., 1987). It is cross-pollinated resulting in variation within populations (Nandini et al., 2011).

Morphology and Distribution of *Tamarindus Indica*

Tamarindus indica is morphologically different in terms of fruit; color, shape, taste, crown size and density, foliage color, trunk diameter, flower characteristics as well as seed color, weight and shape (Nandini et al., 2011). Schabel (2004) evaluated fruit taste, which ranged from sweet to acidic. Obulesi (2011) also documented light brown-reddish fruits in India while Vanden (2014) recorded sour, small and large fruits in Mali.

The tamarind tree is moderate to large in size, evergreen and grows up to 30m in height. It has a 7m girth with an exceptionally beautiful spreading crown (ICFRE, 1993; Rao et al., 1999). The crown has an irregular, vase-shaped outline of dense foliage (see Figure 1). The tamarind tree has evergreen, alternate, pinnately compound leaves consisting of 10–18 pairs of opposite leaflets. The petiole and rachis are finely haired, and the midrib and net venation are moderately visible on both leaf surfaces. As the tree matures, its branches descend from a single central trunk. Notably, the leaflets fold together at night.

Flowers are attractive pale yellow or pinkish and are produced in racemes. They are in small, lax spikes about 2.5cm in width. Flower buds are pink in color and are completely enclosed by 2 bracteoles, which fall very early. Tamarind fruit is a brown pod, indehiscent, sub-cylindrical, 10-18 ×4cm, straight or curved, velvety, rusty-brown. The shell of the pod is brittle and contains many hard-coated seeds embedded in a sticky edible pulp (Hemshekhar et al., 2011). Seeds are 3-10, approximately 1.6cm long, irregularly shaped, and the testa is hard, shiny and smooth. The seeds are contained in loculi, enveloped by a tough, leathery membrane, the so-called endocarp. Outside the endocarp is the light-brownish, red, sweetish acidic, edible pulp, traversed by a number of branched, ligneous strands. The outermost covering of the pod is fragile and easily separable. The pulp color is red-brown and sticky (Simon, 2019). The pods begin to ripen from February to April.

Figure 1: Tamarinds tree, pods and seeds

Several authors have proposed various geographical areas as the origin of the tamarind tree (Simon, 2019). The tamarind tree is considered to have originated in Madagascar (Von Maydell, 1986; Hockin, 1993; Rao & Mathew, 2012). Mishra (1997) and Sawarkar et al. (2021) placed its origin in India, given that the name tamarind comes from a Persian word 'tamar-i-hind', meaning 'date of India'. Its name 'amlika' in Sanskrit indicates its ancient presence in the country (Mishra, 1997). Tamarind is mentioned in the Indian Brahmasamhita scriptures between 1200 and 200 BC (El-Siddig et al., 2006). The fruit was well known to the ancient Egyptians and to the Greeks 400 years BC. (Hiwale, 2015). According to El-Sidding et al. (2006), tamarind originated in Africa, specifically in regions such as Sudan, Ethiopia, Kenya, and Tanzania, and spread westward across sub-Sahelian Africa to Senegal. It was later introduced to India at an early stage in history.

In Myanmar, it is reported as one of the commonest village trees in the dry zone It is now cultivated throughout semi-arid Africa and South Asia, and has been planted extensively in Bangladesh, India, Myanmar, Malaysia, Sri Lanka, Thailand and several African, Australian, Central American and South American countries (Sharma & Bhardwaj, 1997). The fruit became known in Europe during the Middle Ages. The tamarind was introduced into tropical America, Bermuda, the Bahamas and the West Indies certainly much earlier. It is thought to have been introduced to South and Southeast Asia and to have become naturalized in many areas to which it was introduced (Krishnamurthy, 2008).

Tamarind has been dispersed by men worldwide and is nowadays cultivated in all tropical countries (Van der Stage et al., 2011). In West Africa, it is produced in Benin, Nigeria, Mali and Senegal where it is utilized as fodder, food, medicine as well as spiritual and in ethno veterinary purposes (Van der Stege et al., 2011). In East Africa, tamarind trees grow in the semi-arid areas and upon maturity, the fruits are collected and utilized in homes or sold through informal channels (Omari, 2016).

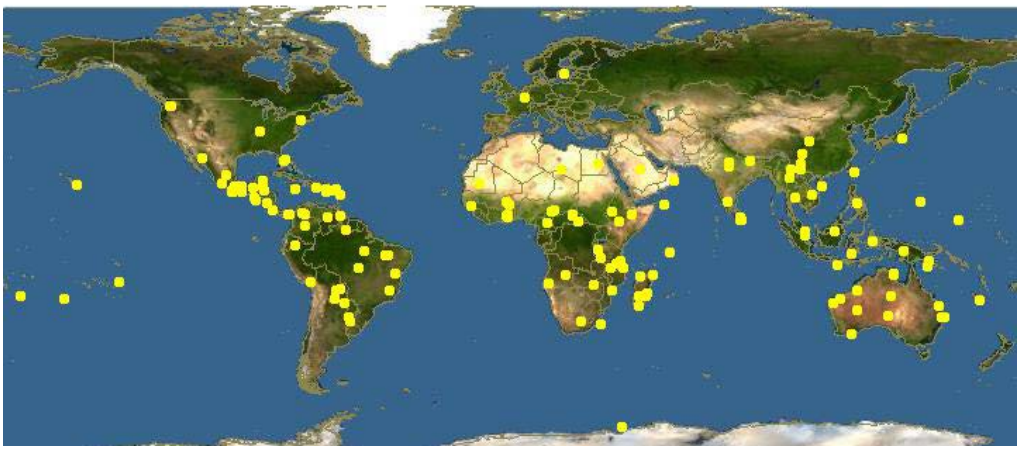

Figure 2: Global distribution of Tamarindus indica (Source: Hattaway, 2011)

In Kenya, tamarinds are mainly found in the dry areas of Kitui, Tharaka Nithi, Baringo, West Pokot, Turkana, Homa Bay, Taita Taveta, Kwale, Lamu, Makueni, Machakos, Kilifi and Embu. The fruits are collected by middlemen and sold in Mombasa where they are used locally in coastal dishes and some are exported to Asian countries (Simon, 2019). Tamarind fruits are mainly marketed through informal channels. Mombasa is the terminal market for tamarind from Kenya and Uganda, from where domestic consumers and exporters obtain their supplies.

Tamarind is known by a wide variety of vernacular names across different communities. In East Africa, these include *Mkwaju* (Swahili), *Ol-masamburai* (Masai), *Oepduran* (Turkana), *Roka* (Borana), *Chwaa* or *Waa* (Luo), *Muthithi* (Meru), and *Oran* (Pokot) (El-Siddeg et al., 2006). Other local names include *Mukai* (Boni), *Roqa* or *Groha* (Boran), *Mkwazdu* (Digo), *Muthithi* (Embu and Mbeere), *Mkwaju* or *Kwaju fruit* (Giriama), *Kithumula*, *Kikwasu*, *Nthumula fruit*, *Nzumula fruit*, or *Ngwasu fruit* (Kamba), *Lemecwhet* or *Lamaiyat* (Kipsigis), *Kumukhuwa* (Luhya/Bukusu), *Morhoqa* (Malakote), and *Aron* or *Oron* (Marakwet) (Shah, 2014). In Arabic, it is known as *Tamre-Lindi*; in French, *tamarin*; and in both Spanish and Portuguese, *tamarindo*. In English, it is simply called *tamarind* (Mishra, 1997).

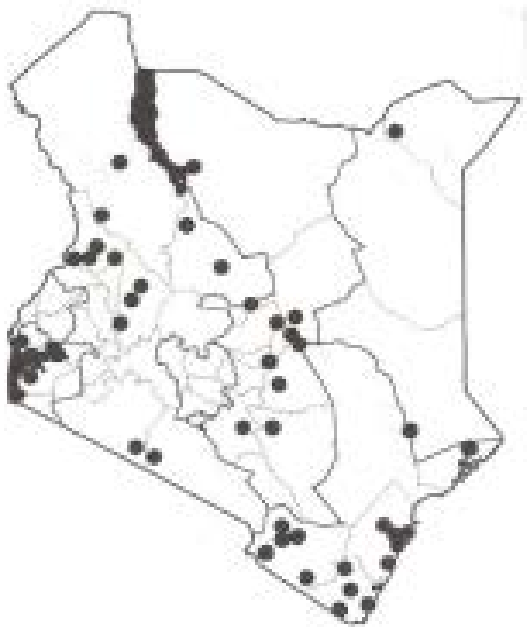

Figure 3: The Distribution of Tamarindus indica in Kenya (Source: Maundu & Tengnas, 2005)

2. Management of *Tamarindus Indica*

Tamarind trees exhibit slow growth, with seedlings increasing in height by approximately 60 cm per year. The juvenile phase lasts between four and five years or longer (El-Siddig et al., 2006). Young trees are pruned to develop 3–5 well-spaced branches, forming the main scaffold structure. The only maintenance the tree requires is pruning to remove dead or damaged wood. Generally, tamarind trees require minimal care. Sweet cultivars are often planted, and early fruiting limits excessive growth. Size control measures, including close spacing and pruning, help rejuvenate fruiting wood, while the trees also respond well to coppicing and pollarding. In India, recommended spacing for tamarind cultivation varies from 8 m × 8 m to 12 m × 12 m, with vegetatively propagated plants requiring less space than seeded trees due to their smaller size, which also facilitates easier harvesting (El-Siddig et al., 2006). Tamarind trees can remain productive for 50–60 years (Orwa et al., 2009).

Efforts have been made to develop improved tamarind varieties through grafting, focusing on the two main types: sweet and sour. In West Africa, the predominant variety is sour, but the World Agroforestry Centre (ICRAF) and national research institutes have been working to introduce the sweet variety from Thailand by grafting it onto local rootstocks. Grafted trees are reported to bear fruit within 3–4 years (ICUC, 1999), whereas tamarind seedlings typically take 10–14 years to reach fruiting maturity (Kalifa, 2010).

Figure 4: Grafting trials

Tamarind is generally resilient to pests and diseases, with few reported cases of significant infestations. However, some pests such as scale insects (*Aonidiella orientalis, Aspidiotus destructor,* and *Saisetia oleae*) and mealybugs, including lac insects and bagworms, have been reported in India (Sambhaji, 2018). In Brazil, beetle larvae damage branches, while in Florida and Hawaii, beetles attack ripe pods. Termites are a concern in China, and fruit borers can cause substantial losses by damaging maturing fruits, reducing marketable yield. In major tamarind-producing countries like India, common diseases include leaf spot, powdery mildew, sooty mold, stem disease caused by fungi, root and wood rot, stem canker, bark parasites, and bacterial leaf spot. In Kenya and other African countries, the tamarind tree is rarely affected by pests and diseases; however, its fruit is vulnerable to attacks by fruit weevils and fungal infections, particularly in humid conditions (Chitra & Parthiban, 2023).

3. Tastes Variation and Products of *Tamarindus Indica*

There are two main types of tamarind which include the sour and sweet varieties (Zohrameena et al*.,* 2017). The sour nature of tamarind can be attributed to presence of tartaric acid. It also contains reducing sugars, pectic, proteins, and fiber and cellulose materials. A sweet tamarind varieties exists in tropical and sub-tropical countries in Asia such Thailand. Sweet tamarind reportedly also grows well in semi-arid region of India characterized by mean monthly temperature ranging from 7 to 8 0^{C} in January and 40 to 42 0^{C} in May and June (Relwani et al., 1988). Tamarinds fruits are harvested when the pod is brittle and brown. The flavor of the tamarind fruit ranges from sweet and sour to tangy and tart. The flavour depends on how ripe the fruit is. The more it ripens, the sweeter it gets. Similar to tart citrus fruit, the flavour depends also on what the fruit is mixed with. Coconut milk and sugar are used to reduce the sour taste while vinegar enhances the tartness.

According to Orwa et al*.* (2009), the fruit pulp, mixed with a little salt, is a favourite ingredient of the curries and chutneys popular throughout India. Most of the tamarind

imported into Europe today comes from the West Indies, where sugar is added as a preservative. When freshly prepared, the pulp is a light brown colour but darkens with time. It consists of 8-14% tartaric acid and potassium bitartrate, and 30-40% sugar. Acidity is caused by the tartaric acid, which on ripening does not disappear, but is matched more or less by increasing sugar levels.

The ripe fruit of the sweet type is usually eaten fresh, whereas the fruits of sour types are made into juice, jam, syrup and candy. Fruit is marketed worldwide in sauces, syrups and processed foods. The juice is an ingredient of Worcestershire Sauce and has a high content of vitamin B (thiamine and niacin) as well as a small amount of carotene and vitamin C. The flowers, leaves and seeds can be eaten and are prepared in a variety of dishes. Tamarind seeds are also edible after soaking in water and boiling to remove the seed coat. Flour from the seed may be made into cake and bread. Roasted seeds are claimed to be superior to groundnuts in flavour.

Tamarind wood is valued for its durability and strength, with sapwood that is light yellow and heartwood that is dark purplish-brown. It is dense (specific gravity 0.8–0.9 g/cm^3), takes a fine polish, and is used in carpentry, sugar mills, wheels, hubs, agricultural tools, mortars, boat planks, toys, panels, and furniture. In North America, it is traded as *"madeira mahogany"* (Singh et al., 2021). The wood also serves as a reliable fuel source, producing high-quality charcoal for cooking, while its ash and bark contain high concentrations of tannins.

Both tamarind leaves and bark are rich in tannins, which can be used in ink production and dye fixing. The leaves yield a red dye that imparts a yellow tint to indigo-dyed fabrics, while wood ash is traditionally used for removing hair from animal hides. Although tamarind foliage has high forage value, it is rarely used for this purpose, as lopping can reduce fruit yield. In southern India, cooked tamarind seeds are regularly fed to draught animals (Singh et al., 2021).

Tamarind is a traditional food plant in Africa and parts of Asia, with the potential to enhance nutrition, improve food security, promote rural development, and support sustainable land management (Saikia et al., 2024). In Kenya, tamarind trees provide firewood, charcoal, timber, poles, and posts, and their wood is crafted into furniture, utensils (such as pestles and mortars), and boats. The fruit pulp is consumed directly and used for souring porridge, making juices, frying seeds, and seasoning food. Various parts of the tree, including leaves, twigs, bark, and roots, serve medicinal and fodder purposes. Tamarind flowers support honey production, while the tree itself enriches the soil by fixing nitrogen, making it an excellent choice for agroforestry (Muga, 2009).

5. Early Trade, International and Domestic Markets of *Tamarindus Indica*

Tamarind fruits have been widely traded since ancient times. Historical records from the eastern Mediterranean indicate that the tree was already under cultivation by the fourth century B.C. (Morton, 1987). It is believed that tamarind was introduced to India and Southern Asia through human transportation several thousand years B.C. and has been cultivated there for so long that it is sometimes mistakenly considered indigenous. From India, tamarind is thought to have spread to Persia and Arabia (Morton, 1987; Rivers & Mark, 2017; PROSEA, 2018).

From the Indian subcontinent, tamarind likely spread eastward into the rest of tropical and subtropical Asia and the Pacific islands. In Hawaii, one of the earliest recorded tamarind trees was planted in 1797 (Morton, 1987). During the early 16th century, Spanish and Portuguese colonists introduced tamarind to Mexico, South America, and the Caribbean. Today, it is commonly cultivated as a shade and fruit tree along roadsides, in yards, and in parks throughout tropical America. Commercial plantations also exist in Mexico, several Central American countries, and Brazil (Morton, 1987; FAO, 2010). In Australia, it was once considered native due to its presence before European settlement. However, it is now believed that Macassan traders introduced the species to northern Australia in the early 18th century (Weeds of Australia, 2018).

The International Market

Tamarind is marketed locally, regionally and internationally. Its market value varies depending on location, variety, quality, processing and demand. Products sold in local markets are usually in the form of fresh fruits, pulp, juice, sauce and paste. Products in international markets include pulp, juice, jam, paste and TKP. Among Asian countries, India and Thailand are the leading tamarind producers followed by Indonesia, Sri Lanka, Bangladesh and Thailand. Apart from that, Mexico and Costa Rica are the prime producers of Tamarind in America. Although in Africa tamarind has wide uses locally, no commercial productions have been reported so far. Minor producers in Africa are Zambia, Kenya, Senegal, Tanzania and Gambia (Van der Stege et al., 2011).

India is the only country in the world to produce Tamarind as fruit crop commercially and recorded a yield of 188,278 tonnes of tamarinds in the year 2007-2008 and 193,873 tonnes in the year 2008–2009 (Rao & Mathew, 2012). About 5.5 million tonnes of Tamarind fruit have been marketed widely within India and about 70,000 tonnes have been exported annually.

The importing countries are mainly Pakistan (3968 tonnes/Rs. 1.71 million/US$ 37,158) followed by UAE (1524 tonnes/Rs 1.95 million/US$ 43,388), Japan (1222 tonnes/Rs.1.23

million/US$ 27,368) and Yemen. The other importing countries include Germany, France, Malaysia, United Kingdom, Italy and Bangladesh.

Cuyvers et al., (2013) noted that, after India, Thailand holds the second position as a leading Tamarind producer with a record of 140 thousand tonnes production margin. Production and export of tamarind from other Asian countries take place at much lesser scale as compared to Thailand and India. Out of the total world production of Tamarind, sour variety is most widespread comprising 95%.

The Domestic Market

Tamarind is a delicacy in the producing countries and is used for various culinary purposes. The ripe pods are processed in households and sold in the village fairs. Intermediaries collect the products from farmers and sell them to retailers or processors. The collectors receive low prices, hence most fruits are not harvested and become wasted. Production in these countries satisfies demand at the village level, but there is increasing demand in towns and cities. Establishment of small-scale plantations would be more attractive to both collectors and buyers (Lakor et al., 2016).

In Indonesia, Philippines and Thailand, in South Asia, and some African and Central American countries provide major markets for Tamarind products such as juice, chutney, sauce, paste, fresh fruits and pulp. In the Philippines, fresh fruits are harvested, placed in baskets or kaings or tied into bundles and sold in rural and urban markets by volume or weight (Wattanadumrong & Liampreecha, 2023).

In India, processed Tamarind products are sold in rural markets and in supermarkets in cities. The major products sold locally are Tamarind pulp powder, paste, chutney and fresh pulp. Similarly, processed products are popular in Sri Lanka, fresh pulp wrapped in polythene bags. Tamarind chutney is also available in Sri Lankan supermarkets and Tamarind-lime pickle is a recently introduced product to the Sri Lankan market by the Marketing Department. In Australia, fresh fruits are packed in 15 kg cartons and sold through wholesalers and Asian groceries. The wholesale price per kilogram is about 3-5 Australian dollars (US$ 3.13) per carton. The demand is mostly from Asian communities that use the fruit as a spice and sweetmeat (Chinnadurai et al., 2028).

Sambhaji (2018) studied the marketing mechanisms of minor forest products (MFPs) in the Raipur district, Madha Pradesh, India. They found that 80 % of the villagers were engaged in the collection of minor forest products (MFPs), including Tamarind, and earned their livelihood by consuming and marketing these products. Tamarind is traded almost entirely through informal channels in Kenya. Kidaha et al., (2017) indicated that mostly tamarinds are transport by roads to Mombasa for export which is costly. In Mombasa, Tamarind fruits

are also exported to the Middle East, Italy, India, Thailand, Philippines, Somalia and Tanzania from where value-added products such as flavours, sauce, spice, flour, sweet chutney, kernel oils are made. However, official Statistics on trade volumes are scanty. There is no data on the annual export from Tamarind though Kenya has been exporting since 1980s or earlier. Horticultural Crops Development Authority (HCDA) in Kenya do not collect tamarind export information, unlike many other exported commodities. In Kenya Tamarind is exported for approximately 9 months of the year. However, official Statistics on trade volumes are scanty. Lack of information is a bottleneck along the tamarind marketing chain. Traders often find it difficult to identify exporters, especially those without coastal networks. This highlights the need for both vertical and horizontal linkages among actors to facilitate information sharing—particularly regarding quantity, quality, and price.

In order to minimise the exploitation of local populations that grow the tree, Singh et al. (2021) suggest incorporating tamarind cultivation in agroforestry systems. Village-level marketing institutions can establish their small-scale collection centres in the villages. Public, private, and cooperative units may then be established near the forest-dominated pockets. Policy and intervention will not only reduce export of raw MFPs to other states, but will also provide an opportunity to develop a network of processing units at a local level for manufacturing finished products. This will increase state revenue and per capita income of the forest dweller cooperative societies. The capital earned by the cooperative societies may be ploughed back into the area to build up social capital infrastructures. believe that in the long run MFPs may emerge as an organised sector and remove forest dwellers from the exploitative market. However, to strengthen the local markets, it will be necessary to establish the size of the market, target consumers, and the type of products in demand. Therefore, efforts to find potential markets for Tamarind products will be useful in exploiting its potential.

6. Empirical review of studies on *Tamarindus Indica* in Kenya

Studies on tamarind in East Africa indicate that both planted and wild populations exist in roughly equal proportions. However, Uganda and Kenya have a higher prevalence of planted trees compared to Tanzania. This distribution is largely influenced by product demand, management constraints, and competing land-use priorities. Wild tamarind trees face significant threats from deforestation for charcoal production, timber harvesting, and agricultural expansion (Nyadoi et al., 2009). Studies note that on-farm conservation of tamarind trees is crucial for maintaining representative and sustainable biodiversity in East African landscapes. Achieving this conservation goal requires active involvement from farmers, who are essential stakeholders in biodiversity preservation. Effective implementation of biodiversity conservation policies across different habitats necessitates the commitment of both the government and local farmers to tree conservation efforts.

Wanjala (2018) conducted a study involving traders and extension officers in Kenya's coastal counties, including Mombasa, Taita Taveta, Kwale, and Kilifi. The findings indicate that tamarind trees predominantly grow in wild woodlands across dry regions such as Kitui, Tharaka Nithi, Baringo, West Pokot, Turkana, Homa Bay, Taita Taveta, Kwale, and Lamu. The fruit is harvested from various locations in Kenya as well as from Eastern and Northern Uganda, where it is then sold in local markets and specialty supermarkets. Kongowea Market in Mombasa is identified as the largest hub for tamarind trade in Kenya. The study also highlights the challenge of aggregating trade volumes due to the scattered nature of tamarind sources. To enhance the tamarind value chain, the establishment of aggregation centers in production hubs is recommended.

Kidara (2022) examined tamarind production in semi-arid Eastern Kenya and found that it is not cultivated as a primary crop but rather intercropped with legumes and cereals. Tamarind trees occupy a small fraction of total farmland, and management practices such as fertilizer application, pruning, and controlled propagation are rarely implemented, leading to lower yields. Additionally, tamarind is not considered a staple food but is primarily used as an ingredient in juices and sauces and becomes an essential food source only during periods of food scarcity. The study also identifies key constraints to tamarind production, including infestation by weevils and inadequate marketing channels, which hinder its commercialization and widespread cultivation.

Organized production has not been documented in Kenya. Kenya Agricultural and Livestock Research Organization (KALRO) established nurseries for seedlings production at its centres in Muguga, Katumani, Matuga, Kakamega, Alupe, Perkerra and Kibos. These nurseries are one of potential source of planting materials by farmers in the country. Tamarind has not yet been prioritized as a farm crop in Kenya neither has it being documented in the Ministry of Agriculture reports. Given the increasing global prominence of Tamarind as an export tree crop, the production stage of the value chain should move from the wild to on-farm cultivation and strengthened through promoting farm production of both the sweet and sour tamarind varieties.

Both individual and institutional farms, namely Agricultural Training Centres (ATCs), Kenya Forestry Service, Kenya Forestry Research Institute, Prisons and schools could be used as production hubs. These farms should also be linked to the necessary support services, namely, access to an efficient tamarind seed/seedling supply system, good agricultural practices (GAPS), post-harvest handling and value addition technologies, financing, and most importantly, farm certification. Productivity and commercialization of tamarind for domestic and export markets could further be augmented through national and county government policy frameworks, development assistance programs, private sector investment and researchable issues such as early maturing varieties, genetic conservation and desirable

market traits. These interventions will be useful in protecting the tamarind tree from the threat of extinction due to human activities such as charcoal burning and timber common in semi-arid ecosystems (Wanjala, 2019).

Tamarind is among the top three prioritized fruits for future crop diversification in Sub-Saharan Africa (Leakey et al., 2021). It is also ranked among the top 100 of over 60,000 tree species prioritized for planting, utilization, and research in tropical and subtropical regions (Kindt et al., 2021). Despite its immense potential, limited research exists on the sweet and sour tamarind provenances, cultivation practices, value addition, commercialization, genetic diversity, and antimicrobial properties in Kenya (Chikamai et al., 2004).

In Kenya's coastal region, tamarind pulp is commonly used to prepare *ukwaju* juice and food sauces, which are popular among local communities. However, traditional extraction methods remain labor-intensive and unhygienic (Adeola & Aworth, 2010). Beyond juice production, tamarind is also used to make local brew, jam, and other products, often packaged in unsterilized polyethylene bottles. Recent research by Khongkow et al. (2024) highlights the potential of tamarind seed jellose, a byproduct of the food industry, as a natural cosmetic ingredient due to its antioxidant properties and ability to inhibit melanin synthesis.

7. Conclusion and Recommendations

Despite its economic and nutritional value, the tamarind value chain in Kenya faces inefficiencies that hinder its full commercialization. Scaling up productivity and ensuring its sustainability require a coordinated effort among national and county governments, the private sector, and research institutions. Developing an efficient value chain will involve establishing organized seed systems, farmer-based production hubs, aggregation centers, and processing units to enhance commercialization. Research and development efforts should focus on improving genetic diversity, increasing fruit yield and quality, and advancing agronomic practices. A comprehensive market analysis is necessary to assess both domestic and international demand, thereby informing targeted production and product diversification.

Moreover, tamarind plays a significant role in supporting rural livelihoods through income generation, food security, and environmental conservation. Further research is needed to explore its bioactive constituents and potential pharmacological applications, particularly its antimicrobial and nutraceutical properties. Developing suitable agroforestry models will promote sustainable cultivation while enhancing soil fertility and biodiversity. In addition, post-harvest handling and value addition technologies should be improved to ensure high-quality tamarind-based products that meet market standards. To safeguard its long-term

availability, conservation efforts should focus on germplasm preservation through efficient seed banks and biotechnological advancements for propagation.

A comprehensive approach that integrates research, commercialization, and conservation will maximize tamarind's economic and nutritional benefits while ensuring its sustainable use. Future studies should prioritize mapping tamarind varieties across different ecological zones in Kenya, improving agronomic practices, and strengthening value chain linkages to enhance productivity and market competitiveness.

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