Chapter

1

INTRODUCTION



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1.1. History of Tea

The history of tea dates back to approximately 2737 BC, during the era of Shen Nong in China. Shen Nong, a legendary figure in Chinese culture, is often credited with discovering the medicinal properties of various plants, including the *Camellia sinensis* (L.) Kuntze, from which tea is derived. Tea was initially consumed for its medicinal benefits and later gained popularity as a beverage. The earliest documented account of tea preparation and manufacturing techniques can be found in the book "Cha Ching", authored by Lo-Yu (Sinha, 2010). This text provides valuable insights into the early practices and culture of tea consumption in China.

The introduction of tea to India is a significant milestone in the global history of tea. In Assam, near Rangpur (now Sibsagar), Major Robert Bruce and his brother C.A. Bruce discovered tea plants during 1823. This discovery laid the foundation of the tea industry in India. In 1834, Lord William Bentinck, the Governor General of India, recognized the potential of tea cultivation in India. He established a Tea Committee that supported the cultivation of wild tea bushes in the hilly slops in Assam. This marked a pivotal moment in the history of Indian tea production. Dr. Campbell played a crucial role in initiating the cultivation of tea in the Darjeeling district of West Bengal in 1839. The unique terroir of the Darjeeling region contributed to the distinct flavour profile of Darjeeling tea. This endeavor paved the way for the growth of the tea industry in the region. Tea cultivation continued to expand in India, along with the terai and duars regions of West Bengal becoming significant tea-producing areas in 1862 and 1874,

respectively. The sub-Himalayan areas of West Bengal are now home to numerous tea gardens, contributing to India's reputation as a major tea-producing nation (Sarkar et al., 2016d).

1.2. Taxonomy and Systematic Position of Tea

The genus *Camellia* L., which encompasses a diverse group of 230 species, is a prominent member of the family Theaceae Mirb. Notably, within this genus, there exists a remarkable and significant plant of great economic and cultural importance, *Camellia sinensis* (L.) Kuntze. Regardless of the wide-ranging individual species-specific distinctions within the *Camellia* genus, all cultivated tea species belong to the taxonomic designation of *Camellia sinensis* (Sealy, 1958).

The tea plant is renowned for its extensive and multifaceted diversity, encompassing morphological, biochemical, and physiological variations. This variation can be attributed to factors such as geographic origin, environmental conditions, and human selection over time. Researchers Kitamura and Sealy have made significant contributions in understanding the intraspecific diversity within *Camellia sinensis*.

Presently four accepted infraspecific taxa of *Camellia sinensis* are recognized. The first is the China variety, officially known as *Camellia sinensis* var. *sinensis* which is originating from China, is notable for its unique characteristics and contributions to the world of tea production. The China variety is often associated with the production of some of the world's finest green tea, including Longjing and Dragon Well.

The second infraspecific form is the Assam variety, designated as *Camellia sinensis var. assamica* (Royle ex Hook.) Steenis. This variety, hailing from the Assam region in India, has its own distinctive features and has been instrumental in the production of black tea, which are widely consumed and appreciated globally. Two more infraspecific

taxa are *Camellia sinensis* var. *pubilimba* Hung T. Chang and *Camellia sinensis* var. *dehungensis* (Hung T. Chang, H. S. Wang & B. H. Chen) T. L. Ming was described from China (POWO, 2024).

Four infraspecific forms of *Camellia sinensis*, the China and Assam varieties, showcase the intricate diversity within the species and underline how different subtypes of this remarkable plant have contributed to the world's rich tapestry of tea varieties and flavors.

However, the categorization of tea plants into the erect small-leafed China variety and the horizontal broad-leafed Assam variety was somewhat arbitrary. This classification system posed challenges as some tea plants displayed intermediate leaf characteristics, making it difficult to unequivocally assign them to either of these varieties.

1.3. Morphology and Physiology of Tea

Evergreen shrubs or trees belonging to the *Camellia* genus are classified as C3 plants, characterized by several distinctive botanical features. These plants possess simple, alternate leaves with serrated margins. The flowers are bisexual and exhibit regular symmetry. Typically, both sepals and petals are found in sets of five, and the plants have numerous stamens with anthers that contain two cells. The ovary is situated superiorly and is usually 2-4 locular, although it can be solitary in some cases, and the arrangement is axile. The fruits of these plants are in the form of capsules, and their seeds have the unique property of being recalcitrant, meaning they lose viability when exposed to drying conditions. The diploid chromosome number for these plants is 2n=30 (Kabir and Das, 2015).

In the case of cultivated tea plants (*Camellia sinensis*), they are known to be cross-pollinated and self-incompatible. The extent of selfing, or self-pollination, varies within

a range of 6% to 40%, depending on the specific tea type. It's noteworthy that these attributes are most pronounced in the China type and least pronounced in the Assam type of tea plants. This variation in selfing tendencies among different tea varieties is crucial to the breeding and cultivation of tea, as it can significantly impact the quality and vigor of the resulting plants.

One important consideration in tea cultivation is the risk of breeding depression. This phenomenon occurs when self-pollination or inbreeding leads to a decrease in the overall fitness and quality of the tea plants. High levels of breeding depression can result in a loss of vigor and reduced tea quality, which is undesirable for tea production. Therefore, it is crucial to avoid relying on self-pollinated seeds to propagate tea plants, as this can exacerbate the issues associated with breeding depression (Kabir and Das, 2015).

The maintenance foliage on a tea bush, those permanent leaves found below the plucking table, plays a crucial role in sustaining the productivity of the tea plant. These leaves are essential for photosynthesis, which is the process through which plants produce energy from sunlight. However, it's important to note that a leaf doesn't achieve its maximum photosynthetic efficiency until it expands to more than half of its maximum size (Mondal et al., 2014).

Young tea shoots, which are the growth points of the tea plant, rely on the maintenance foliage for photosynthesis. The maintenance foliage acts as the primary source of energy for these shoots, enabling them to grow and produce new leaves. Therefore, having an adequate amount of maintenance foliage is essential for achieving high and sustainable tea productivity (Mondal et al., 2014).

The life span of a tea leaf on a tipped primary shoot is approximately ten months. It remains at its peak of photosynthesis for up to six months after full expansion, after

which it begins to age, and its efficiency gradually declines (Mondal et al., 2014). This suggests that younger leaves are more efficient at photosynthesis, which is vital for the growth and productivity of the tea plant.

The top ten centimeters of the maintenance foliage on a 20-centimeter-tipped primary shoot after pruning are responsible for contributing about 70% of the tea crop (Mondal et al., 2014). This highlights the significance of maintaining a healthy and abundant maintenance foliage layer for optimal tea production.

Temperature plays a critical role in tea photosynthesis. The ideal temperature range for maximum photosynthesis in tea plants is between 25 and 30 degrees Celsius. However, photosynthetic efficiency declines rapidly above 37 degrees Celsius, and no net photosynthesis is observed at or above 42 degrees Celsius (Mondal et al., 2014). Conversely, the lowest temperature at which photosynthesis occurs is around 10-12 degrees Celsius. In regions with temperatures exceeding this range, providing appropriate shade is necessary to ensure higher productivity, especially in North East India (Yadava et al., 2014).

In the context of tea plucking, it's ideal to harvest either "2 leaves + Bud" or "3 leaves + Bud" as these stages provide the best quality tea leaves for processing. These stages are characterized by young and efficient leaves that are rich in flavor and aroma (Mondal et al., 2014).

The bidirectional flow of photosynthate in tea plants in North East India begins in mid-October, indicating the start of the growth phase. The next bidirectional flow occurs in May. This pattern influences the tea flush period, which averages around 31 days, and the entire growth cycle, which spans approximately 57 days. This information is essential for planning and managing tea cultivation, as it suggests that four flushes can be obtained per year, contributing to a higher overall yield (Mondal et al., 2014).

1.4. Global Production of Tea

Tea production is predominantly concentrated in the continent of Asia, with countries such as China, India, and Sri Lanka serving as major players in the global tea industry. Additionally, several African nations, particularly those situated in tropical regions, also make substantial contributions to the world's tea output. Key African tea-producing countries include Kenya, Malawi, Rwanda, Tanzania, and Uganda. While these nations are at the forefront of global tea production, there are also other regions and countries making notable contributions to the industry.

In South America, countries like Argentina, Brazil, and Peru engage in tea cultivation, albeit on a smaller scale compared to their Asian and African counterparts. The Middle East, represented by countries such as Iran and Turkey, also plays a role in tea production. Furthermore, the Commonwealth of Independent States (CIS), comprising nations like Russia and Georgia, contributes to the global tea supply (Barua, 2008; Basu Majumder et al., 2010).

Beyond these regions, numerous other countries produce tea to varying degrees. These include Bangladesh, Nepal, Taiwan, Indonesia, Vietnam, Thailand, Mozambique, Ecuador, South Africa, Mauritius, Congo, Cameroon, Papua New Guinea, Australia, and New Zealand (Figure 1.1). These countries may not be the largest producers, but they collectively add to the diverse tapestry of global tea cultivation (Sinha, 2010).

In terms of scale, approximately 3.94 million hectares of land worldwide are dedicated to tea cultivation, yielding an impressive annual production of around 4,162 million kilograms of processed tea.

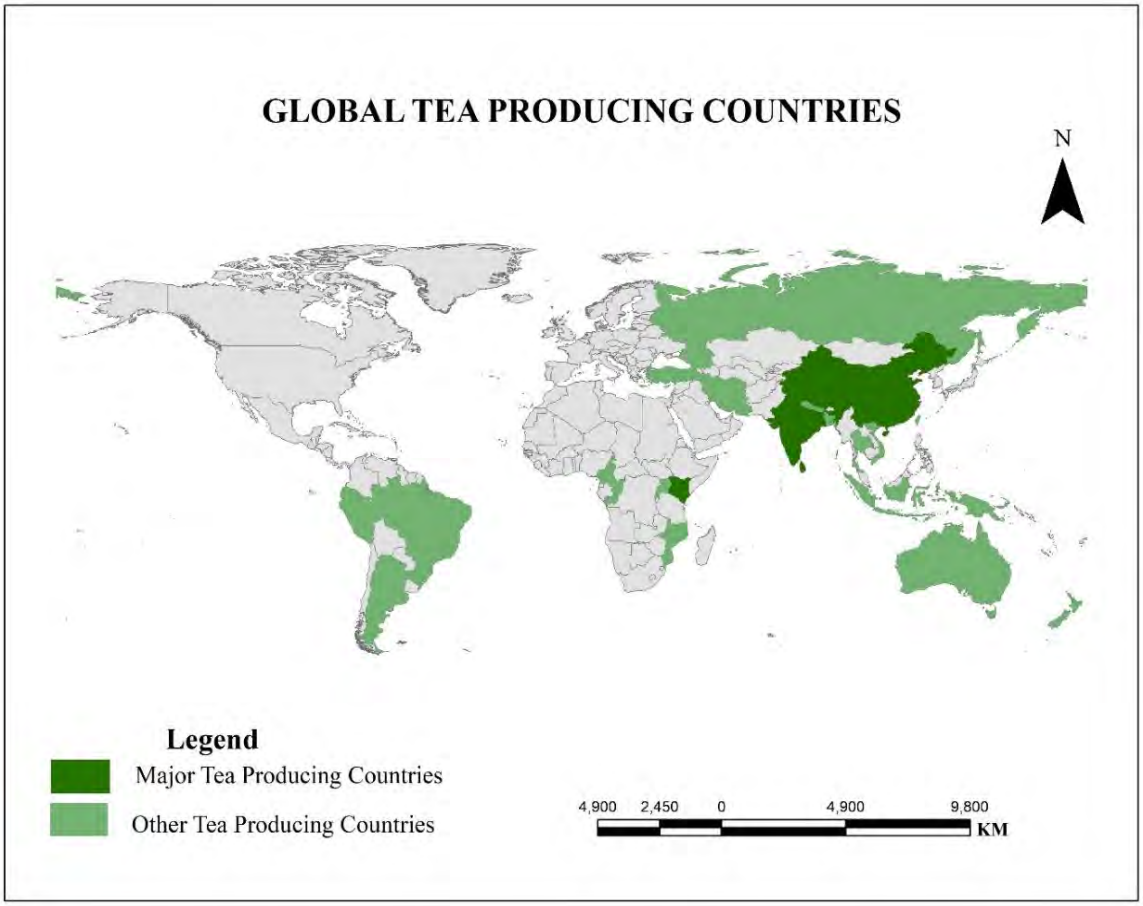


Figure 1.1 Global tea producing countries (Map generated from the obtained information from Barua, 2008; Sinha, 2010).

1.5. Tea Production in India

The tea industry in India holds a prominent and deeply rooted presence, playing a vital role in the country's economy, culture, and daily life. As the second-largest producer and the largest consumer of tea globally, India contributes significantly to the international tea market, with renowned varieties like Assam, Darjeeling, and Nilgiri being prized worldwide for their unique flavors and high quality. The industry is not only a major source of export revenue but also provides livelihoods to millions, particularly in the northeastern and southern regions, where vast tea plantations dominate the landscape. India has a total of 619,773.70 hectares of land under tea

cultivation, with West Bengal contributing 138,691.37 hectares to this total. This means that West Bengal accounts for approximately 22.38% of the nation's tea-growing area, showcasing the state's significant role in India's tea industry. West Bengal, particularly known for its renowned tea-producing regions like Darjeeling hills, Terai and Dooars, contributes to both domestic consumption and international exports. The state is renowned for its premium tea varieties, particularly Darjeeling tea, which is famous worldwide for its distinct flavor and aroma. The expansive tea estates in West Bengal not only drive the state's economy but also play a crucial role in India's position as one of the largest tea producers globally. Interestingly, a substantial 80 percent of the tea produced in India is consumed domestically, reflecting the country's strong affinity for this popular beverage (Basu Majumder et al., 2010).

In recent years, the economic transaction amount of Indian tea in the international market has seen fluctuations due to varying factors such as demand shifts, climate impacts, and market competition. India exports tea to over 100 countries, with major markets including Russia, the United States, Iran, and the United Kingdom. The country generates substantial revenue, with export earnings in the range of USD 700-800 million annually. Indian teas, particularly Assam, Darjeeling, and Nilgiri varieties, command premium prices in the global market, contributing to the country's foreign exchange earnings and supporting millions of livelihoods within the tea industry. However, global competition from countries like Kenya and Sri Lanka, along with evolving consumer preferences, continues to influence the dynamics of India's tea trade.

The Indian tea industry primarily focuses on the production of three main types of tea: Crush, Tear, and Curl (CTC) tea, Green tea, and Orthodox tea. These varieties cater to diverse tastes and preferences. In certain regions of India, particularly in areas with

tribal communities, limited quantities of oolong tea, a traditional variety, are also produced (Sarkar et al., 2016d). However, it is important to note that CTC tea holds a dominant position in the Indian market, being both produced and consumed in large quantities.

In the year 2016, India produced a staggering 1,239,150 metric tons of made tea, of which approximately 216,790 metric tons were exported to various parts of the world. The majority of these exports consist of Orthodox and Green tea (Majumdar, 2020).

The history of tea cultivation in India dates back to 1823, marking the introduction of this industry in the country. Since then, the Indian tea industry has made substantial contributions to socio-economic development (Hazarika and Borah, 2013). It has played a pivotal role in generating employment, promoting economic growth, and bolstering the livelihoods of numerous individuals.

In India, tea plantations span across 16 states, but the predominant tea production is concentrated in four key states: Assam, West Bengal, Tamil Nadu, and Kerala. Assam leads the pack with the highest production, accounting for about 52% of India's total tea output. West Bengal follows, contributing around 25% of the nation's tea. Tamil Nadu, with its major tea estates in the Nilgiri hills, adds approximately 10% to the total production. Kerala, known for its tea gardens in the Wayanad and Munnar regions, contributes about 8%. Collectively, these states produce a staggering 95% of India's total tea, underscoring their critical role in the country's tea industry (Hazarika and Borah, 2013). These regions are renowned for their favorable climatic conditions and topography, which are highly conducive to tea cultivation (Figure 1.2).

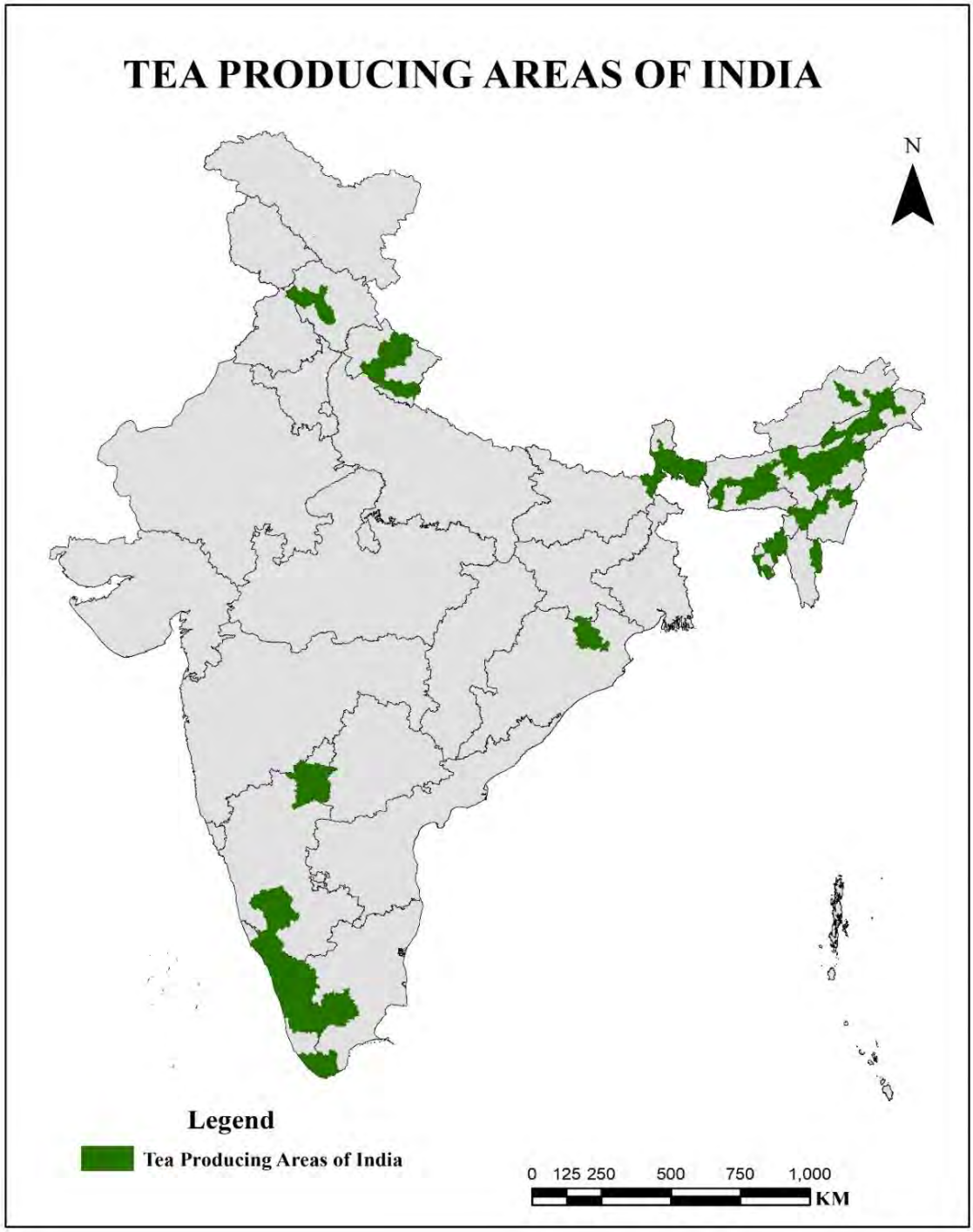


Figure 1.2 Tea producing areas of India (Map generated from the obtained information from Basu Majumder et al., 2010; Hazarika and Borah, 2013).

Furthermore, the Indian tea industry encompasses two distinct types of plantations: large plantations and small plantations. Small Tea Growers (STGs) are defined as

individuals or groups that manage plantations covering up to 10.12 hectares, as per the norms set by the Tea Board of India (Chowdhury et al, 2016b). This categorization reflects the diversity of tea cultivation practices within the country, ranging from large, organized plantations to smaller, more independent growers.

1.5.1. Crush Tear and Curl (CTC) Tea

Tea is a time-honored and globally cherished beverage, with an extensive history that spans centuries. Among the various types of tea, CTC (Crush, Tear, Curl) tea holds a prominent place in the world of tea consumption. India, as the largest producer of CTC tea, plays a significant role in the global tea industry. To truly appreciate CTC tea, it is essential to understand its distinctive processing techniques and its historical evolution.

The process of manufacturing CTC tea involves several unique steps that contribute to its distinct flavor and appearance. One of the key steps is aeration, which entails withering the tea leaves for an extended duration. This process results in the oxidation of flavonoids in the tea leaves and imparts a characteristic dark color to the leaves.

The inception of CTC tea manufacturing is credited to Sir William McKercher, who served as the Superintendent of the Amgoorie Tea Estate in 1930. His groundbreaking invention of the CTC machine marked a turning point in tea production, enabling the large-scale production of CTC tea. The 1950s saw the increasing recognition and adoption of CTC tea manufacturing techniques in the tea industry.

In contemporary times, the majority of tea produced in West Bengal, India, belongs to the CTC category, underlining its continued relevance and popularity. The CTC tea manufacturing process is distinctive in its approach, involving the disruption of the cellular integrity of tea shoots, as outlined by Sinha (2010). This disruption facilitates the mixing of various substrates, polyphenols, and enzymes, notably polyphenol

oxidase. These interactions initiate a cascade of biochemical and chemical reactions, leading to the uptake of atmospheric oxygen and the formation of pigmented, hot water-soluble polyphenolic compounds characteristic of CTC or Black tea, as described by Singh (2005).

1.5.2. Green Tea

Green tea stands as one of the most beloved and widely consumed types of tea, particularly when compared to its counterparts. It earns this distinction by virtue of its unique characteristics and rich history. Green tea is categorized as unfermented or unoxidized tea, and it is meticulously manufactured to prevent the oxidation of green leaf polyphenols. This process sets it apart from other teas, contributing to its distinctive flavor and health benefits.

The origins of green tea can be traced back to China, where it first emerged for medicinal purposes. This remarkable beverage has an impressive historical lineage, with its recorded use dating back an astounding 4,000 years. Over time, it evolved from being a specialized medicinal brew to a daily staple in the lives of people, leading to the cultivation and refined processing techniques we know today.

The Japanese tea industry made its debut in the production of green tea in 1191. This marked a significant milestone in the spread of green tea beyond China. Nowadays, green tea is enjoyed worldwide, with China boasting a diverse array of green tea varieties, each with its own unique flavor profile and characteristics.

Green tea is not limited to China and Japan; several other countries have joined the ranks of green tea producers. India, Indonesia, Korea, Nepal, Sri Lanka, Taiwan, and Vietnam have also contributed to the global green tea supply. Each of these regions

offers its own distinct take on green tea, influenced by the local climate, soil, and traditions.

In terms of its composition, green tea is a treasure trove of compounds that contribute to its flavor and health benefits. Polyphenols, amino acids, Theaflavin (TF), Flavanols, Catechins, caffeine, and volatile flavor components are just some of the constituents commonly found in green tea (Sanyal, 2011). These compounds not only provide its distinctive taste but also offer various health advantages, making green tea a popular choice among health-conscious individuals.

1.5.3. Orthodox Tea

Orthodox tea, a highly esteemed and widely consumed variety, stands out for its exceptional production methods and distinctive flavor profile. This type of tea is crafted using machinery that closely mimics the hand-rolling process, resulting in a unique and artisanal quality that sets it apart from other teas. Unlike the more common CTC (Crush, Tear, Curl) method used in mass production, orthodox teas are made by rolling whole tea leaves, which further contributes to their exceptional characteristics.

The production of orthodox tea adheres to traditional techniques, and this dedication to quality is why it is highly regarded by tea connoisseurs. While orthodox tea is produced in various tea-growing regions, it is most famously associated with the picturesque Darjeeling hills in India, where the climatic conditions and elevation provide the perfect environment for cultivating this exquisite tea. Darjeeling orthodox tea is often referred to as the "Champagne of Teas" due to its unparalleled quality, unique flavor, and the care that goes into its cultivation and processing. The distinct notes of muscatel and floral undertones make it a sought-after choice for tea enthusiasts around the world.

Aside from Darjeeling, orthodox tea production is also prominent in other parts of India, including Assam and South India. These regions produce orthodox teas with their own characteristic flavors and profiles, adding to the diversity of options available to tea lovers.

The distinctive taste of orthodox tea is a result of the meticulous plucking, withering, rolling, oxidation, and firing processes that it undergoes during production. This attention to detail and traditional craftsmanship is what gives orthodox tea its unique and rich flavor.

In a world where many teas are produced on an industrial scale, orthodox tea stands as a testament to the enduring artistry and craftsmanship of tea production. It continues to be cherished by those who appreciate the nuanced and sophisticated flavors that can only be found in teas produced through these time-honored methods.

Orthodox tea, a beloved and widely consumed variety, stands out for its unique production process and distinctive flavor profiles. Orthodox teas are meticulously crafted, with a method that closely replicates the hand-rolling technique. This dedication to traditional production methods results in a tea that is prized for its exceptional taste.

The heartland of orthodox tea production is the picturesque Darjeeling region nestled in the Indian Himalayas. Renowned for its lush tea gardens and breathtaking scenery, Darjeeling is celebrated for its exquisite orthodox teas. The term "orthodox" in the context of tea production refers to the meticulous, time-honored methods used to craft these teas. This process involves hand-picking the tea leaves, withered and rolled with precision, followed by oxidation and firing. The focus on preserving the integrity of the tea leaves' shape and flavor is central to the orthodox method, which distinguishes it from more modern, mechanized production techniques.

The result of this labor-intensive process is tea leaves that retain their natural character and nuances, offering a delightful range of flavors and aromas. Orthodox teas are often characterized by their floral notes, subtle astringency, and a depth of flavor that captures the essence of the tea leaves. Connoisseurs and tea aficionados particularly appreciate the nuanced and layered taste that orthodox teas provide, making them highly sought after in the world of tea.

Although Darjeeling is the primary region associated with orthodox tea production, other parts of India also contribute to this tradition. Assam and South India, known for their significant tea cultivation, produce orthodox teas as well, albeit in smaller quantities compared to Darjeeling. These regions also employ traditional methods and a focus on preserving the integrity of the tea leaves, contributing to the diversity of India's orthodox tea offerings (Sarkar et al., 2016d).

1.6. Tea Production in West Bengal

In the state of West Bengal, India, tea cultivation is predominantly concentrated in the Himalayan hills, Terai, and Duars regions, encompassing areas such as Darjeeling, Kalimpong, Jalpaiguri, Alipurduar, Cooch Behar, and some parts of Uttar Dinajpur district. Among these, Darjeeling stands out as a globally renowned tea-producing region, celebrated for its distinctive flavor and captivating aroma. Darjeeling specializes in the production of Orthodox tea and a smaller quantity of Green tea. The Terai and Duars regions, located at the foothills of the Himalayas, along with the lower foothills of Uttar Dinajpur district, boast an abundance of both large and small-sized tea gardens situated along the banks of rivers Tista, Torsha, and Mahananda (Chowdhury et al, 2016b; Sarkar et al., 2016d).

The tea industry in North Bengal comprises around 400 big industrial tea gardens (BGs) and a substantial number of small tea growers (STGs). These two categories

contribute roughly 52% and 48%, respectively, to the total tea production in North Bengal, with a predominant focus on CTC (crush, tear, and curl) teas. Over the recent years, more than 85% of teas produced in West Bengal fall into this category. The vast expanse of tea plantations in West Bengal spans over 140 thousand hectares and yielded approximately 329.70 million kilograms of made tea in the 2015-2016 period (Sarkae et al., 2022).

The cultivation of tea holds a pivotal role in the economy of North Bengal, making it one of the noblest professions in this region. The favorable climatic conditions in the area have led to a strong dependence of rural ethnic groups on tea gardens for their livelihoods. Notably, tribal women are the primary workforce, often employed as tea leaf puckers (Sarkar et al, 2016c). As a significant cash crop, tea plays a vital role in the region's economy, resulting in the gradual replacement of other crop fields with tea gardens, primarily due to its higher profit potential. Commercial tea cultivation has gained substantial popularity among farmers, significantly altering the agricultural landscape.

Unfortunately, in recent times, a significant number of tea growers in North Bengal have faced severe economic challenges due to a drastic drop in the prices of green tea leaves, which plummeted to as low as Rs. 10 to 12 per kilogram, compared to the normal market average value of Rs. 15 to 16 per kilogram (Tea Board India). This market fluctuation has posed significant challenges to the livelihoods of those involved in the tea industry, emphasizing the need for support and sustainable practices in the region's tea sector.

1.7. Tea Variety and Clones in West Bengal

In the tea gardens of North Bengal, a wide variety of tea clones are cultivated, each with its own unique characteristics and qualities. These clones are carefully selected to

suit the specific conditions and requirements of the region. These clones are primarily classified into three categories: China Variety (*Camellia sinensis var. sinensis*), Assam Variety (*Camellia sinensis var. assamica* (Royle ex Hook.) Steenis and sometimes Cambord Variety (*Camellia sinensis var. assamica* (Royle ex Hook.) Steenis. The choice of clones is essential for ensuring optimal tea production in the Darjeeling hills, Terai, Duars, and lower foothills of the Himalayas.

In the Darjeeling hills, a number of noteworthy tea clones are cultivated, primarily belonging to the China Variety (*Camellia sinensis*). Some of the notable clones in this region include BT-15/1, BT-15/263, RR-17/144, RR-4/5, B-157, B-668, B-777, T-78, T-135, T-145, T-246, T-253, T-383, P-312, P-1258, P-1404, TV-14, TV-19, CP-1, HV-36, HV-39, AV-2, K-1/1, MB-6, TTV-1, TA-17, TS-378, TS-379, Thurbo-3, Thurbo-9, Balasun-7/1A/76, Balasun-9/3/76, Nanda Devi st. - 378, and Sundaram-13/5/63 (Singh, 1989; Dasgupta et al., 2013).

In contrast, in the Terai, Duars, and lower foothills of the Himalayas, predominantly the Assam variety is observed, with occasional cultivation of the Cambord variety. The major planting materials in these regions are the TV Clones, which include TV-1, TV-9, TV-17, TV-20, TV-22, TV-23, TV-24, TV-25, TV-26, TV-27, TV-28, TV-29, and TV-30. Additionally, some local garden clones such as Huldibari-19, Leesh River-9/14, Mohargung & Gulma-25, Sanyasithan-8, Sanyasithan-9, Sanyasithan-10, Sanyasithan-27, Sukna-7, Sukna-23, Sukna-25, Bormajan-2, Bormajan-5, Heeleakah-22/14, Teenali-17/1/54, Panitola-126, Kamalpur-6, and Kamalpur-17 are also planted.

Biclonal seeds like TS-491, TS-462, TS-464, TS-506, TS-520 and TS-589 are utilized as planting material in the tea gardens of these regions. Specifically, clones such as TV-9, TV-20, TV-22, TV-23, TV-25, TV-26, TV-29, TV-30, Teenali-17/1/54, TS-491, TS-

462, TS-464, TS-506, and TS-520 are commonly used for infilling and inter-planting within the gardens (Konwar and Das, 2002).

1.8. Tea Waste

Tea production generates a significant amount of by-products, commonly referred to as Factory Tea Waste (CTC-FTW). These by-products primarily consist of discarded tea leaves, buds, and tender stems from the tea plants. It's important to note that the generation of CTC-FTW is more prevalent in the production of Crush, Tear, and Curl (CTC) tea, while Orthodox and Green tea manufacturing processes tend to produce minimal waste, as they involve more delicate handling of tea leaves.

The proper disposal of tea waste is essential due to its potential to cause environmental pollution, affecting soil, water, and air quality (Mugambi, 2006). The Tea Board of India has established guidelines and regulations for managing tea waste, emphasizing the need to minimize waste production and suggest that there should be a minimum volume of tea waste in relation to the quantity of made tea, typically ranging from 2 to 4 percent (Tea Board India, 1959).

Unfortunately, many tea factories do not adhere to these regulations and continue to inadequately dispose of tea waste. In an effort to regulate the handling of tea waste, the Tea Board India, as far back as 1959, stipulated that before tea waste is exported, sold, or stocked, it must be denatured. Denaturation involves mixing the tea waste with specified substances such as urea (not less than five percent), cow dung, slack lime, or other denaturants as specified by the Tea Board India (Tea Board India, 1959).

Besides the waste generated in tea factories, there is also a considerable amount of waste generated in tea shops and by domestic tea consumers, commonly known as Domestic Tea Waste (CTC-DTW). The management of CTC-DTW also plays a vital

role in minimizing the environmental impact of the tea industry. Proper disposal methods and recycling or repurposing of CTC-DTW could contribute to reducing the overall environmental footprint of the tea industry (Figure 1.3).

Tea waste, a byproduct of tea production and consumption, has proven to be a valuable resource with a wide range of applications. Researchers have explored various uses for tea waste, spanning from agriculture to environmental remediation and even the extraction of valuable compounds.

In Assam, India, tea waste has been utilized as an economical source of poultry and piggery feed, as observed by Chutia et al. in 1983. Furthermore, both factory and domestic tea waste have been employed to enrich the nutrient content of soil when producing compost, as reported by Pettinelli and Hirsch.

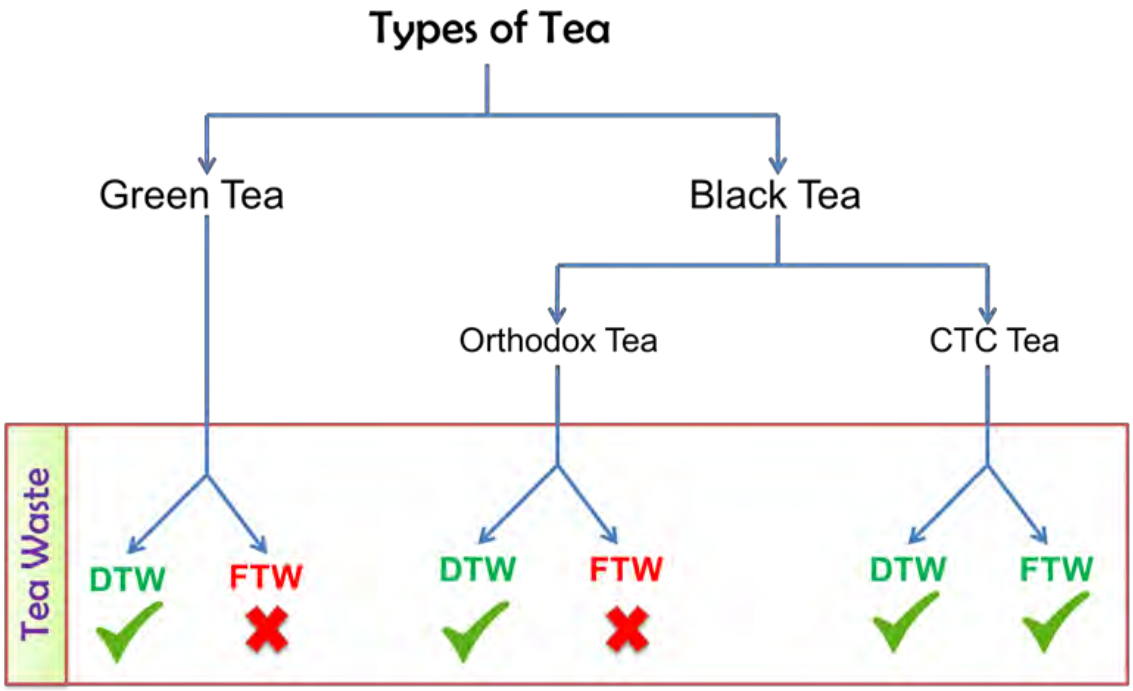


Figure 1.3 Types of tea waste.

Chinese scientists, as per the findings of Yang et al. in 2016, have established that tea waste is a cost-effective substrate for cultivating Oyster Mushrooms. In Egypt, Elekhtyar et al. (2017) demonstrated that compost made from domestic tea waste,

combined with chemical fertilizer, outperforms conventional NPK fertilizer in hybrid Rice cultivation. Similarly, Liguori et al. in 2015 found that domestic tea waste compost enhances the quality of watermelon cultivation. In Japan, researchers discovered that compost comprising domestic green tea waste and rice bran can effectively replace chemical fertilizers in spinach cultivation (Khan et al., 2007).

Tea waste has also shown promise as a nutrient source for various crops. Hargreaves et al. (2009) observed its positive effects on strawberries, while Radin and Warman (2011), Morales-Corts et al. (2018), and Kim et al. (2015) found that it benefits tomato, ryegrass, lettuce, soybean, and sweet corn cultivation. In Nigeria, Tizhe et al. (2015) developed trimethylol urea compost from tea waste fiber, further expanding its utility.

The high C:N ratio of tea waste has led to innovative applications. Sau et al. (2013) demonstrated that it can be used for biogas production by adding human urine as a catalyst. Additionally, tea waste has potential as a biomass fuel, replacing fossil fuels like coal and natural gas through pyrolysis and gasification techniques, as explored by Nagaraja et al. (2013).

Furthermore, researchers have delved into the production of activated carbon from tea waste. Yagmur et al. (2008) introduced a method for producing activated carbon from both factory and domestic tea waste using microwave energy. This activated carbon has found use in removing chlorinated phenols from aqueous solutions (Joseph et al., 2017) and adsorbing compounds like acetaminophen (Dutta et al., 2015).

Tea bag waste containing tea waste has also been repurposed as an absorbent for the removal of chromium, with activated carbon derived from this waste. Additionally, the extraction of caffeine is another valuable application in the tea industry, as described by Konwar in 1988. Factory CTC tea waste has even been used to produce instant tea, marketed as tea bags (Chowdhury et al., 2016c).

1.9. Significance of the work

This current research is to delve into the various forms of waste generated as byproducts in tea processing industries, in addition to examining the domestic tea waste. The study specifically focuses on the northern region of West Bengal, a prominent tea-producing area in India. In this region, the study assesses the quality and quantity of waste produced by tea factories and explores potential methods for their efficient management and disposal.

Notably, the study underscores that very few companies or societies are involved in purchasing factory tea waste, and their impact on the overall management of tea waste in the region remains quite limited. Furthermore, the research highlights a significant gap in the West Bengal tea industry, where no companies are dedicated to addressing this issue. While a handful of companies in Assam deal with factory tea waste, the study points out that this only addresses a portion of the problem.

The study underscores the potential economic value of tea waste as an alternative source of income for both tea growers and factory owners. Given the substantial quantity of tea waste generated in the region, there is a pressing need to manage it effectively to mitigate potential environmental hazards and promote sustainable practices.

Finally, the research identifies a critical gap in the form of a lack of comprehensive and standardized guidelines for tea waste management in the study area. This deficiency underscores the importance of developing clear and uniform procedures for the proper disposal and utilization of tea waste to safeguard the environment and promote economic opportunities for tea industry stakeholders in the region.

1.10. Objectives

The objectives for the study include was the following aspects:

1. Survey, data collection and determination of the average annual tea waste production.
2. Chemical Characterization of CTC tea waste.
3. Establishment of CTC tea waste as an organic manure for the production of vegetable crops.
4. Establishment of CTC tea waste as supplementary or alternative or nutrient food materials for carp fishes.