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REVIEW ARTICLE

Flavor in a Tea Glass to Present from Past: Safely Organic Production and Health Effects of Tea

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ABSTRACT

Tea (*Camellia sinensis* (L.) O. Kuntze) is the second most-consumed non-alcoholic beverage in the world after water. The health-beneficial properties of tea, known to contain more than 4000 bioactive substances, of which about one-third consist of polyphenols, are increasingly well understood. The medicinal properties of the tea plant have been proven by laboratory and clinical studies to have an anti-cancer effect, benefits for dental health, protect against Alzheimer with anti-paralytic, anti-diabetic, and antiparkinson properties, and its use against skin diseases. However, it is known that the tea plant, which requires plenty of fertilizer, can cause excessive pollution of the groundwater when chemical fertilizers are washed away with precipitation in the areas where it is grown. In order to eliminate this negative situation, studies regarding organic and microbial fertilizers that are more environmentally friendly and do not harm the soil and human health that could be substituted for chemical fertilizers as much as possible or mitigate their use and enable to grow products of adequate amount and quality should be accelerated. The aim of this review is to bring together scientific information about the characteristics and health effects of tea and organic tea cultivation.

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The Origin and History of Tea

The beverage known as tea, *Camellia sinensis* (L.) O. Kuntze, can be described as the infusion of the leaves of one of the varieties of an evergreen shrub that has been variously processed. The plant is a member of the *Camellia* genus of the Parietales order of the Theaceae family and grows in warm climates and areas rich in precipitation (Namita et al., 2012). Tea is known as the second most consumed beverage in the world among non-alcoholic beverages after water (Singh et al., 2011; Hayat et al., 2015). Many studies have demonstrated that green and black teas have numerous pharmaceutical properties, including antihypertensive (Henry & Stephens-Larson, 1984), antioxidant (Ding et al., 1992; Zhu et al., 1999; Leung et al., 2001), antiarteriolemic (Hertog et al., 1993): anticarcinogenic (Shi et al., 1994; Wang et al., 2009), and hypocholesterolemic (Imai & Nakachi, 1985; Kono et al., 1992; Yang et al., 2001). Tea is a rich source of flavonoids and other polyphenols, like grapes, apples, and cocoa. However, the flavonoid content can be affected by different processing modes. The degree of oxidation affects the polyphenol profile of tea (Zhu et al., 2002). Three specific types of tea, namely green, oolong, and black tea, are obtained from freshly harvested tea leaves depending on the fermentation process. Green tea is dried and heated to avoid enzymatic oxidation. Oolong tea is semi-fermented to allow moderate enzymatic oxidation and then dried. Black tea is enzymatically fully oxidized (Mahmood et al., 2010).

According to botanical classification (Barua, 1965), there are three varieties of tea grown in South-East Asia which are specific to the geographical regions of China, Assam, and Indo-

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China. The first two are believed to be *C. sinensis* L., and the third is considered to be *C. assamica* Masters. The third one, known as the 'Southern' (or Cambod) form, is considered a subspecies of the Assam type. “Chinese species” are characterized as small-leaved cold-resistant shrubs, while “Assam species” are tall trees with large leaves and are less resistant to cold (Sealy, 1958). The "Cambod type" (Kingdom-Ward, 1950; Roberts et al., 1958) is considered to be of medium height between the Chinese and Assam types. In general, all teas are classified under the name *C. sinensis* (L.) O. Kuntze, regardless of taxonomic variation (Sealy, 1937; 1958; Barua, 1965; Visser, 1969).

The homeland of the tea plant is considered to be a fan-shaped region between the hills of Nagaland, Manipur, and Lushai with the Assam-Burmese border in the west, China in the east, and the hills of Burma and Thailand in the south extending into Vietnam. The name tea comes from the Chinese word ‘ça’. Tea is called “cha” by the Japanese, ‘shaye’ by Arabs, while Russians call it ‘chay’. The word was transposed into Turkish from Chinese as ‘çay’, ‘the well-known leaf that is boiled and drunk’ (Alikılıç, 2016). ‘Red Emperor’ Shen Nung, one of the three legendary emperors of Chinese medicine, estimated to have lived about 5000 years ago who holds an important place in Chinese history and mythology claims to have discovered tea for the first time in 2737 BC when some tea leaves accidentally fell into boiling water. The aroma and flavor of the mixture of different colors generated by tea leaves falling into boiling water were appreciated and spread first throughout China and then to the whole world (Üstün & Demirci, 2013).

The first mention of tea in Europe took place in 1559, and 1606 is the year that tea was introduced to Europe. After 1635, the Netherlands and France were known as the pioneers of tea consumption in Europe. The first teapot samples from China reached Europe in the 1650s. The name that brought tea to America was Peter Stuyvesant. The Dutch colonies, which settled in New Amsterdam, now known as New York, were known as the first theics in the history of America. In the 1800s, the tea industry gradually began to emerge in Europe and America. Thomas Lipton's first shop opened in 1871 in Glasgow, England. In 1890, Thomas Lipton bought his first tea plantation in Ceylon. Richard Blechynden, who struggled to sell tea in hot weather in the United States, came up with the idea of offering cold tea. The American concept of Ice Tea was born with this coincidence. Tea bags were discovered in 1908 (Anonymous, 2015).

Tea Production

According to the 2017 FAO statistics, China has the highest tea area and production in the world. China, which has 35.30% of the world’s total tea area, counters 28.84% of the world’s total tea production (Table 1). 78% of the consumed tea is black tea, 20% is green tea, and 2% is oolong tea (Singh et al., 2015). As shown in Table 1, India has ranked second in the country’s ranking with the highest tea area and production in the world. Turkey has a tea production area of 82000 ha and an amount of dry tea production of 234 000 tons.

Table 1. World tea production area and amount of dry tea production (Anonymous, 2019)

Countries	Area (1000 ha)	Production (1000 tons)
China	2224	2473
India	622	1325
Sri Lanka	234	350
Kenya	219	440
Indonesia	114	139
Vietnamese	123	260
Turkey	82	234
Total of Other Countries	2682	3354
Grand total	**6300**	**8575**

The Aroma of Black Tea and the Chemical Composition of Tea Leaves

Although one-third of the tea plant consists of polyphenols, it is known to contain more than 4000 bioactive components (Tariq et al., 2010). Polyphenols, mostly composed of flavonoids, are a large group of plant chemicals containing catechins, and polyphenols have traditionally been considered responsible for the health benefits of tea and especially green tea (Sumpio et al., 2006). Green tea is richer in catechins than black tea. Oolong tea has a mixture of catechins and complex polyphenols. Green tea, black tea, and oolong tea are extremely good sources of vitamin C (Mukhtar & Ahmad, 2000; Wu & Yu, 2006).

Although there is a similarity between the chemical composition of black tea and green tea, chemical changes (fermentation and processing conditions) that occur in the production process lead to some differences between black and green tea and oolong and white tea. The polyphenols of green and black tea are shown in Figure 1.

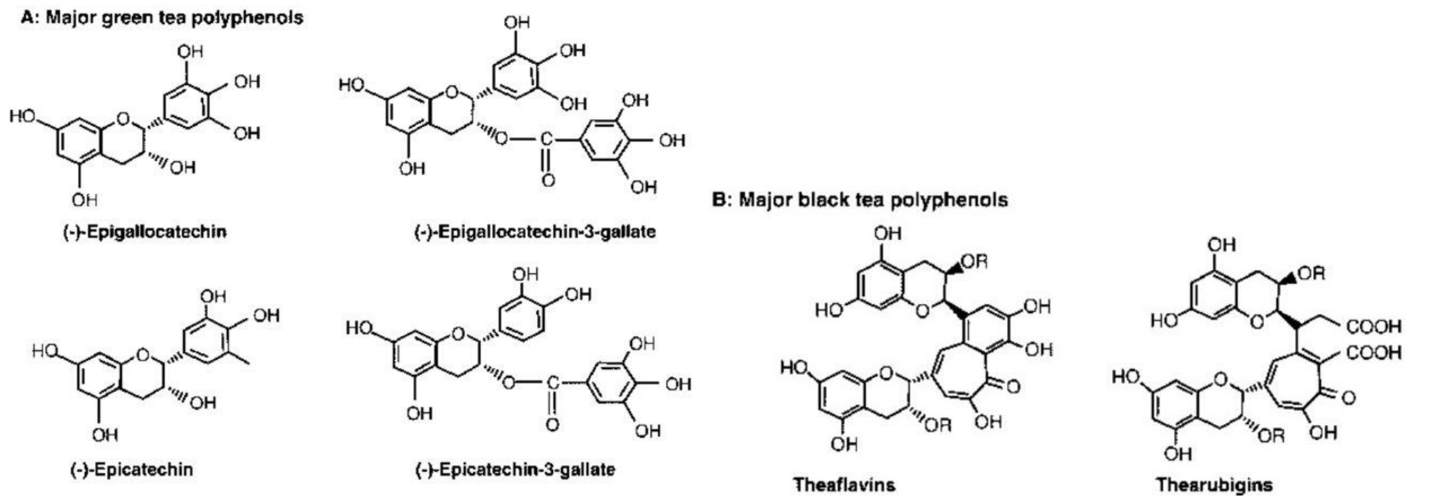

Figure 1. Polyphenols in tea (*Camellia sinensis*). A: The major polyphenol in green tea. B: The major polyphenol in black tea (Anesini et al., 2008).

Carbonyls, which are effective in the aroma of black tea, make up more than 50% of the total aroma and are the compounds with the greatest contribution to sensory properties. Volatile acids make up 10-30% of total black tea volatiles. They are natural or formed in a secondary way (Renner & Melcher, 1978). Some of the phenolic compounds in black tea are formed as natural biosynthesis products. However, some phenolic volatiles, especially phenolic acid derivatives, occur in the drying process (Schreier, 1988). Alcohols are present in small amounts in fresh leaves. Quantitatively significant amounts occur in different processes in black tea production (Hatanaka & Harada, 1972). **Furans** are found in heat-treated foods. The main products of this class of compounds in black tea are furfural, 5-methyl furfural, and furfuryl alcohol (Çalıkoğlu & Bayrak, 2006). There are trace amounts of aromatic and aliphatic hydrocarbons in the tea. Aromatic hydrocarbons are formed by the thermal decomposition of carotenoids (Kawashima & Yamanishi, 1973). The thermal decomposition of amino acids, pyrolysis of amadori compounds, and the reaction of amino acids with carbonyls form pyridine. Pyrazines are components with low sensing thresholds that occur in the heat treatment process of foods (Suyama & Adachi, 1980; Çalıkoğlu & Bayrak, 2006). **Esters** cannot reach the sensing threshold due to low concentration; therefore, they can not directly participate in the aroma (Schreier, 1988). Polyphenols, on the other hand, are considered to be the most biologically active group of tea components with antioxidative, antimutagenic, and anticarcinogenic effects (Yao et al., 2004). Polyphenols and their oxidized derivatives (mainly theaflavins and thearubigins) are important chemical components responsible for the color formation and the aroma of black tea during infusion (Venkatesan & Ganapathy, 2004). The catechins of the flavan-3-ol type constituting 25-30% of the dry weight of tea leaves are the main flavonoid compounds of tea, which are beneficial to human health and have a high antioxidant capacity (Higdon & Frei, 2003). High catechin ratios intensify the tea content, increase the bitter taste and thus affect the sensory quality of the tea. Nutrients have a significant effect on the production of catechins (Chen et al., 2011; Ruan et al., 2013; Li et al., 2016). For example, nitrogen forms (NH_4 or NO_3) affect not only growth but also catechin and flavonoid composition in tea plants (Fallovo et al., 2011; Kovacik & Klejdus, 2014). Furthermore, tea contains other compounds that are beneficial to human health, such as fluoride, caffeine, and essential minerals (Cabrera et al., 2003). Total free amino acid concentrations in tea range from 1-5% and are highly influenced by many factors, including variety, climatic conditions, soil properties, and fertilization. The most common amino acids found in tea are theanine (Thea), glutamine (Gln), glutamic acid (Glu), and arginine (Arg), and theanine accounts for 70% of the total free amino acid in tea (Wang & Ruan, 2009; Ruan et al., 2011). Theanine has many beneficial properties, such as preventing certain cancers and cardiovascular diseases, promoting weight loss, and strengthening the immune system (Vuong et al., 2011). The chemical structure of tea leaves is given in Table 2.

Table 2. Chemical composition of tea leaves (Tosun & Karadeniz, 2005)

Component	Dry matter (%)	Component	Dry matter (%)
Flavanols (Catechins)	17-30	Polyphenolic acid and Deposits	5
Epicatechin (EC)	1-3	Total polyphenols	30-36
Epicatechallate (ECG)	3-6	Caffeine	3-4
Epigallocatechin (EGC)	3-6	Amino acid and protein	15-19
Epigallocatechin gallate (EGCG)	9-13	Simple Carbohydrate	4
Catechin	1-2	Polysaccharides	13
Gallocatechin (GC)	3-4	Ash	5
Flavanols and flavanol glycosides	3-4	Cellulose	7
Lignin	6	Lipid	2-3
Organic Acid	0.5-1.5	Pigment	0.5
Anthocyanins	2-3	-	-

Tea Culture

Tea is a beverage that is consumed almost all over the world. Different consumption patterns have developed in different cultures. Some of these consumption models are as follows. In the USA, tea is consumed as hot and cold in large amounts, especially in southern states; tea is either brewed with cold water or left to cool after brewing with hot water. The British preferred to sweeten their strong tea with milk and sugar, thus reducing the astringency in taste, and the concept of '5 o'clock tea' was conceived by the British. In Europe, where black tea is generally preferred, tea is brewed in a short time, mostly in the form of glass sachets, and herbal, fruit, and aromatic teas are also great favorites in this region. In Turkey, black tea is generally brewed in double-layered kettles (in the samovar fashion): it is strong and consumed mostly with sugar in small, slender waisted glasses, and it is available throughout the day. In North Africa, mostly green tea is preferred; tea prepared with milk and lots of sugar can be served in glass cups and consumed at any time of the day. Green tea is also preferred in Japan; it has an important place in the culture of the country and is served with a ritual from its preparation to drinking and is consumed with a light and soft consistency. Tea is very important in China, where green tea and other regional teas are in high demand. In China, tea is brewed in cups with lids and consumed with these cups. In Tibet, tea is brewed with milk or water for quite a long time and is prepared and drunk after churning in wooden churns with butter. In India, local teas with a strong aroma are prepared and drunk with plenty of sugar, milk, and cinnamon (Anonymous, 2015).

Tea for Health

Anti-Cancer Effect

It has been reported that catechins which are available in abundance in green tea, inhibit tumor cell proliferation and also promote the destruction of leukemia cells (Smith & Dou, 2001). In a study conducted in China, it was found that consumption of green tea was effective in the struggle against gastric cancer, which is the second most common cancer type and chronic gastritis (Setiawan et al., 2001). A study was carried out in Japan with 8552 subjects to investigate whether green tea is an effective anti-carcinogen (Nakachi et al., 2000). According to the results of this study, a relative risk of cancer was reduced for those who consumed more than ten glasses of green tea per day compared to those who consumed less than three glasses. The results of a study conducted on 69 thousand women aged 40-70 showed that consumption of green tea helps protect against colorectal cancer (Chung et al., 2003).

Anti-Alzheimer Effect

Although there is no epidemiological evidence in human studies of the benefit of green tea for Alzheimer's disease, many studies in animal and cell culture models have shown that catechins from green tea can have an impact on the progression of Alzheimer's disease. Catechins provide protection against beta-amyloid-induced neurotoxicity in hippocampal neurons due to their antioxidant properties. Epidemiological studies of the prevalence of Parkinson's disease and the consumption of green tea have shown that it is encountered 5-10% less in Asian populations (Zhang & Roman, 1993; Pan & Le, 2003).

Anti-Stroke Effect

As a result of an 11-year study conducted on 40,530 Japanese people aged 40-79 years without a history of cardiovascular disease, an association was demonstrated between green tea consumption and low stroke risk (Kuriyama et al., 2006). Another study showed that there was an inverse relationship between strokes and the consumption of 5 cups of green tea per day and that those who drink less green tea are at least twice as likely to die from stroke or cerebral hemorrhage (Sato et al., 1989). Another study found that people who consume 3 or more cups of green or black tea are 21% less likely to have a stroke (Arab et al., 2009).

Anti-Parkinson Effect

Some studies based on animal models have shown that catechins in green tea significantly inhibit Parkinson-causing pathologies (Levites et al., 2001). Catechins have been reported to inhibit iron, and alpha-synuclein accumulation in MPTP-treated mice. These effects have been associated with antioxidant activity and the iron-binding properties of catechins (Mandel et al., 2004).

Anti-Diabetic Effect

Green tea has an anti-diabetic effect. In a study carried out with mice, the glucose levels in the bloodstream of diabetic mice were reduced without affecting insulin levels (Tsuneki et al., 2004). When administered to fructose-fed rats, it was determined that green tea extract also prevented the development of insulin resistance, hyperglycemia, and other metabolic defects (Wu et al., 2004).

Tea for Dental Health

Green tea extract is effective in preventing tooth decay. Polyphenols have an antiplaque activity. Sesquiterpene hydrocarbons (delta cadenen and caryophyllene) show a synergistic effect of 128 to 256 times when combined with indole (Duke, 2000); tea leaves have been reported to be rich in fluoride, known to improve dental health and prevent tooth decay (Onisi et al., 1981): and catechins in tea suppress the growth of bacteria that induce 10 types of tooth decay (Sakanaka et al., 1989). In a human study, it was shown that washing the mouth with 0.05 to 0.5% green tea polyphenols for 3 days after meals prevents tooth plaque formation by 30 to 43% (Sakanaka, 1997).

Tea for Skin Care

In laboratory studies using animal experiments, it has been shown that green tea extract taken orally or applied to the skin inhibits the formation of skin tumors caused by chemical carcinogens or ultraviolet radiation. Many cosmetic and pharmaceutical companies support their skincare products with green tea extracts (Katiyar & Elmets, 2001).

Tea Plant Characteristics and Growing Requirements

The tea plant has a strong taproot and sequential hairy roots, which begin to form after the third year. The taproots go very deep, while the hairy roots are located near the surface of the soil. The ramification feature is high, and there are many gemma buds in the trunk and branches. The first shoots are green, starting from the lower parts with the onset of lignification; the annual shoots darken and become brown. The shoots are made of wood buds located in the axil part of the ripe leaves. The shoots in the upper part of the branches are superior to the shoots in the lower part, but after the offshoots in the upper part are harvested, the superiority passes to the developing bud in the lower part (Figure 2). The leaves of a growing tea offshoot are different in shapes and named differently from each other. Growing tea offshoots are named as follows: Bud (floveri-piko), first leaf (oranj - piko), second leaf (piko), third-fourth leaf (sukong), fifth-sixth leaf (kon) (Anonymous, 2013a) (Figure 2 (b)). The flower buds of the tea plant are seen with two or three eyes at the end of the short stem on the leaf axils. The stem of these buds grows, and flamboyant white flowers appear. There are 5 calicles and 5 petals in the tea flower; the flowers are in a whorled array with a combination of male and female organs. After pollination, the petals are shed, and small fruits form at the end of the flower stem. These fruits start to swell in the first days of autumn and then reach their normal size; they are bright green in color, three-eyed and thick-shelled, and contain 3 seeds. When the seeds ripen, the fruit peel opens, and the seeds spontaneously emerge. The seeds contain 20-30% oil, and this oil contains saponin (Anonymous, 2013a).

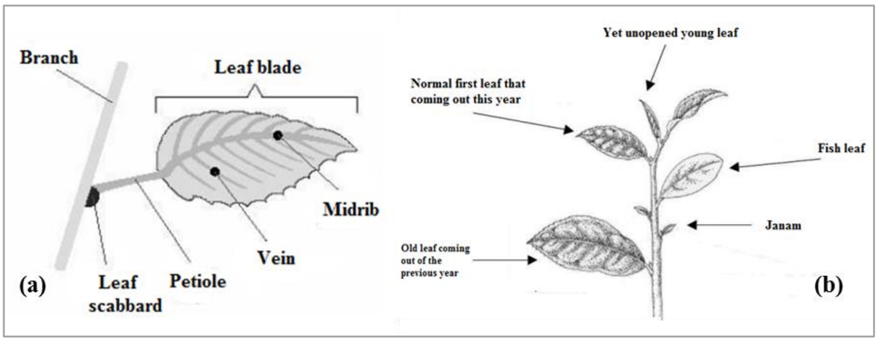

Figure 2. Leaf shape of the tea plant (a); actively growing tea shoot (b).

The tea plant is a perennial plant and can survive up to 100 years. However, after reaching 50, the plant yield decreases gradually. After 50 years, the yield of Assam teas decreases by 1% every year. Chinese tea survives for up to 100 years (Tekeli, 1976).

The most important factors affecting the growth of tea plants are climate and soil properties. The annual average temperature must not fall below 14 ^{0}C, the total annual rainfall must not be less than 2000 mm and its distribution throughout the months must be regular, and the relative humidity must be at least 70% to ensure the necessary climate conditions for the normal development of tea plants. The tea plant, which likes acid-reacting soils in terms of soil properties, shows optimum development in soils with a pH ranging between 4.5-6 and low active lime (Gökhale, 1952; Sharma & Ranhanathan, 1985). While soil pH is adversely affected by acid or alkali changes, when the soil pH falls below 4, the product with the desired yield and quality becomes unavailable (Tekeli, 1962; Tekeli, 1976; Kacar, 1984). The tea plant, which can be grown in soil textures ranging from sand to clayey, likes the soil to be deep and rich in plant nutrients, while plant growth is negatively affected in areas with heavy clay, lime, and a high water table. Therefore, while flat areas where tea is cultivated needs to be rich in organic matter and have high permeability, it is recommended that slopes in inclining areas are not more than 50%, and slope terracing is recommended to reduce the effect of slopes (Özyazıcı et al., 2014).

Shading is an important cultural practice as it is effective in increasing the amount of product in the tea plant as well as the pruning material. In shaded tea plantations, the surface width of the leaves is larger, and their dry weight increases as well. Shading prevents negative changes in soil temperature and causes better root development in tea plants (Kacar, 1984).

Thanks to good nutrition, the roots, branches, and organs of the plant develop and expand better. When fertilization is done in full, and according to the method and maintenance, pruning, leaf collection is done according to the proper methods, seedlings develop quite well, and the plants fill the entire tea plantation with full coverage. Plantations are fertilized at a rate of 70 kg per ac. Fertilizer is not sprinkled on the seedbed but applied to the roots of the tea plant (Haznedar & Sekban, 2012).

In the tea plant, the product is taken from fresh shoots showing periodic development during the whole vegetation on the collection table. The shoot consists of the active peak bud during the growth period and the subsequent fresh 2-3 leaves. Currently, three types of collection systems are in demand in the world of tea cultivation: Janam collection, fish-on-leaf collection, and fish-on-leaf collection leaving one leaf. It is important to note that the harvested leaves must not be coarse. Coarse leaves damage the quality of the product. Tea harvesting is started when the temperature rises above 11°C in the region to be harvested. The collection period is 7-15 days. The harvested fresh tea products consist of buds, a bud with a leaf, a bud with two leaves, a bud with three leaves, a tender bud, a tea flower, and fresh single leaves (Turna et al., 2008).

Fertilization of Tea Plants and Applications of Organic Fertilizers

The nutrients used by the plant and reduced in the soil by washing must be returned to the soil for the plants to yield high quality and abundant products and healthy growth, and fertilizer application is the second most expensive agricultural input in tea production (Bonheure & Willson, 1992; Zaman et al., 2016). The basic nutritional needs of tea plants are nitrogen, phosphorus, potassium, calcium, and magnesium. Micronutrient needs consist of manganese, boron, copper, zinc, molybdenum, and iron.

It is known that nitrogen, a plant nutrient, plays an important role in improving the vegetative growth of the plant, and its presence in the soil is directly reflected in the yield. Nitrogen is an important element affecting the formation of essential organic compounds such as amino acids, proteins, coenzymes, nucleic acids, ribosomes, chlorophyll, cytochrome, and some vitamins (Marschner, 1995). Phosphorus is the second plant nutrient required by the plant after nitrogen. The availability of phosphorus depends on the mineralization and immobilization processes in which biological processes are effective in the soil. It is fixed even if it is high in the soil or if it is applied in high amounts and regularly, and it turns into a form that is not obtainable as Fe and Al phosphates in acidic soils and Ca phosphates in alkaline soils (Çakmakçı et al., 2010). Potassium is another important nutrient required by the plant (Ranganathan & Natesan, 1985). Potassium increases root growth, stronger stalk formation, resistance to cold and water stress, links directly with improving product quality, reduces crop and disease effects by increasing crop resistance, and is the main nutrient that affects the quality of marketable tea (Venkatesan et al., 2006; Bagyalakshmi et al., 2012).

Tea production is significantly influenced by the N: K ratio because these nutrients play a direct or indirect role in all stages of metabolic processes from absorption to assimilation, which not only increases productivity but also improves the biochemical properties of leaves (Venkatesan et al., 2004). When there is a deficiency of these elements in the tea plant, the leaves weaken, the green leaves become yellowish, leaves fall off, and changes incur in the physical structure of the plant. The better and equal amounts of nutrition the tea plant has, the better the growth and development. Improper fertilization damages product health. There are technical requirements for fertilization in accordance with the requirements.

Tea plants are known to grow in acidic soils; the low pH of these soils, high Al concentration, and small amounts of nutrients indicate strong washing (Singh et al., 2010). Soil acidification threatens the sustainability of the agricultural system. Low soil pH has an adverse effect on the availability of plant nutrients, physiological deterioration in the absorption of calcium, magnesium, and phosphorus, decreased molybdenum availability, and reduced phosphorus availability as a result of reacting with aluminum and iron. Therefore, it is reported that organic fertilization should be carried out in order to maintain sustainability in tea plantations and thus mitigate soil acidification in tea plantations (Li et al. 2016). Plants that are grown in acidic soils often experience severe mineral stress, and such effects include toxic (Al and Mn) deficiency symptoms (Marschner, 1995; Fang et al., 2014). Excess Al is detrimental to root growth and overall growth, especially for plants that grow on acidic soils (Ding & Huang, 1991). Reducing N fertilizer moderately and adding organic matter can be effective in protecting plants from the risk of Al toxicity (Fang et al., 2014).

However, the soil of tea plantations is often strongly acidified due to the high nitrogen fertilizer applied, and the acidity in the soil of tea plantations gradually increases with the age of the plantation (Konishi, 1991; Hayatsu & Kosuge, 1993; Nioh et al., 1993; Tachibana et al., 1995; Shi et al., 1994). Likewise, soil pH may be affected by a variety of anthropogenic factors, including dense plant production, which tends to lower soil pH (Ok et al., 2007).

Globally, anthropogenic N_2O emissions are approximately 10 times higher in tea plantations than forests. N_2O gas has been reported to have ozone-depleting potential similar to that of hydrochlorofluorocarbons and is equal to approximately 300 times the global warming potential of CO_2 (Hall & Matson, 1999; Akiyama et al., 2006; Ravishankara et al., 2009; Li et al., 2013). Nitrogen fertilizer also affects soil nitrification significantly. N_2O flow after winter precipitation was higher than during non-rainfall periods (Zou et al., 2014). Chemical nitrogen fertilizers, controlled-release fertilizers, and organic fertilizers are different from the N-release feature (Fernandez et al., 2007). Compared to chemical fertilizers, organic fertilizers have a slow release of N, thus reducing N_2O gas emissions by preventing high emissions (Ball et al., 2004; Burger et al., 2005; Syväsalo et al., 2006; Petersen et al., 2006; Meijide et al., 2007; Deng et al., 2017). In particular, it has been reported that the nitrate-nitrogen (NO_3, -N) pollution in water sources is caused by the over-fertilization of tea plantations, and the main cause of regional water pollution in tea production areas is tea production (Kemmit et al., 2005) and environmental protection measures should be taken in basins where environmental pollution is observed and that the reduction of excessive N implementation has become mandatory (Morita et al., 2002; Kanazawa et al., 2005; Çakmakçı et al., 2015; Zaman et al., 2016).

It is possible to group fertilizers used in the fertilization of tea plants as chemical, organic, and microbial fertilizers. As a result of studies carried out in Turkey, it has been determined that the most appropriate chemical fertilizer to be used for tea is 25: 5: 10 (N P K) composite fertilizer, and the recommended dosage of this fertilizer is 70 kg per ac per year (Anonymous, 2013b). However, prolonged and excessive use of chemical fertilizers cause deterioration of the herbal properties of tea and a decrease in growth (Müftüoğlu et al., 2010). Research has shown that the high rate of nitrogen fertilizer applied to tea plantations increases economic costs and soil acidity, leads to deterioration, underground and surface water pollution, affects the rate of nitrification, and causes high environmental pollution by causing low nitrogen use efficiency (Ruan et al., 2004; Guo et al., 2010; Bagyalakshmi et al., 2012; Yuan et al., 2013; Fang et al., 2014; Çakmakçı et al., 2016). Furthermore, the intensive use of chemical fertilizers in tea production causes a decrease in soil organic matter content and beneficial soil-borne microorganisms, which affect product yield and soil sustainability (Bagyalakshmi et al., 2012).

The high cost of chemical fertilizers, the deep gap between supply and demand, and the negative impact on the environment have led growers to seek alternative strategies. Organic fertilizers have many agricultural and environmental advantages over chemical fertilizers (Bouldin, 1988). Fertilizers from organic sources play a critical role in the short-term availability and long-term protection of soil organic matter (Pang & Letey, 2000). Soil organic matter, nutrients, biological activity, soil structure, and nutrient content increase are important for productivity (Palm et al., 2001). The addition of organic fertilizers in any way helps to protect the soil organic matter and fertility levels of applied fertilizers and enhances yield (Bokhtiar & Sakurai, 2005).

With the organic management system, it is possible to improve the quality characteristics of tea (epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin gallate (ECG) and epicatechin (EC), and thus to improve the important catechin concentrations depending on the quality of the tea with accompanying benefits to human health as well as the environment (Han et al., 2018). The significantly higher soil pH, organic carbon (C), and total nitrogen (N) contents in organically managed tea agro-ecosystems also increase the benefits of organic fertilizer (Han et al., 2013; Subramanian et al., 2013). The benefits ensured by controlling insect damage and their effects on biodiversity are also manifested by organically managed tea systems (Saikia et al., 2014).

Tea yields in organically managed agricultural ecosystems are typically 10-20% lower than in traditional agricultural ecosystems (Bisen & Singh, 2012; Han et al., 2013; Das et al., 2016). However, in addition to yield, the quality of tea is equally important in countering consumer preferences (Ahmed et al., 2014). Hallmann et al. (2007) and Kazimierczak et al. (2013), who determined that organic teas had a higher concentration of polyphenols than conventional teas, stated that organic tea contains much higher levels of polyphenolic flavonol and tannin. Roussos (2011), Fernandes et al. (2012), and Baranski et al. (2014) emphasized that organic crops and foods have statistically higher antioxidant concentrations than those grown with conventional systems.

The use of integrated organic and inorganic fertilizers also helps to improve the productivity of various crops and improves soil health. It has been reported that the application of organic fertilizers together with chemical fertilizers increases the absorption of N, P, and K in sugar cane compared to chemical fertilizers alone and leads to higher sugar yield (Bokhtiar & Sakurai, 2005). A study carried out to investigate the effect of using organic (vermicompost, pig litter, and Azolla biomass) and inorganic nitrogen sources (urea) on young tea plants (Clone TV22) determined that the nitrogen supply in the YTD mixture (a mixture of NPK recommended for young tea at the rate of 2: 1: 3) through organic and inorganic and only through organic sources produced comparable results in the initial years as that of conventional treatment. Thereafter (+3 years), the integrated treatments showed better results. Higher number and thickness of pruning sticks, pruning litter weight, canopy spread, plucking point density, and yield were recorded in treatment with vermicompost and urea (T2): followed by pig litter and urea (T4) and *Azolla* biomass with urea (T6). Nitrogen, when supplied through only organic sources, the highest record was in vermicompost (T3), followed by pig litter (T5) and *Azolla* biomass (T7). Nitrogen in YTD mixture as 50% through organic and 50% through urea can be recommended for satisfactory growth, development, and yield of young tea in an integrated nutrient management system (Baruah et al., 2019).

The application of organic fertilizers and bio-inoculants in tea plantations can minimize these problems as they are advantageous over chemical fertilizers in increasing soil fertility. Bio-inoculants are environmentally safer and a cost-effective complement to chemical fertilizers. The literature on the use of organic and biological fertilizers on tea crops is very limited (Karthikeyini, 2002). Therefore, the number of studies examining the effects of single or integrated applications of organic fertilizers and bio-inoculants should be increased, especially for the possible reduction of the amount of inorganic fertilizer used in tea production. The use of organic fertilizers and microbial inoculants or bio-fertilizers is a sustainable alternative to the high input of chemical fertilizers used in conventional production systems (Tanwar et al., 2013).

Bio-fertilizers are apparently eco-friendly and non-bulky, farmer-friendly renewable resources with low-cost organic agricultural input. Although *Rhizobium*, blue-green algae (BGA), and *Azolla* are crop-specific, bio-inoculants such as *Azotobacter, Azospirillum*, phosphorus-soluble bacteria (PSB), vesicular arbuscular micorisers (VAM), arbuscular mycorrhizal fungi (AMF) (Songachan, 2012; Sharma & Kayang, 2017) can be accepted as broad-spectrum bio-fertilizers. Since bio-fertilizers are based on renewable energy sources, they are cost-effective, environmentally friendly, and support chemical fertilizers (Baby et al., 2001). Therefore, fertile organism species must be found, folded, and included in soil. Chemical fertilizers can be significantly reduced in fertilization programs with the application of bio-fertilizers (Gebrewold, 2018).

Bio-agents such as *Trichoderma viride, T. harzianum,* and *Bacillus subtilis* are currently used in many tea plantations. Bio-fertilizer is the main source of N and P inputs in tea. Biological N is an attractive and economic resource to counter the N requirements of a tea plantation. As biotic N fixators, *Azotobacter* and *Azospirillum* are most suitable for growing plants such as tea. However, it is clear that bio-fertilizers alone cannot meet all the nitrogen requirements in tea. It is estimated that 20-50 kg N ha^{-1} can be supplied by N fixers. PSBs such as *Bacillus* and *Pseudomonas* spp. play an important role in increasing P nutrient activity for the total development of tea plants. At the same time, they also increase the solubility/usability of P available in tea soil which is in an insoluble form (Baby et al., 2001). There are reports of the application of bacteria that promote the dissolution and uptake of elements/minerals to increase yield without affecting the quality of black tea (Mandal et al., 2007). Çakmakçı et al. (2017) stated that the use of stable formulations developed with plant-promoting bacteria is promising for sustainable tea cultivation.

Conclusion

Although tea was discovered by chance by one of the three legendary emperors of Chinese medicine, it is a medicinal plant that has been loved by people since its discovery. Laboratory and clinical studies have proven that the plant provides protection against skin diseases as well as cancer, Alzheimer's disease, paralysis, diabetes, and Parkinson's prevention and is beneficial for dental health. In addition, the fact that it is the most consumed beverage after water in the world shows how important this plant is. It is known that the tea plant grows in regions where the rainfall regime is regular, and annual rainfall is more than 2000 mm. Such areas are exposed to soil washing due to the intensity of rainfall. Therefore, in addition to the known hazards of chemical fertilizers for human health, they also lead to excessive groundwater pollution. In recent years, scientists have accelerated their studies on organic and microbial fertilizers that are more environmentally friendly and do not harm human health yet enable equal or more yields than chemical fertilizers in order to eliminate this negative situation.

Such studies are very important so that tea, which is so much in our lives, can be consumed safely without posing a threat to human health. In terms of health, transforming a product that has all the important features mentioned above into a product that is harmful to human and environmental health instead of an organically healthy and environmentally friendly product is an important issue for everyone whether they are interested parties or not. Once man loses his health to have more product and more gains; unfortunately, those gains will not restore his lost health.

Conflict of Interest

The authors declare that they have no conflict of interest.

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