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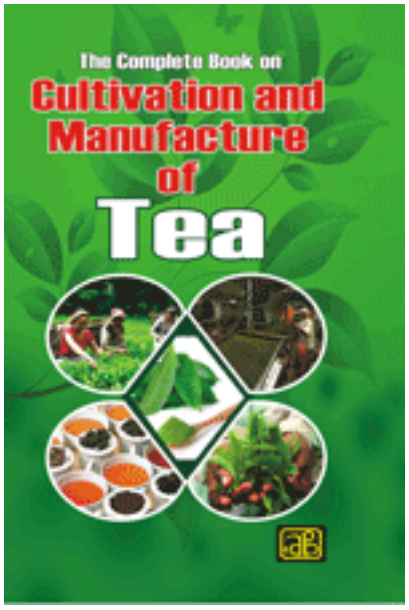
# The Complete Book on Cultivation and Manufacture of Tea (2nd Revised Edition)

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Tea is one of the most popular beverages that are being consumed all over the world. Tea is known as a soothing drink and a way of life. Owing to its increasing demand, tea is considered to be one of the major components of world beverage market. Tea is very beneficial for health and is also known as anticarcinogenic properties. Green tea acts as an antiviral agent. Growing tea requires sufficient amount of work and there is additional level of work that must be incorporated to harvest it. Tea is cultivated in tropical and sub tropical regions. There are various kinds of tea such as black tea, green, oolong tea that can be obtained from real tea plant, Camellia sinensis. The making of different varieties of tea mainly depends upon plucking and rolling, spreading, storing process.

The handbook describes aspects of tea cultivation, ranging from the history of old crop, machinery & equipment for various Tea, biological control, organic tea- and many more. This is a sincere attempt to open up the world of this wonderful beverage, its cultivation methods, types of tea available worldwide, manufacturing process, to the common man.

Some of the fundamentals of the book are growth of tea in other countries, tea in Indian economy, biochemical constituents, pharmacological properties, selection, pollination and propagation, nutritional requirements, growth, photosynthesis and respiration, nursery management, water theory, oxidative degradation of protein, biological effect of polyphenols, analysis of tea, tea processing, green tea processing, tea bag production etc.

This book will be a mile stone for its readers who are new to this sector, will also find useful for entrepreneurs, tea scientists and tea research establishments.

**Content:**

(Horizontal  Design Vibratory Sifter & Grader for Tea)
Vibro Screen Sorter
(Vertical Design Vibratory Sifter & Grader for Tea)
Pulverizer
Powdering Machine for Tea
6. Packaging
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Technical Specification
Tea Bag Packaging Machine
Technical Specification
28. MACHINERY & EQUIPMENT FOR CTC TEA/TEA/ OOLONG TEA/ TEA BAGS

**Sample Chapter:**

# Historical Evidences

Although tea has been grown for nearly two centuries now, its origin and dispersal continue to be as baffling as ever. Indeed, there is still considerable speculation about the place of origin of tea. It is generally believed that it originated somewhere in South-east Asia. In China, for example, tea as a beverage was known for about 3000 years, though wild tea has not been found in China. The wild types recorded from time to time in southern China are possibly relics from cultivation in the unrecorded past. However, current distribution patterns of tea types or varieties suggest that tea possibly originated somewhere in the vicinity of the Irrawaddy basin from where it dispersed to South-east China, Indonesia, and Assam. Tea varieties specific to these three principal regions have characteristic biological features, but it is rarely that only one particular type is to be found in a particular locality.

Tea in India

The saga of commercial development of tea in India is both awe-inspiring and fascinating. The search for tea in Assam was started by the East India Company as an alternate source of supply to the U.K. which till then was mainly dependent on China. It was generally thought by the tea committee established by the Governor General in 1834 that the tea plant was indeed indigenous to Assam, especially in its upper reaches. The investigations of Dr. Nathaniel Wallich at the Botanical Gardens, Calcutta, for identifying tea plants from different parts of India are fairly well documented. Equally interesting was the observation of Sir Joseph Banks, the English Botanist, who thought that tea might exist indigenously in the Dooars because climatic conditions in parts of the Dooars, proximal to Bhutan, were comparable to those of China where tea was grown.

Growth of Tea in Other Countries

Large scale commercial planting under both corporate and private sectors started in India in the early eighties. The idea of planting tea originally mooted for India gradually found its way to other parts of Asia and Africa, though in Indonesia tea cultivation was a little older than in India. Planting in Sri Lanka began in 1880 in a serious way, when a little over 14,000 acres were brought under tea. In the following 15 years, vigorous expansion followed and about 305,000 acres were brought under tea; and by the First World War, most of the corporate sectors became established. Tea in Sri Lanka was essentially a replacement for coffee which was fast dying out because of attacks of coffee rust fungus. Today 242,130 ha are under cultivation in Sri Lanka with an annual average production of 208,058 tonnes of which 164,704 tonnes were exported.

Tea in Indian Economy

India emerges on top in all aspects of tea production, consumption and export. Tea is grown only in the rural areas and it contributes significantly and substantially towards the national economy averaging Rs. 1,000 crores annually.

A fact often overlooked is that tea provides direct employment to about one million people, and unlike other agricultural crops, tea provides the highest employment per unit of arable land. It provides the largest quantum of jobs to rural people, people in the weaker sections of society and women. Many more are employed by sectors like tea machinery and packing, agricultural chemicals, in services like warehouse facilities, road and river transport related to tea and in tea trade in general throughout the country. More than 70 per cent of the country's population comes in contact with tea in one way or another, including tea drinking, thus rendering tea to play a key role in India's economy and society, both directly and indirectly.

# Relation with Health

Tea currently is the hot topic in both nutritional and therapeutic research worldwide. This is not so because

tea is the most preferred drink after water, but because of the presence of crucial therapeutic compounds in tea which are more bio-stable and direct acting than those found in other plants. The activities of these compounds are so all pervading that they are virtually broad spectrum in their actions. Besides, the natural integration of aromatic and therapeutic compounds in tea is a rather unique attribute.

### The Core Compounds

Flavonoids generate powerful antioxidant activities which are basically responsible for the therapeutic effects of both of black and green teas, as well as for their deliciously rich flavour and colour. As light is essential for the synthesis of flavonoids, they are common only on those parts of plants and fruits which are optimally exposed to sunlight. They are common on the outer skin of fruits, outer leaves of cabbage and on the leaves of tea. While the outer peels of fruits and vegetables are generally discarded before consumption, it is not so in the case of tea. Hence, the singular important aspect of tea as an exceptional and rich source of polyphenols (like flavonoids), which possess health promoting potential, makes it a beneficial drink. Flavonoids have rich chemical diversity and the level of their presence in tea can be classified as rich, moderate or lower on the following scale (Table 1).

### Flavonoids in Tea Infusion

About 30% of the solids extracted in a typical black tea infusion are the flavonoids, of which 10% are water soluble flavonols. Most of the remaining flavonoids are the flavanols present as catechins or their derivatives. During the processing of black tea, these catechins are oxidized to produce theaflavins or thearubigins, depending on the colour they take, but they maintain the basic structural configuration (C6-C3-C6) of the flavanoids.

### Antioxidant Activity of Tea Flavonoids

From the perspective of therapeutics, the antioxidant activity rather than the quantity of flavanoids, are crucial. Antioxidants protect the body against the damaging effects of free radicals produced naturally within the body. But overproduction of these free radicals due to environmental pollution, smoking or physiological disorders may disrupt the body's own antioxidant system resulting in the production of free radicals far in excess of what is good for health. An imbalance between free radical production and natural antioxidants could cause oxidative damages to proteins and DNA, the genetic material within the cells. A compound that prevents oxidative damage is, therefore, an antioxidant.

### Tea Flavonoids and Cancer

The evidence here is more gripping as a majority of research on tea therapeutics concentrate on cancer. Cancer occurs when the cells lose their natural control mechanism leading to their unregulated growth, eventually causing damage to the genetic information system coded in the DNA of cells. The damage process continues over a period of time leading ultimately to the cell growth rate in excess of that is needed for normal growth, repair and reproduction of cells.

The effects of tea (flavonoids) on cancer prevention are both strong and unique. Based on typical tea consumption by humans, it can be said that both black and green tea have the potential to inhibit tumor formation in different parts of the body and are likely to be protective during the initiation, promotion and progression of both smoke and arsenic induced cancers. Tea flavonoids prevent initiation of cancer by inducing enzymes that help eliminate the toxins responsible for cancerous growth.

# Importance of Therapeutic Compounds

Tea has interesting chemical constituents, some of which are as unique as the plant itself. Like the chequered history of tea, the chemical history of tea is quite fascinating, to say the least. From the dawn of commercial planting of tea in India, attention has been paid to identify what is the basic element that is attributable to the quality of tea, though earlier the search was based on the assumption that a single influencing factor or ingredient could be responsible for the quality of tea.

Slowly but surely, the perspective changed with advances in chemical research and the main constituents of tea leaves were broadly identified to be carbohydrates, proteins, polyphenols, caffeine, theanine, vitamins and minerals. But these chemicals in tea leaves undergo dynamic changes as green tea leaves are converted into black tea during the process of manufacturing. There is, therefore, nothing static about these compounds because they undergo rapid changes not only during manufacturing process, but also according to agricultural practices, shade from sunlight or its absence, plant location, season, and of course, leaf types or varieties. The leaf also contains enzymes that facilitate the chemical reactions in processing young shoots to produce green, black and oolong tea.

Polyphenols

Tea contains 30 to 42% polyphenols on a dry-weight basis, catechins being particularly important. Catechins generally belong to a group of compounds, the flavonoids, which have C6-C3-C6 carbon structure with two aromatic rings (Fig. 1). Catechins in tea are unique, as a kind of them are not akin in any other plants.

Catechin derivatives of primary polyphenols were first reported using the technique of paper chromatography by Roberts and Wood.

These are present in small qualities.

A cup of tea may contain between 300 and 400 mg of polyphenols in totality. EGCG is the major polyphenolic constituent, contributing about 25 to 40% of the total catechin load of tea.

During the biosynthesis of catechins, C6(A) catechin ring is produced by the acetc-malonic pathway and C3-C6 (B) by the shikimic-cinnamic acid pathway starting from the glucose pool. Synthesized catechins are stored in cell vacuoles without undergoing any further metabolism. (-) Epigallocatechin is produced by hydroxylation of (-) epicatechin. (-) Epicatechin gallate and epigallocatechin gallate are, however, synthesized by the esterification of catechins with gallic acid present in the cell.

Caffeine

Caffiene (trimethylxanthine), a purine alkaloid constitutes 2.5 to 5.5% of the total chemical constituents of tea leaf one dry-weight basis and occurs along with small quantities of dimethylxanthine, monomethylxathine and theophylline. Caffeine, being a product of the methylation of purine nucleotides, does not result from the degradation of ribonucleic acid, as was supposed to be earlier. Recently, a gene in the tea leaf encoding caffeine synthase, N-methyltransferase, has been cloned and the recombinant enzyme produced in *E. coli* has opened the possibilities of generating caffeine-free tea plants.

Vitamins

Tea contains a wide range of vitamins that include carotene, riboflavin, nicotinic acid, pantothemic acid, ascorbic acid and theamine, though most of them are lost during the processing of fresh green tea leaves to black tea. Theanine, which is g-ethylamide to glutamic acid having an antagonistic action against the stimulating action of caffeine, is also unique to tea. Vitamin B content of black tea ranges from 1.4 µg of bioten to 127.5 µg of riboflavin.

Carbohydrates

Carbohydrates constitute about 4-5% of the solids extracted in tea infusion. Though concentrated mostly in the roots, carbohydrates are not uncommon in the leaves. From nutritional point of view, carbohydrate content is significant.

# Production of Therapeutic Compounds

The antioxidant properties of tea are fairly well established, though more than tea leaf per se, it is the chemical compounds within the leaf that are of consequence. Most *in vitro* studies have used tea extracts in evaluating the effects of tea against simulated human diseases. It would therefore be worth noting the compounds that are present in fresh green leaf compared to the processed leaf, and the chemical

transformations as the green leaf is processed into black tea.

Polyphenols

From therapeutic point of view, the polyphenols in tea leaves are most important, despite the presence of many other compounds in the leaf. Young tea shoots are rich in polyphenolic compounds, the largest component being those of catechins constituting about 30% of the total chemical biomass on dry-weight basis.

Flavanol, the other important group, is present at a level of 1% or more in the leaf, again on dry-weight basis.

Variations in Specific Compounds

One can possibly look at freshly harvested tea shoots for the distribution of polyphenols and then note the quantitative changes in the individual compounds during processing. This is important because for therapeutic purposes, the black tea extract (BTE) containing the penultimate compounds is mostly the working substrate.

Changes During Processing

During withering the water content of the harvested shoots is reduced to around 16% but a process of chemical withering starts almost from the time of plucking. It is not clear, whether this is the point for generation of catchins, or the products of therapeutic importance. However, in the next step, i.e. rolling, disruption of cells ensures release of enzymes, particularly polyphenol oxidase, that initiates a series of chemical reactions culminating in the serial production of catechins, and other compounds of importance in tea flavour and quality.

Theaflavins and Thearubigins

These two major chemical complexes of tea are of great significance both for quality and medicinal attributes. They are basically products of oxidation of catechins, which were identified by chromatographic studies. Additionally, a gallate of theaflavin, namely, theaflavingallate, was also identified.

Theaflavins are chemically complex with the identifiable fractions. The identifiable fractions and their proportions in black tea are shown in Table 2.

The proportion of the fractions of thearubigins, however, varies according to fermentation time and possible plant genotypes.

Each fraction of thearubigin contains 18-26% of anthocyanidins and these fractions, in general, have a structure base of polymeric proanthocyanidins. This view has, however, been disputed, though there is little doubt that thearubigins are directly derived from the catechins as well as from the breakdown of theaflavins and theaflavin intermediaries. Overall, the dynamics of thearubigin is still a contested subject.

# Biochemical Constituents

Biochemical characteristics of tea are of importance not only for an understanding of the growth processes, but also for the very basics of tea quality which is related to the interactions between biochemical components of the leaves during different phases of processing. Consequently, biochemical analysis has been generally restricted to the flush because of its economic significance; that is, only the young shoots that produce the black tea with characteristic aroma. An idea of the chemical composition of the tea bush as a whole (Table 1) is always helpful in developing a perspective for an appreciation of enzyme dynamics. Unlike mature leaves, green and mature stems, roots and seeds; the flush contains high levels of polyphenols, amino-acids and caffeine but the mature leaves are rich in carotenoids.

Polyphenolic Compounds

The most important and characteristic components of tea leaves are the polyphenolic compounds; they are mainly responsible for the unique character of processed teas. Out of the polyphenolic compounds identified fresh tea flush (Table 2) flavanols are oxidised by polyphenol oxidase during processing of tea

and they are the major determinates of the colour of tea brews.

The polyphenolic composition of tea undergoes changes with leaf age and its activity is at its optimum in young leaves; hence, the finest tea from the young flush. The main effect is a progressive decline in total phenolic material along with an alteration in the proportions of flavonols, relative to each other. Polyphenols are also of chemotaxonomic significance; phenolic patterns in different parts of tea flowers vary according to their morphological affinities to the leaf.

Amino-acids

The amino-acids present in young tea leaves plucked for manufacture have been identified as: aspartic acid, glutamic acid, glycine, serine, glutamine, tyrosine, threonine, a-alanine, b-alanine, valine, leucine, isoleucine, phenylalanine, lysine, arginine, histidine, trytophan, asparagine, proline and theanine. Of these theanine, identified as 5-N-ethyl glutamine, accounted for more than 50 per cent of the total amino-acid content and comprised about 1 per cent the total dry weight of tea leaves. This amino-acid has particular relevance in the manufacture of green tea as it protects enzymes from inactivation by polyphenolic products and is primarily responsible for the quality of green tea. In general, green teas contain a greater proportion of theanine than black teas. Theanine, constituting about 1.5 to 2.0 per cent of the dry matter of tea is also an important constituent of the thearubigin complex of black tea liquors.

Biochemical Changes during Leaf Processing

The starting material in black tea processing is the young shoot, the terminal bud and the two adjacent leaves. The flush is processed in distinct stages, which are withering, rolling, fermentation, firing (drying) and grading. Each stage involves characteristic changes in the physical and biochemical composition of the leaves and the cumulative effects of these changes are ultimately reflected in the quality of the finished product, namely, the black tea.

Withering

Withering brings about physical and chemical changes in the shoots to produce quality, apart from conditioning the flush for rolling by reducing turgor, weight and volume. The process is generally achieved either by thinly spreading the flush on mats, or in thicker layers in troughs for eight to 18 hours depending on the condition of the leaves. During this period, the moisture content of the leaf drops to between 60 (soft wither) and 50 per cent (hard wither). The physical part of withering can be achieved quickly by passing a blast of hot air (35ºC) through the leaves but this may adversely affect quality because of the inhibition of full biochemical changes.

Development of Aroma

The formation of volatile flavour constituents starts with the degradation of lipids (mentioned earlier) during withering but it gains momentum during rolling, and particularly during fermentation. By lowering the fermentation temperature it is possible to reduce the rate of polyphenolic oxidation reaction, thus allowing VFC formation from the flavour producing substrates that survive rolling. The amounts of volatile compounds also vary depending on fermenting time (Table 6); hence the need for optimum timing for fermentation.

The volatile compounds are formed either by the oxidation of flavanols in the presence of polyphenol oxidase or by direct biosynthesis. The oxidation of flavanols causes oxidative degradation of amino-acids, carotenes and linolenic acid; the amino-acids in turn are transformed to carbonyl compounds, particularly phenylacetaldehyde from phenylalanine. It is important that the typical aroma of tea develops during various phases of manufacturing and constituents responsible for it which were not originally present in the fresh leaf.

Changes in Carotenes and Fatty Acid

A general decrease in carotenoids during fermentation is mostly due to the conversion of carotenoids to volatile compounds responsible for flavour by oxidative degradation of carotenoid compounds. However,

this aspect has not been studied in full details. The proportion of trans-2-hexenal in the aroma complex is a major determinant of flavour.

Firing

Although firing reduces the moisture contents of rolled and fermented leaves from 45 to 50 per cent level to a 3 per cent level in dried black tea, it also allows development of black tea aroma. Firing is physically achieved by blowing hot air through fermented leaves as they are conveyed in chains; the temperature of the hot air at the inlet is 87º to 93ºC, while that at the outlet is 56ºC. The drying process lasts for about 20 minutes. The principal biochemical process involves conversion of chlorophyll to phenophytin, responsible for the black appearance in the manufactured tea.

Biochemical Basis of Tea Quality

Every step in tea processing aims at optimising and improving the quality of the finished product and yet a mundane definition of quality is difficult to offer. Consequently, the term continues to be subjective and is used to express anything from the market value of the finished product to the aroma of tea infusion. Some of the attributes used in assessing quality are the appearance (black or brownish) of the dry tea, and the colour (coppery or greenish) of the infusion; the ‘strength', the ‘briskness' and the formation of ‘cream' and ‘body'. Quality, therefore, is a multicomponent measure of the interactions between physical and biochemical components of the finished product, acceptable to a discerning user.

Colour and strengths are particularly important from the consumer's point of view, as the market value of tea is greatly dependent on the interactions between these factors. While the colour is determined mostly by the ratio of the theaflavins and thearubigins, and in a small measure from the presence of flavanotropolones, strength is a function of the oxidation of polyphenol content of the green leaves during fermentation. In a general way, therefore, a positive relationship may exist between quality and theaflavin content, and the theaflavin/thearubigin ratio, particularly their optical density values. Likewise, market valuations of black teas have been correlated to theaflavin, epicatechin gallate and theogallin contents of black teas, as also oxygen uptake of unprocessed green shoots.

# Pharmacological Properties

Tea (*Camellia sinensis*) is one of the most commonly consumed beverages in the world today. Since time immemorial, tea has been regarded as a healthy beverage. In ancient Chinese literature (from Tang Dynasty), tea has been rated as a leading health giving beverage and cure for many diseases. According to a report published by Jelinck the consumption of tea infusion was probably popular even 500,000 years ago. As per the available information, LuYu authored the first book on tea during 780 A.D.

The different varieties of tea (Green, Black and Oolong) were possibly introduced during the 14th century (Ming Dynasty). The Darjeeling variety of tea was first cultivated during 1841; however, commercial production experienced a major growth during the second half of the 19th century.

The health benefits of tea have been known to human civilization for centuries. However, when we take a look into the historical aspect related to tea, we find that in earlier days tea infusion was popular for improving blood flow, detoxification and disease prevention.

Pharmacological Actions

**Polyphenols:** The polyphenols have the property of mopping up oxygen radicals which can be generated in the body by partial reduction of molecular oxygen. They enzymic production of superoxide anion and the presence of superoxide redical have strengthened the free radical theory of oxygen toxicity. Cancer, arthritis, skin wrinkling of the aging process have all been ascribed to superoxide anion causing lipid peroxidation. The polyphenols present in tea can after a logical chemical explanation for protecting against oxygen toxicity of the hazards of diseases induced by free radicals. The Mitsui Norin Co. food research laboratories have obtained proof of tea polyphenols showing antioxidative, antibacterial, hypolipidemic and

hypotensive activity as well as suppression of the growth of inoculated, drug-induced or virus induced tumours in animals. A number of reports on the beneficial activity, particularly antitumorigenic and hypolipidemic activity, of GTP were presented at the International Tea Quality-Human Health Symposium in China in 1987.

## Pharmacological Aspects Associated with Tea Consumption

### Cardiovascular System

A number of epidemiological studies indicate that the total polyphenol content following tea consumption can be linked to protection of the Cardiovascular system (CVS). However, some other studies have reported dissimilar results with respect to protective effects as discussed earlier.

From different studies (in vitro and in vivo), carried out with tea, it is evident that flavonoids and other polyphenols present in tea may protect the cardiovascular system by prevention of LDL oxidation, lowering serum lipids, anti-inflammatory actions, improvements in blood vessel function and inhibition of platelet aggregation. Clinical studies on human subjects are not conclusive, although some epidemiological studies seem to indicate that tea can reduce serum cholesterol.

### Cancer

There is increasing evidence that specific compounds present in certain natural foods, are vital requirements for human nutrition. These foods, if included in the regular diet, can improve the healthy lifestyle. Tea is rich in specific phenolic compounds including flavonoids, which are known to be powerful antioxidants and have been reported to possess anticancer properties. In a population survey (conducted in Japan), the study indicated towards an overall protection coupled with a decrease of cancer incidences, in individuals habituated to tea drinking. The effects were more prominent when the consumption rate was increased (per day).

In some reports it was observed that there was a decrease in the incidence of stomach cancer with increased consumption of tea and according to one report, it was observed that green tea drinkers had experienced a 48% reduction in the risk of developing stomach cancer. Studies indicate that tea consumption (polyphenols) can inhibit tumorigenesis at its initiation, and also during progressive stages of cancer.

### Tea and Dental Health

Epidemiological surveys have reported that a considerable percentage of populations, who drink tea on a regular basis, have a reduced number of carious teeth. Green tea and various catechins are also known to inhibit the growth of cariogenic bacteria by preventing the adherence and growth of such bacteria on the dental surface. Also, the adsorption of theaflavins to dental enamel may play an important role in curbing the formation of plaque, and keeping the teeth clean and shining.

A recent study on the bio-availability of fluoride (from tea) demonstrated that 34% of the fluoride was retained in the oral cavity and that some of this showed a strong binding ability to the tooth enamel, thereby indicating that tea could be effective towards replenishment of fluoride to the oral cavity, as well prevent dental decay and gum diseases.

### Tea and Fluid Replenishment

In the early days, tea was not considered to be an alternative to fluid replacement because of its diuretic action (due to the presence of caffeine). However, it was later observed that tea did not exert any diuretic action, unless the amount of tea consumption exceeded 6 cups (i.e. 250-300 mg caffeine equivalent).

### Gastrointestinal System

Administration of black tea extract, to rats, for seven days inhibited the development of both aspirin and cold-restrained stress induced acute gastric ulcer. Tea extract was found to reduce acid and peptic activity of gastric secretion, induced by aspirin and cold-restrained stress peroxidation, black tea infusion (Darjeeling variety) significantly inhibited malondialdehyde formation in a dose-dependent manner. Such

antipreoxidative (Figs. 5 and 6) activity was comparable to that of standard drugs Vitamin C, E, sodium metabisulphite and quercetin.

# Importance of Black Tea

Tea, an extract of the leaves of the plant *Camellia sinensis,* has been considered a medicine and healthful beverages for ages. This beverage is consumed worldwide because of its unique aroma, low cost and wide availability. The scientific research facilitates that the beneficial effects of tea are due to its polyphenolic components that may affect carcinogen metabolism, free radical scavenging, and formation of DNA adducts. The tea plant originated in Southeast Asia and is presently cultivated in about 30 countries around the globe. Although no firm data is available, it appears that tea is universally accepted with a per capita worldwide consumption of approximately 120 ml per day. Of the approximately 2.5 million metric tons of dried tea manufactured annually, only 20% is green tea, less than 2% is oolong tea and rest is black (regular) tea.

Composition and Chemistry of Tea

Normally the composition of the tea leaf varies with climatic conditions, season, horticultural practices, variety of plant and age of the leaf, i.e., the position of the leaf on the harvested shoot (top two leaves or top three to four leaves). Three main commercial tea beverage varieties are available, and their composition varies according to the manufacturing process involved. In the process of green tea manufacture, the steps include plucking, rapid enzyme inactivation by steaming or pan firing, rolling, and air-drying at high temperature. During the final drying step many new aromatic compounds are formed which provide the characteristic flavour to tea.

Pharmacological Properties of Tea

The medicinal use of tea was known long before it was being used as a beverage. Tea is one of the most widely commonly consumed non-alcoholic beverages and is popular due to its refreshing properties. Regular ingestion of tea maintains homeostasis in humans. The pharmacological beneficial effects of tea and its components on health, its role in varied pathophysiological conditions, germicidal, antioxidant, antiatherosclerotic, antimutagenic, anticarcinogenic and detoxifying functions are described briefly.

Antioxidative Effects of Tea

Tea catechins and its metabolites act as bioantioxidants. Tea polyphenols are strong scavengers against superoxide, hydrogen peroxide, hydroxy radicals and nitric oxide produced by various chemicals. Black tea has been identified to act as a powerful chemopreventor of reactive oxygen and nitrogen species. Black tea exhibits protective effects against oxidative damage in human red blood cells. Treatment of EGCG to human skin inhibited ultraviolet radiation induced oxidative stress. EGCG also exhibited protective effect against oxidative damage to cellular DNA. Black and green tea inhibits lipid peroxidative damage in rat liver and kidney. Besides this, green and black tea ingestion reflected a significant increase of human plasma antioxidant capacity.

Modulation of Metabolizing/Detoxifiying Enzymes

Tea consumption modulates hepatic drug metabolizing enzymes. Theaflavins prevent DNA damage by inhibiting oxidative stress and suppressing Cytochrome P450 1A1 in cell cultures. Green tea polyphenols have been found to inhibit rat liver microsomal mono-oxygenase activities, including aryl hydrocarbon hydroxylase, 7-ethoxyresorufin O-deethylase and 7-ethoxycoumarin O-deethylase. Black tea has been found to reduce lipid peroxidative damage and increase glutathione levels in female rats thus enhancing detoxification of toxicants. Another report indicated that treatment of rats with green and black tea for 4 or 6 weeks caused significant induction of cytochrome P450 enzymes, such as CYP1A2, CYP1A1, CYP2B and CYP4A1.

Modulation of Immune Function

Tea drinking has been associated with increased cell-mediated immune function. Black tea catechin suppresses the expression of high affinity IgE receptor FC-E RI in human basophillic KU 812 cells. Increase in both number and activity of lymphocytes including NK cells has been reported. Tea also possesses the property to stimulate the formation of interleukin 2, which has important immuno-regulatory roles. The phenolic components EGCG and EGC of tea have also been found to regulate the production of pro- and anti-inflammatory cytokines by human leucocytes in vitro.

Antimutagenic Activity

***Microbial systems:*** Antimutagenic activity of tea polyphenols in microbial systems has been extensively investigated. EGCG and ECG showed inhibitory effects against the mutagenicity of MNNG in*Salmonella typhimurium* TA98 and TA100 with and without rat liver S9 mix. EGCG also had a strong inhibitory effect against the mutagenicity of BaP diol expoxide in TA 100 strain without S9 mix. Theaflavins, gallate esters and catechins inhibited mutagenicity of PhIP in *Salmonella typhimurium* TA 98. The gallate esters of the catechins EC, EGC and EGCG, theaflavonoids TF, TFMG and TFDG and glucose (tannic acid) had low IC50 in the 80-250 µM range against mutagenicity of 10 µM PhIP. Non-polyphenolic fraction of green tea suppressed 3-amino-1, 4-dimethyl-5H-pyrido[4,3-b]indole (Trp-P-1) or mitomycin C (MMC) induced umu C gene expression in *Salmonella typhimurium* TA1535/psk 1002 in the presence or absence of S9 metabolizing enzyme mixture.

Germicidal and Antiviral Activity

Investigations have proved that tea exhibits germicidal and antiviral activity. Crude catechins, gallated catechins and TFs, TFDG, TF monogallate A and B inhibited the growth of both spores and vegetative cells of *C. botulinum s.* ECG and EGCG possessed the inhibitory activity against hemolysin excreted by *Vibro cholera,* the toxin excreted by *Staphylococcus aureus* bacteria and damage to CHO cells induced by *Cholera toxin.* Tea polyphenols have been found to retard the infectivity of influenza virus. Besides this EGCG has been found to exhibit inhibitory effects on the life cycle of human immunodeficiency virus type 1 [HIV-1]. Black tea extract, thearubigin fraction, counteracts and protects against the adverse effect of tetanus toxin in mice. Recent studies indicate that epicatechin gallate in tea may be a valuable therapeutic agent against *H. pylori* infection.

# Taxonomical Properties

Like its origin, the botanical classification of tea has also been a subject of intense speculation, but without an agreed solution for a uniformity in nomenclature. Although Index Kewensis lists tea as *Camellia sinensis,* the genesis of the problem could be traced right up to the great taxonomist Linneaeus, who originally described tea as *Thea sinensis,* but later described two more species, *Thea bohas* and *Thea viridis,* while abandoning earlier nomenclature of tea as *Thea sinensis.* Although *Thea and Camellia* are considered today synonymous, dual nomenclature of tea as *Camellia thea* Dyer was in practice for quite sometime, while in Indonesia tea was botanically known as *Camellia theifera.* Currently, *Camellia thea* and *Camellia sinensis* (L) O. Kuntze are considered synonymous.

The problem in nomenclature arose mostly because of the simultaneous presence of many varieties or types of tea, growing indigenously in different parts of south-east Asia and India, in addition to the major cultivars or *jats.* Although in tea nomenclature, the term *jat* is considered a near approximation to what is taxonomically known as the ‘variety', it has no botanical significance, except to denote localities where seed *baris* (equivalent to orchards) are located (Betjan, Rajgarh etc.), or the source wherefrom seeds were originally obtained (Manipur, Burma etc.). But the term *jat* in tea taxonomy is often used to distinguish the distinctive types, that is, the Assam, China, Cambod etc.

Tea Varieties

(1) The China variety

The China variety normally grows as a shrub, 1 to 3 m high with straight and near erect branches arising from the base of the plant at the ground level. Consequently, the fully grown plant takes the architectural shape of a dome. Leaves are thick, small, deep green and erect. Based on the variation in leaf-forms, Sealy identified two morphological forms within this variety; these are (i) *macrophylla* (Sieb) Kitamura having leaves 5 to 15 cm long, 22 cm wide; and (ii) *parviflora* (Miq) Sealy characterised by extremely narrow leaves, 2 to 6 cm long and 1.5 to 2 cm wide.

(2) The Assam Variety

The Assam variety is more of a small tree, growing up to a height of 10 to 15 m with a ramifying branch system and a distinct trunk. Leaves are large, glossy with acuminate apex and distinct marginal veins. Leaf blades broadly elliptic, 10 to 20 cm long, 4 to 8 cm wide; base cuneate, margin indistinctly denticulate. Flowers arise singly or in pairs from cataphyllary leaf axils. Pedicels bear scars of three bractioles, smooth and green. Sepals five to six, of unequal length, leathery; petals seven to eight without any pigmentation.

Biology of the Plant

Phasic and Vegetative Growth

Unlike other perennials, tea is unique because only its vegetative parts-the two leaves and the bud-are commercially exploited. Tea is also maintained as a low bush in a continuous phase of vegetative growth. Both these aspects call for manipulation of plant parts for optimal productivity and growth. The terminology of plant parts of tea is also somewhat unconventional and may not always fit standard botanical descriptions.

The term ‘flush' describes the growth by the apical bud between two successive phases of dormancy, which in effect means that a bud passes through alternate phases of growth and dormancy. The phase of dormancy or resting period of the shoot is *banjhi* phase, and the apical bud is then described as the *banjhi* bud. The bud in *banjhi* phase is extremely small, blunt without the usual closely serrated margin and is closed by two (rarely more) bud scales or cataphylls called the *janams* (Fig. 4). The position of *janam* or fish leaf on the shoot is of great importance in considering the standard of plucking.

Tea Flowers and Reproductive Phase

The tea flower buds (Fig. 6) appear in the axils of scale-leaves on current season's growth of shoots. The axil buds shed minute bud scales, at the axil of which flowers are borne. Flowers which appear in the axil of a leaf are actually inserted into the axils of the cataphylls of the axillary bud. Each cataphyll axil bears one or two flowers. In the initial stage of the growth of a flower, two or more outgrowths or bracteoles enclose the flower on the pedicel or stalk. These bracteoles are alternately arranged on the same side of the pedicel, though sometimes they may even be placed on the opposite side.

Dormancy

Tea enters into a phase of dormancy during the winter (December-January) months in north-east India (Assam and the Dooars), but not in countries close to equator. Dormancy occurs mostly due to short day-length, though a combination of short day-length and low atmospheric temperature appears to be equally crucial.

Tea Gene Pool

Cytotaxonomy and Chromosome Numbers

Most species of the genus *Camellia* appear to maintain a comparable chromosomal structure and numbers (Table 2) suggesting they might have arisen from the same basic genome. In most species, particularly in the three principal tea varieties, diploid chromosome number is 2x = 30, but a seed population, originating in Vietnam, was a triploid with 2x = 45. Even in some wild populations of *Camellia (C. caudata, C. kissi* and *C. irrawadiensis*) diploid chromosome numbers are the same as in cultivated varieties, that is, 2x = 30. But one species, *C. sasanqua,* appears to be a hexaploid in having 2x = 90. An interspecific hybrid between *Camellia sinensis* (tetraploid 2x = 60) and *C. japonica* (2x = 30) produced a diploid 2x = 30

suggesting a strong genetical basis for production of interspecific hybrids with the optimum chromosome numbers, involving distinct geographical races.

### Wild Populations of Tea

The extent of genetic variability in natural tea populations is not clearly known. This apart, tea being grown in one way or the other for about 3000 years, it is difficult to say if wild tea still exists. The geographical distribution of more important *Camellia* species (Table 4) suggests possibilities of existence of wild varieties in the region bordering Assam-Burma and China. Wild tea was also thought to have existed in the hills of Assam, Nagaland, Mizoram, Manipur, Burma and China, but the so-called wild patches of tea could also be the abandoned tea, left behind by migratory tea drinking tribes in the course of their movements.

# Selection, Pollination and Propagation

As pointed out in the earlier chapter, the enormous genetic potentiality in tea breeding is revealed by the phenotypic variation in tea populations. Tea is bred for quality and yield, yet the mutants of agronomical significance to plant breeders are still unknown. Nevertheless, the progenitors of most of the existing cultivars can be traced to one or the other of the wild or semi-wild tea plants. Although an element of subjectivity cannot altogether be avoided in selecting the parents, as indeed the mass or random selection method implies, a more systematic approach in tea breeding was the application of the techniques of line-breeding involving selection for specific characters of importance. The latter essentially involves maintenance of each ‘selection' with discernible features separately to establish a new seed *bari (bari* is equivalent to orchard) which would form the nucleus for further selection.

### Development of Seed Varieties

A very basic problem in the early stages of tea breeding was whether or not all plants from which a product was manufactured and traded as tea were indeed identifiable with *Camellia sinensis* (L) O. Kuntze. Though later studies showed that tea as a consumed today is produced only by the three varieties of *C. sinensis,* but because of the wide heterogeneity of the plant, it is difficult to achieve isogenic single crosses between plants differing in specific morphological features. The situation became more complicated because seeds from more than 100 seed orchards having seeds of diverse origins were used in raising the cultivar varieties. The net result was that populations raised from these seeds were extremely heterogeneous and yield levels were always not very high.

### Vegetative Propagation and Development of Clones

Plant improvement by seed had been the standard practice in India and in most tea growing countries, but the great variation found in seedling populations made the breeders aware of the advantages of clonal propagation for establishing large and uniform populations. Possibilities of propagation by cuttings were explored by Tunstall but standardisation of the technique took another decade or so. The utility and possibilities of using this technique in producing cultivars resistant to blister blight were also explored. But the well-proven fact that a major part of the yield of an individual field is contributed by a relatively smaller member of bushes, turned the attention of breeders towards evolving methodologies for rapid propagation of these high yielding seed grown plants.

### Selection for Yield and Quality

In selecting cultivars for yield from large yielding established bushes with well-established frames, good flushing behaviour is also needed to be identified from seedling populations. Seed varieties therefore provide the basic genetic materials for selecting clones by vegetative propagation for high yield and quality potentials. Although visual selection for morphological traits of some agronomical value has generally been successful in selecting genotypes for clones, chloroform test and theaflavin analysis have also been varyingly successful. In this procedure for selecting basic plants for developing high yielding clones, the morphological attributes continue to play a major role, with little or no consideration being given to the

effects of soil variation or interplant competition, all of which could be crucial in plant growth and production dynamics.

Hybridisation

Natural hybrids between the two main varieties of tea, that is, Assam and China were earlier in common use. These hybrids were designated the genetic base of the cultivars. Also efforts towards production of a homozygous pure line of tea by inbreeding were not particularly successful because of extremely low percentage of seed-set under selfing. This was further compounded by the emergence of a large number of segregates from the selfed population and this made the proposition rather unviable.

A major problem in tea hybridisation is the inherent difficulty in predicting the genetical base of yield and quality from the offspring resulting from the recombinations of matings. Although quantitative inheritance of calcium oxlate crystal frequency of the leaf petiole and partial dominance of China variety over the Assam variety are known, it is generally believed that many morphological features are polygenic and are inherited quantitatively.

Interspecific Hybridisation

Although intraspecific hybrid categories are known in tea natural interspecific hybridisation between different species of *Camellia* are not common. Certain cultivated populations of China hybrids were supposed to have had either *Camellia irrawadiensis* or a *Camellia* species close to *C. irrawadiensis,* as one possible progenitor, the other being *C. sinensis.* Chromatographic evidence of chance hybrids between *C. irrawadiensis* and *C. sinensis* var. *assamica* also exists with possibilities that uncontrolled crossing occurred between *C. irrawadiensis* and *C. sinensis.* The plant types that possibly originated from these free interspecific crosses had many morphological features that did not always indicate their origins, though in some cases biochemical characteristics, particularly distribution of polyphenols, helped in differentiating their phylogenitic relationships.

Polyploid Breeding

The objective of polyploid breeding is to induce more vigour and a degree of resistance than is possible to achieve with the existing diploid tea plants (2n=30). But the problem of polyploid production is complicated in tea because of extreme heterogeneous nature of the plant due to natural hybridisation between geographical races (mentioned in the earlier section Table 3). Nevertheless, open-pollinated progenies often produce natural diploids, triploids, tetraploids and aneuploids. But tetraploids are not of very high quality; therefore efforts were directed more towards the production of high quality triploids by controlled hybridisation between natural tetraploids and high quality diploids. The triploids thus produced were superior to normal diploids in their rooting ability, leaf size and dry weight.

Mutation Breeding

This technique could be used to induce variability in those genetic components that are primarily responsible for yield, that is, mostly for multigenic characters. Likewise, the quality components of the cultivars could also be increased by mutation breeding, provided the genetic basis of yield and quality are known. This technique has immense potentiality in tea breeding, yet in the absence of basic genetic information, it has been of little consequence so far. The technique also needs improvement and modification to be more specific to tea, and it is essential to identify the foci of the genes to be ‘bombered' to achieve mutation. Once again, underlying the development and application of this technique is the knowledge that specific traits of agronomical importance fundamentally result from the expressions of discrete regions of the DNA molecules present in each cell.

Tissue Culture and Genetic Engineering

The technique of tissue culture has opened possibilities for widening the genetic base of tea, as it helps in selecting and isolating useful mutants from cultures for their eventual utilisation in the development of clones. By tissue culture it is often possible not only to obtain a large number of clonal plants from high

quality mother bushes, but it also induces organ differentiation in excess callus, which is a common phenomenon in many a single node cutting. Another advantage of tissue culture technique is that suitable mutants for quality and resistance to pests and diseases could be screened within a very short time.

### Breeding Strategies

The large number of tea varieties in various germplasm collections suggest the wide genetic diversity of the base population from which known cultivars of tea were selected. The subsequent variation that appeared in cultivars was possible due to spontaneous or natural mutations of major genes conditioning their yield and other characteristics, though hybridisation also greatly contributed towards conditioning of the plants. However, because of its self-sterility, breeding of pure line in tea by hybridisation had not been possible. Hybrid progenies (seed plants) resulting from crosses between clones with desirable characters show a fair measure of morphological uniformity, yet retaining a measure of genetic diversity. Thus, a clone-seed-clone cycle helps in maintaining the genetic heterogeneity, but breeding is basically concerned with development of cultivars, which under the circumstances of climate, soil, cultural practices, and pest and disease incidence, would give maximum economic returns.

# Characteristics of Soil Biology

Tea grows well within the range of ideal physical and environmental conditions, which include soil. Yet, heterogeneity in soil and climatic conditions under which tea is grown is fairly wide, suggesting strong adaptability of tea to physical aspects of the environment. Thus, though tea grows ideally on soils with pH varying between 4.5 and 5.6, on many sites having pH more than 5.6, tea appears to grow well. Acidity within the correct range is, however, not the only requirement; necessary nutrients must be made available to tea plants at a reasonable level in appropriate proportions. Utilisation and absorption of nutrients are dependent on the ideal acidic status of the soil; the more the intrinsic nutrient level of the soil departs from the optimum because of soil acidity-conditions, the more will it affect the productivity of tea.

### Origin and Characteristics of Tea Soils

Despite the need for the idealised physical and soil conditions, tea is grown as a monoculture over a large area (for example, from the extreme end of upper Assam to the border of Nepal), where land cannot be topographically or geologically alike; and hence the element of heterogeneity in the physical and chemical attributes of tea soils. The alluvial deposits laid down by rivers like the Brahmaputra (Assam Valley), Barak (Cachar Valley) Toorsa and Teesta (Dooars) during the recent geological times form the tea soils in north-east India as we know them today. Depending on the nature of the detritus as well as the mode of its deposition and time-lag since deposition, several layers of alluvia in tea soils can be recognised.

### Soil: Physical Properties

Ideally, deep soil provides the perfect condition for root proliferation, which shows a marked seasonal variations. Greater volume of root proliferation which is possible only with deep soil, brings more nutrients and water within the range of the roots, but the size of the soil particles basically determines whether the soil is light, medium or heavy (Table 3), and their suitability or otherwise for the growth and proliferation of roots.

An associated requirement is that soil structure should be such that water from the peak precipitation is drained away quickly from the root zone. However, this capacity, as well as permeability, varies according to soil types (Table 4). Heavy clay soils, for example, permit slow drainage and lead to accumulation of more water and hence restrict the growth of roots.

### The Basis of Soil Nutrition

In a broader sense, a measure of fertility of a soil is the amount of nutrient it can make available to the plant growing on it. Therefore, the objective of soil analysis in relation to fertility assessment is to quantitate the amount of each major nutrient available to the plant. The potential of a soil to absorb major nutritional

‘bases' is known as the cation exchange capacity (CEC), which is the fundamental basis for determining the nutrient status of tea soils. The rupture of crystal structures of the particles which form the soil, basically leaves free electric charges on the surface of these particles. The negatively charged ions (anions) are absorbed when there are positive charges, and positively-charged ions (cations) are absorbed when there are negative charges.

Soil Acidity

There is a limit to pH values of the soil in which tea will thrive and grow well. Tea grows well between 4.5 and 5.6, though there are extreme cases of tea growing even at 4.0, the lowest level attainable without the presence of free acid. Tea is an aluminium accumulator, though the role of aluminium in the relationship often to acidic soils is not known, except that soils on which tea is grown are rich in sesquioxides of iron and aluminium. Aluminium content of tea may be 17,000 parts million, but what the plant does with such a huge reserve of aluminium is not known; it may play some role in nutrient economy of tea, perhaps in respect of toxic ions like manganese though this needs confirmation. Where soil pH values are around 6.0 and 6.5, the exchangeable aluminium in the soil sharply declines, and can be extracted only with great difficulty.

Soil Physical Properties

Physical properties of soil affect root growth and hence productivity, apart from controlling soil moisture and conserving soil fertility. Some major aspects are:

Soil Aggregate

Soil aggregate refers to the degree to which individual soil particles are grouped together to form aggregates. Aggregation has a pronounced effect on such soil properties as erodibility, porosity, permeability, infiltration, and water holding capacity. In general, the greater the aggregation of tea soil, the lower its erodibility. The presence of large aggregates (> 0.5 mm) increases the amount of pore space in the soil, particularly the aeration porosity. Thus aggregation is highly desirable in tea soils, but the degree of aggregation depends to a large extent on the extent of organic matter present in the soil.

Physical Environment

Rainfall

The causal relationship between tea growing and rainfall is well-known: tea grows well in areas having a precipitation of about 1,150 to 8,000 mm. The effect of rainfall is perhaps more manifested by its influence on moisture status of the soil and in inducing vegetative growth. Therefore, distribution of rainfall is as important as the total annual rainfall. The intensity of rainfall is the rate at which it falls at any time (expressed as inches or mm per hour); initially rainfall intensity increases linearly till it reaches the peak after which it decreases slowly (Fig. 2). The crop distribution pattern does not, however, always correlates with the main rainfall period; it thus becomes difficult to say what exactly is the water requirement of tea in different phases of its growth and development.

# Nutritional Requirements

Recommendations on tea manuring are mostly based on the results of long-or short-term agronomical experiments; they do not generally consider the physiological attributes, like the nutritional needs of different tea cultivars nor the effects of differential pruning, plucking, age and dry-matter production. The biological variables in tea are too many, and it is difficult to sort out or rank them in order of their importance, especially in their relative importance. Yet the most logical approach would be replenishment of the nutrients consumed by the crop and those lost in the soil by leaching and other means. In drawing this balance sheet, allowance should be made for the nutrients recycled by pruning litter, tea leaf droppings and shade tree droppings. Tea flush normally contains 5 per cent nitrogen, 1 per cent phosphorus and 2 per cent potash (Table 1), but when this level is exhausted these three major nutrients may affect the entire

dynamics of crop productivity.

## Nutrient Composition of the Tea Plant

Among essential elements, oxygen, hydrogen and carbon are obtainable from air & water & need no specific consideration. The other 13 essential elements are not adequately present in the soil and need to be supplied. Tea being a vegetative crop, the concentration of N is the largest of all the various elements. When the tea bushes are pruned, the pruning litter of mature foliage and thin branches is retained in the field, and the elements in the litter are thus recycled.

## Assimilation of Various Nutrients by Parts of the Plant

Assessment of the distribution of dry matter among the different parts of the tea plant in a pruning cycle indicates that about 10 percents goes for pluckable shoots, 18 percent for mature foliage, 12 percent for small steam, 35 percent for thick wood, and 25 percent for root. Nitrogen is assimilated in the largest quantity, followed by K, Ca, P and Mg, among the major nutrients. This provides a valuable guide to the total amount of various elements required for producing a certain amount removed and recycled in the plant system. The nutrient requirements vary with the severity of pruning operation and the year after pruning.

## Individual Nutrients

### Nitrogen

Nitrogen is the most important element required by tea and accounts for about 4 to 5 per cent of the dry weight of the shoots harvested for manufacturing tea. Nitrogen is also needed to induce more vegetative growth and reduce, the reproductive phase. Pruning and plucking also provide the stimuli for new growth for which nitrogen is essential. It is therefore only to be expected that tea would freely respond to nitrogenous manuring. Long-term, experiments in the different tea growing countries do not give a very clear picture about nitrogen requirements of tea, though a moderate dose (up to 135 kg ha-1) gives yield responses that are proportionate to the amount applied, with no indication that the law of diminishing return is operating at this level.

### Basis of Nitrogen Absorption and Uptake

A major cause for the variation in nitrogen response in different tea growing areas can be related to soil characteristics, particularly those aspects concerned with the process of mineralisation and rapid conversion to nitrate by nitrification. The chemical form in which nitrogen is added to tea soils is either as sulphate of ammonia (20.6 per cent nitrogen) or as urea (46.0 per cent nitrogen), but by mineralisation of immobilised soil nitrogen it is ammonia (Fig. 3). Soil microorganisms convert urea to ammonia utilising enzyme urease; the ammonia is then converted into nitrite by nitrification. Depending upon soil conditions, nitrate may be taken up directly, or may be leached from the root zone.

### Phosphorus

Phosphorus plays a major role in the growth of tea plants, especially the young plants, and tea soils are fairly rich in phosphorus. Yet its role in improving tea productivity did not receive adequate attention, though regional responses were discerned. This was so because traditionally in Assam phosphate application was restricted to once in three years, that is , during the year of pruning at the rate of 20 kg P2 O5 ha-1. In contrast, in south India phosphate is applied by placement annually, and depending on the length of cycle, the total quantum may vary between 160 and 270 kg P2O5 ha-1 y_1. Recently, however, there is a trend that phosphate could indeed be an annual requirement in north-east India, though actual quantum needed would vary according to soil phosphate status and interactions of phosphate with two other major nutrients, that is, nitrogen and potash.

### Zinc

Zinc virtually occupies a position between macro and micro-nutrients which are essential for growth and productivity of tea. For most situations zinc is considered to be an essential element for tea, and its importance in sustaining tea productivity is well-established. Zinc deficiency reported from Sri Lanka was

mostly due to limited zinc reserves in soils and non-replacement of loss of zinc with crop removal, particularly in areas with high yield potential. Application of zinc is a standard practice today in most tea growing countries, though dosage varies. In south India for example, zinc is applied at the rate of 11.25 kg zinc sulphate ha-1 in five splits (each of 2.25 kg ha-1) in the second and fourth years field. In north-east India, zinc sulphate is applied at rates varying between 12.5 and 20 kg ha-1 yr_l depending on soil conditions, but tea under all forms of skiffing (light, deep and level of skiff) responds well to zinc application.

# Growth, Photosynthesis and Respiration

In exploring the dynamics of tea productivity, the term yield is used in a very general way as an integrated expression of growth and development; perhaps it is not the best way to do so. For example, much growth that takes place on the top hamper following pruning but before tipping, is not reflected in yield measurements. Moreover, all the new leaves that are being formed throughout the pruning cycle are not harvested and recorded as yield. The other aspect is the root growth which is usually not considered in any expression of productivity though root functioning is essential for productivity. This apart, the alternating flush and *banjhi* periods complicate the true interpretation of yield data, particularly if measured over a shorter period of time.

Carbon Input; Sink Source Ratio

The importance of carbon input in tea productivity can be appreciated from the fact that 95 per cent of dry weight of plant is derived from photosynthesis. Therefore, increase in net photosynthesis and more efficient partitioning is the most logical step for increasing productivity. Nevertheless, two aspects have a considerable bearing on any effort towards increasing net photosynthetic rate. Firstly, tea is sink-limited and secondly it is a C3 plant, that is, the first stable product of CO2 fixation contains three carbon atoms. Photosynthetic assimilates move from mature foliage which is the source where they are produced, to sites where they are consumed, which are the tender stems and shoots, the roots and stems (the sinks).

Limitation of CO2 Assimilation

Although the photosynthetic rate of detached tea leaf is around 13 mg CO2/dm2/hr, photosynthetic carbon dioxide uptake by leaves is saturated at iridescence about one-fourth of full sunlight. Moreover, carboxylation reaction or physical diffusion resistance may also limit the rate of photosynthesis by tea. By increasing the carbon dioxide concentration from that normally found in air, CO2 uptake by teagenotypes increases and net photosynthesis may also increase as ‘sinks' are formed. A decrease in the photosynthesis is not uncommon when the ‘sinks' are removed, such as it happens when tea shoots are picked at short intervals.

CO2 Assimilation and Light Limitation

In most crop canopies photosynthesis increases with increasing light right up to full sunlight, but in tea net assimilation rate drops sharply below 50 per cent of full daylight, the compensation point being 0.02 g calories cm-2 min-1. Tea cultivars with diverse leaf pose also show varying responses to natural light. The erect China types are highly light limited, bull the semi-erect Cambod varieties are the least light limited. Howevermore than visible light alone, it is the infrared portion of the light spectrum that affects photosynthesis by interacting with leaf temperature Thus, tea leaves in full sun may reach a temperature of 40° to 45°C whereas shading causes an immediate drop in leaf temperature to ambient ± 1-2°C. This temperature response ties up with photosynthesis which declines sharply at leaf temperatures above 35°C but between 39° and 42°C it virtually stops. Therefore, leaf temperature above 35°C is too critical for photosynthesis by tea leaves. The paradox is that both full sun and full shade inhibits photosynthesis-the former by overheating of the top layer of canopy and the latter by reducing the light intensity as it happens in the lower canopy of tea.

Regulation of Photosynthesis

Oxygen has an inhibitory effect on net photosynthesis of tea because of its stimulatory effect on photorespiration. Generally, any significant increase in oxygen in atmosphere from 1 to 21 per cent inhibits photosynthesis by about 35 per cent, though this inhibition is reversed by increases in $CO_2$ concentrations. Light-limited nature of photosynthesis in tea suggests that it is the interaction of oxygen with light reaction which is of importance because only a decrease in photorespiration cannot account for the total increase in the light-limited photosynthesis by tea leaves.

Regulation of Photosynthesis by Transport and Partitioning

Tea is sink limited primarily because of repeated plucking which creates an artificial limitation to growth. The sink effect also involves interactions of several hormones like indo-leacetic acid, cytokinins and gibberellins. Increased capacity of the sinks to accept photosynthates also increases net photosynthesis, and the resultant activites of the competing sinks may influence the partitioning of photosynthates among plant parts. Once out of the source, that is, maintenance foliage, the photosynthates are partitioned among all competing sinks, but as stated earlier, the unopened bud is the strongest sink and the sink capacity declines with unfolding of new leaves. The basis for distribution of photosynthates to sinks in tea is however poorly understood, though it is possibly more temperature sensitive than photosynthesis itself.

Effect of Leaf Age on Photosynthesis

It is of interest that though young expanding tea leaves are photo-synthetically more active, they are dependent on mature leaves for their sustenance. Photosynthetic efficiency of a leaf is maximised when it is about four weeks old and the efficiency is maintained optimally for about six months. Radioactive carbon (14C) studies show that though the young third leaf from the bud (Fig. 2) is capable of fixing carbon dioxide, it has to depend on importation of photosynthates from the mature lower leaves to grow and respire. In transporting photosynthates, the topmost layer of the maintenance foliage contributes the maximum followed by the successive lower layers of leaves in sequence, but the fourth leaf is relatively more efficient than the second and third leaves possibly because of a vascular connection between the top and the fourth leaf.

Photorespiration and Dark Respiration

Respiratory losses of carbon are extremely high and these are mostly wasteful. Decreasing respiration would result in increases in net photosynthesis because respiration generally consumes 30 to 70 per cent of the net carbon assimilated during photosynthesis. In theory, regulation of photorespiration appears to be a practical means of obtaining large increases in carbon input and yet success depends much on solutions of some important problems about the process and control of photorespiration. The most important of these is the causes of variation in respiratory losses in tea cultivars, though they are least in detached leaves. Secondly photorespiration in tea in bright light is much faster than dark respiration at a temperature higher than 25°C. At the atmospheric level of oxygen and carbon dioxide, photorespiration is 19 per cent of photosynthesis.

# Nursery Management

Nursery Management

In any long-term project on cultivation and in planning for high productive levels, better plants are essential imperatives. But a good plant can be developed and grown only under a regime of good agro-management in the nursery, till it is transplanted to the field. Therefore, a nursery must not only provide the most optimum conditions for growth of the plants but the chosen sites should also be convenient for the area to be planted to minimise any damage to the plants during transit, and indeed minimise transport cost. It should be reasonably levelled with no risk of waterlogging during heaviest of rains. The soil should be chemically suitable with a good structure. A deep top soil normally ensures a good depth of fertile soil in the bed. A useful nursery requires all weather access, shade, drained beds and water.

## Planting

### Land Preparation

The essence of land preparation is to ensure adequate protection from soil erosion, good cultivation for optimal root development and adequate shade to protect the exposed soil and young plants. This apart, if the land suffers from serious waterlogging, it should be adequately drained as well. The method of clearing land and the amount of work involved depend on initial vegetation. The land should be ploughed and disced to destroy the roots of small plants as in many cases they act as focuses for future pathogenic infection. Complete clearance may need more that one operation, which is worth doing because once tea is planted the land may not be available for any amelioration or soil management programmes for the next few decades.

### Planting Density

It is difficult to generalise on the number of plants ideal for a ha of land because uncontrollable variables are too many and too diverse. For example, a ha of poor soil will need more plants, and if soil is good but plants are small framed the necessity would again be for more plants per ha to achieve a good ground coverage. Another important aspect in deciding on bush population is that unless the gap between the hedges is 120 cm in plains or 90 cm in hills and the centre of the hedge is conveniently reached, plucking productivity will be low. Yet closeness of planting is an important determinant of yield and the trend all over is to go for more bush population per ha, though a norm remains to be developed.

### Field Planting

From all accounts planting is a most crucial operation as it basically determines the development and productive level of tea throughout its economic life. Wrong planting of good planting materials is doubly unproductive as investment is lost both on account of producing the plants and in the failure to put them up for productivity. Therefore, care, planning and refinement of techniques are essential for long-term benefit. The very fundamental to planting, apart from good planting materials, is that the planting hole should be of adequate size. The size of the hole partly depends on the consistency of the soil but a diameter of 45 cm and a depth of 75 cm is ideal (Fig. 2); the hole could be dug in three phases-the first phase is dug to 15 cm involving cutting of top soil with a hoe and placing it separately; the second phase involves digging up to 30 cm which involves subsoil layer-the excavated portion is also maintained separately. In the third phase the balance 30 × 15 cm across is loosened with post hole auger or deep forking. The size of hole also depends on the consistency of the soil but in general a standard size of 45 × 75 cm ought to be maintained.

### Planting Operations

The age at which plants are removed from a nursery varies, and generally, plants between nine and 12 months are used; the exact age is determined partly by the local conditions of growing. Plants remaining in a nursery for more than one year become large enough to be stumped though this is not the general practice in north-east India. In deciding the time of planting, the most important consideration is that young plants must have the longest possible time to establish themselves before adverse weather sets in. Generally, too dry a period is avoided; in Assam and the Dooars June-July is preferred. If soil is sufficiently moist, planting can be done during September-October. Such plants will be sufficiently developed to withstand subsequent dry spell.

### Bringing up of Young Tea and Bush Formation

When a young plant is established in the field it is essential to train or modify it to form a low bush of good spread and of convenient height for plucking. The essence therefore is to establish a good frame and ensure a good coverage of ground within the shortest possible time. According to a recent finding this is achievable either by decentring and pruning, or by bending or pegging, or by a combination of decentring and bending. Each of these systems has its drawbacks and advantages but they arebasically based on manipulation of branch growth rather than on an extended principle of growth physiology.

# Theory of Pruning, Plucking and Maintenance Foliage

## Theory of Pruning

Perhaps from a productive point of view no field operation is as important as pruning is, as it basically helps in maintaining the plant as a low bush in a phase of continuous vegetative growth. Pruning therefore is considered as "at best a necessary evil" as it both stimulates and controls growth.

Plant variety, environmental factors and general growing conditions affect the measure necessary to maintain a particular pruning system. Although the essence of pruning system is to maintain an optimum amount of wood, so that, the plants remain in a steady state of productivity, very little is known of the physiological and biochemical basis of pruning. Basically, a pruning system is determined from the balance of growth of the plants in relation to their productivity, particularly potential or expected levels of yield. Pruning must therefore consider its effect on the plant as a whole and maintenance of an adequate food reserve because pruning itself removes a part of food in circulation within the plant.

## Types of Pruning

### Collar Pruning

Collar pruning is the severest form of pruning, requiring as it does, cutting the bole of the bush near or at the ground level. In some cases, the cut may even be given slightly below the ground level to ensure protection of the exposed tissues against die-back. Recovery from this severe form of pruning is greatly influenced by carbohydrate reserve. By and large, collar pruning is suitable for tea that is characterised by a well-marked dormancy period. The main objective is to provide a new frame to the plant by removing old and unproductive branches affected by diseases and pests, particularly in situations where up-rooting of unproductive bushes is not possible. Tea recovering from collar pruning also needs special care and management.

### Medium Pruning

The main objective of medium pruning is to reduce height of the bushes, so that, they do not exceed 80 cm. Continuous picking of shoots on the top of a bush gradually increases the height of the bushes, apart from causing congestion on the top with weak and twiggy branches. This apart, with age, the unproductive wood accumulates on a bush causing a drain in the physiological resources which otherwise could have been utilised for increasing productivity. Therefore, to bring back the plants to a productive level, stimulate new wood and renew maintenance foliage, medium pruning becomes a useful means. Though relatively less severe than collar or heavy pruning, medium pruning is generally not done below 50 cm, and certainly not lower than what is necessary to remove the knots and congested top.

### Top or Light Pruning

This is the standard method of recurring pruning in Assam and the Dooars. The main objective of this pruning is to renew the leaf bearing branches, apart from cleaning out the bush. Normally top pruning is done 2 to 3 cm above the last prune; in effect this system of pruning leaves a considerable amount of foliage on the plants though much of it defoliates naturally; but under certain conditions of growing this foliage may even remain intact and carry on normal physiological functions. The technique of light pruning therefore essentially involves a uniform cut-across followed by a cleaning out operation to remove thin unproductive branches and dormant shoots.

## Choice of Pruning System

The pruning system chosen must ideally be related to growth characteristics of plant types, general health of the bushes, Quality and quantity of crop needed. The other related but important factors that need consideration are soil-climatological conditions and susceptibilities to pests and diseases. With so many interacting factors in operation, it is often difficult to generalise anything on an ideal pruning system, but it is perhaps reasonable that crop requirement, crop distribution and crop quality are the important attributes of

an ideal pruning cycle.

Leaf and Bud Dynamics

In common with other plant species, tea leaves unfold and grow early leaves are essential for shoot elongation and it is likely that their assimilates are also channelled towards elongation. The dynamics of leaf production is dependent on the production rate of bud. Factors, such as, vigour, water supply, light intensity, temperature, pathogens and herbivores influence production of buds and unfolding of the leaves. For example, with a reduction in temperature, leaf period increases, but other factors may be equally consequential and simultaneously effective.

Plucking

Plucking or picking denotes harvesting of tea crop. Plucking of young shoots, the two leaves and buds, is an intricate art consuming about 15 per cent of the total cost of production of tea and much of the quantity and quality of harvested crop depends on the standard of plucking. It involves removal of young growing shoots comprising the apical bud, the internodes and two or three leaves below it, which together constitute the crop. The tender shoots removed are the sinks as they cannot support their normal growth.They are harvested at regular intervals to stimulate successions of a new crop of shoots. The growing shoots in turn are dependent on the assimilates from the mature foliage where they are produced, that is, the source.

Plucking System

A plucking system is ideal only when it is based on growth of shoots. This growth rate varies with plant types or nature of the cultivars, conditions of growing, and general environmental conditions, particularly temperature and humidity. When growth rate is fast *'janam* plucking' or plucking up to *janam* is practised, that is, young shoots consisting of two to three leaves and growing apex are broken back to a horizontal surface (previously fixed by tipping) at the level close to *janams* or cataphyll.

# Diseases of Seeds and Cuttings

Fungal disease of tea plants have been reported from the very beginning of planting, for over 150 years. For a monoculture, abundance of pest and disease is not uncommon, but diseases of tea are rather numerous and they specialise attacking different parts of the plants, such as, leaves, stems and roots. Though the incidence of disease is generally high in older tea, younger teas do not altogether remain free from attacks by pathogenic fungi. In the first ever comprehensive report on tea diseases, only about 12 fungal diseases were mentioned and this rose to 17 later. While Ramakrishan added 18 more species to the list, it is fairly known today that about 385 species of fungi occur on tea world over, of which just about half occur on tea in north-east India.

Diseases of Tea Seeds and VP Nursery diseases

Mature tea seeds are often afflicted by a mouldy growth inside though outwardly they may appear normal. The mould inside usually infects the rudimentary cotyledons, apparently without causing any perceptible damage, but sometimes the infection may even reduce the cotyledons and the embryo to a shrivelled mass. An infection of this magnitude greatly reduces the vitality of the seeds, most of which fail to germinate. The moulds involved in the seeds are mostly common species of *Penicillium;* the etiology of their damage being comparable to that of the decay of ripe fruits.

In Sri Lanka the disease is mainly confined to the tea belt in the northeast monsoon zone, but in South India the occurence is unrelated to monsoon pattern. Diseases are a legacy of jungles and spread in tea fields which are planted after clearing the jungles. One group of estates in southern India reported uprooting about a hectare of tea every year because of these diseases. A survey in tea estates in wynaad revealed the existence of over 700 line root disease patches.

Leaf Diseases

Red rust disease caused by the alga *Cephaleuros parasiticus* Karst was reported first by Cunningham, but

its widespread occurrence and symptoms of infection and economic significance were reported later by Watt. Spores of red rust are common almost throughout the year and most come from collateral hosts which are plenty in tea areas. However, red rust is a disease of weak plants; unsound cultural practices aggravate and encourage the disease. Adequate manuring, proper stands of shade, drainage, safeguard from pests and other diseases - all aimed at improving the bush health are essential for prevention of red rust infections.

Though red rust is a secondary disease, at times it could be serious enough to cause extensive die-back of the stems of young tea during its formative stages. Apart from the predisposing factors like poor drainage, lack of soil fertility, low potash status of the soil, lack of shade, use of wrong green crop or lack of proper soil rehabilitation, are some of the predisposing causes; some tea cultivars are particularly prone to red rust attack. These cultivars should at best be avoided in areas liable to suffer from drought and waterlogging as both encourage red rust infection.

Stem Diseases

Thorny stem blight, common in Darjeeling and the Dooars, is caused by *Tunstallia aculeata* Agni; an allied disease was reported earlier from Sri Lanka. The disease occurs rarely in the plains of Assam although the effect is more pronounced in Darjeeling. Two distinct variants of *T. aculeata* based on characteristics of ascospores (spore-bearing sac) are known and both are pathogenic. The disease is also known as *Aglaospora* in Darjeeling. The pathogen enters the stem through pruning cuts, then spreads downwards killing the branches in the process; finally, the pathogen reaches the collar and then into the roots, when the plant is killed. Unlike black rot, this fungus generally does not produce any external mycelium, but produces fructifications on the bark in the shape of black pointed projections. Affected parts of the stem and branches have the characteristic black patches and lines, though very rarely dull white stands of mycelia are noticed when the bark is peeled off.

Root Diseases

The soil-borne fungal pathogens causing primary root disease include *Ustulina zonata* (Lev) Sacc. (Charcoal stump rot); *Fomes lamaoensis* (Murr) Sacc. and Trott. (Brown root-rot); *Rosellinia arcuata*(Petch) (Black root-rot); *Armillaria mellea* (Vahl ex Fries) Kuman *(Armillaria* diseases); *Poria hypolateritia* (Berk) Cook (Red root-rot); *Hypoxylon asarcodes* (Theiss.) Mill (Tarry root-rot) and*Helicobasidium compactum* Boedign (Purple root-rot) are common all over. But black root-rot *(Rosellinia arcuata* Petch) and *Armillaria* root-rot are confined mostly to the hills in Darjeeling and Sikkim.

Primary root diseases cause extensive damage to tea, resulting not only in immediate crop losses but functional physiology of the bushes is also affected. These pathogens spread subtly by direct contact between infected and non-infected roots. Moreover, if bits of infected roots are left in the ground following uprooting of infected plants, they may also serve as potential sources of infection.

Strategies for Controlling Diseases

In the absence of reliable methods for quick detection of primary root pathogens, particularly in the early stage of infection, very often these diseases are not detected until the whole plant or parts thereof die suddenly. The problem is further compounded because a bush infected on lateral roots only partially, may present a normal appearance for several years despite the death of infected roots. Despite partial infection plants are capable of continuing their physiological functions until the disease becomes all pervasive with the corresponding losses in yield.

# Pesticide Management

As a long-lived woody perennial and monoculture, tea provides a stable microclimate and a continuous supply of food for rapid build up of phytophagous species that include insects, mites and eelworms. This accumulation takes place rather rapidly, enabling the phytophages to reach an asymptote level within a

perceptibly shorter time of about 40 years-a situation not known for any other monoculture. Even the shade trees have their own share of pests but their life systems are altogether different from those of the tea pests.

Crop Losses

An accurate assessment of crop loss is difficult because the intensity of attack varies seasonally depending on climate, altitude and cultural practices. But the loss due to red spider mite, *Oligonychus coffeae*(Nietner), varies between 6 and 11 per cent in the Dooars, and 5 and 7 per cent in Assam. A steady loss of 10 per cent due to overall pest attack is a generally accepted figure though it could be 40 per cent in devastating attacks by defoliators.

Mite Phytophagy

Mites are the perennial pests of tea. Out of the 12 species recorded the more important ones are *Oligonychus coffeae* (Nietner) (the red spider mite), *Brevipalpus phoenicis* (Geijskes) (the scarlet mite),*Acaphylla theae* (Watt) Keifer (the pink mite) and *Calacarus carinatus* (Green) (the purple mite). These four species are present on tea at varying density levels almost throughout the year. They start increasing in numbers from March and their population peaks between April and July; thereafter, with the onset of the monsoon, their numbers decline being mostly washed down. A second but small peak may develop during October-November. Each species produces characteristic symptoms of damage without overlaps; their diagnosis is essential for the selection of specific acaricide as all are not broad spectral in their actions.

Stem Borers

The stem of mature tea is often bored by the cerambycid, *Haplothrix griseatus* Gah. The larva tunnels through the branches to reach the main stem. In the process, the affected branches become unproductive and eventually they die-back. The shot hole borer, *Xyleborus fornicatus* Eich., is a major pest in Sri Lanka and in south India but is rare in north-east India. A crop loss varying between 18 and 40 per cent due to severe infestation is not uncommon. The damage is caused by the female which constructs galleries within the branches in which eggs are laid. The larvae do not extend the gallery any further, but feed on the mycelia of the fungus *(ambrosia)* growing on the walls of the gallery; pupation also takes place within the gallery. The newly emerged adults mate within the galleries. The female then emerges through an exit hole, attacks a fresh branch, constructs fresh galleries and transplants *ambrosia* fungus on the wall of the gallery. Eggs are then laid and a generation starts. The life cycle completes in about 40 days.

Pesticide Specifications for Tea

The seasonal appearance of pests needs timely management of pests mostly by use of pesticides. Pesticides in tea must not be phytotoxic, should in not way taint the aroma of tea (such as BHC does) or leave residues in manufactured (black) tea. Residues of pesticides from sprayed leaves to manufactured tea must not be carried in quantities large enough to create consumer hazards. It is therefore essential to maintain a balance between pest toxicity and mammalian toxicity, ensuing at the same time, the balance between pests and their natural enemies is not upset.

Pesticides: Applications and Management

For achieving optimal pest control with minimal residue problems, pesticides should be applied in rotation following the sequence in the appearance of pests (Table 1). On account of restricted distribution of pests, blanket applications of pesticides are often avoided in favour of treating the known focuses of infestations provided these are identifiable. Success in this approach depends on the knowledge of the damaged threshold of different pests under varying agro-ecological conditions.

Against red spider *(Oligonychus coffeae)* tetradifon (8 per cent W/V of 2, 4, 5, -4' tetrachlorodiphenyl sulphone) is most effective as it acts against all stages of the mite. Even at 80 cc a.i./ha the acaricide retains a strong ovicidal action, apart from killing the developing and developed nymphs in various stages

of growth. The residual toxicity of tetradifon ideally lasts for about six to eight weeks. It can therefore act on emerging populations of red spider provided there is no heavy rain soon after its applications.

# Cancer Prevention

Cancer-an Overview

Caner is one of the leading causes of death in industrialized nations. The mechanisms of carcinogenesis involve multiple stages of biochemical and molecular alternations in target cells. Diagnosis of and therapy for cancer are usually high-cost elements in health management. Thus, there has been increasing emphasis on research to develop an understanding of cancer, as well as the action of modulating factors, as the bases for prevention and therapy. The process of carcinogenesis involves the step wise accumulation of genetic changes, ultimately leading to malignancy.

As treatments for infectious diseases and the prevention of cardiovascular disease continue to improve, and due to the benefits of these treatments, the average life expectancy of man increases, cancer is likely to become the most common fatal disease in developed countries. Cancers are caused by the progressive growth of the progeny of a single transformed cell. Therefore, curing cancer requires that all the malignant cells be removed or destroyed without killing the patient. An attractive way to achieve this would be use such an agent that would discriminate between the cells of the tumor and their normal cell counterparts and be selectively lethal to the malignant phenotypes.

Cancer and the Intrinsic Defense Machinery of the Host: A Tug-of-War

It is interesting to note that each organism has the built-in capacity to tolerate carcinogenic/toxic insult up to a certain limit, which of course depends on the physiological status of the individual and varies from one form of stress to another. Interestingly, interaction with the products of nature and those developed by human ingenuity does not normally lead to physiological catastrophe since human and other higher organisms have developed a number of defense mechanisms to protect themselves against toxic and carcinogenic insult.

Why Cancer Therapy Fails

Mainstream medicine (relying upon surgery, chemotherapy and radiation) may initially appear successful in the treatment of cancer, but they have their own specific shortcomings. For the past 30 years, cancer therapies have experienced tremendous setbacks because of an associated toxic response, resulting in significant numbers of treatment-induced deaths rather than disease-induced fatalities. During the regimen of cancer chemotherapy, various popular and effective drugs in use these days exert concurrent toxic manifestations including oxidative stress, liver damage and immuno-suppression in the tumor bearer. Many toxic metabolic products of the cancer drugs repress Phase I and II biotransformation and detoxication enzyme systems, which otherwise are required to detoxify and eliminate the unwanted metabolic products from the body.

Why Tea?

The inhibition of carcinogenesis by tea have been demonstrated in cancers of skin, lung, esophagus, stomach, liver, duodenum and small intestine, pancreas, colon, bladder, prostate and mammary glands. Green tea has been shown to possess cancer chemopreventive effects in a wide range of target tumors. Furthermore, the Japanese and Chinese populations who regularly consume green tea, have one of the lowest incidence of prostate cancer. Multiple biological effects of lavonodis have been described, among them are anti-inflammatory, anti-allergic, anti-hemorrhagic, antimutagenic, anti-neoplastic and hepatopreventive activities.

Tea and Its Constituents - A Historic view

From its legendary disovery in the year 2737 BC by the Chinese emperor (a scholar/herbalist) Sheng Nung when a leaf accidentally fell into a pot of boiling water, to the universally enjoyed beverage it is today, tea

has played a significant role in human history. It has many health friendly properties in addition to its delicious taste as a drink. Moreover, various reports from different parts of world have demonstrate its anti-tumor, anti-cancer and immunomodulatory properties.

Tea has been used as a daily beverage and crude medicine in China and India for several thousand years. This beverage is primarily manufactured as green, black or oolong tea according to the degree of fermentation involved. Most Japanese and Chinse people in northern China prefer green tea, whereas Indians, Americans and Europeans prefer black tea.

Hypothesis

We hypothesize that tea may act as an effective anti-cancer agent by: (1) directly killing tumor cells via apoptosis, and (2) protecting and potentiating the intrinsic defence machinery of the tumor-bearing host (Fig.3) Some studies that are currently being carried out in our laboratory and others supporting this hypothesis are detailed below.

(1) Direct Effect of Tea in Tumor Regression

(a) *Anticancer Activities of Tea by Alteration of Signaling Cascades* Tea has been show to have a direct tumor killing effect by altering the signaling cascade in tumor cells of the host without affecting the normal cells. Topical application of green polyhenols to mouse skin was found to inhibit 12-O-tetradecanoylphorbol-13-acetate (TPA)-caused induction of ODC activity in a dose-dependent manner. Many studies demonstrated that EGCG and TF-3 inhibited TPA-induced transformation, PKC activation and AP-1 binding activities in mouse fibroblast cells showed that ECGC and theaflavins inhibited epidermal growth factor- TPA-induced cell transformation in a dose-dependent manner.

(b) *Tea-induced Cell Cycle Regulation and Induction of Apoptosis*-Aberrant proliferation and modulated apotosis leading to impaired cellular homeostasis represent crucial early events in the multi-step carcinogenic process. Effect of tea on cell cycle has been well documented. It has been reported that tea polyphenols inhibited the growth of human lung cancer cell line PC-9, with G2/M arrest. EGCG can inhibit cervical cancer cell growth in human papilloma virus HPV-16 associated cervical cancer cell line, CaSki cells, through the induction of apotosis and cell cycle arrest as well as regulation of gene expression *in vitro*.

(2) Indirect Effect of Tea in Cancer Prevention: Tea-induced Tumor Regression by Rejuvenation of Host's Intrinsic Defense Machineries

(a) *Tumor Regression by Amelioration of Tumor-induced Immunosup pression* The tumor microenvironment influences the functional potential of immune cells. Escape from immune surveillance prefigures the rapid progression of cancers. Various immune escape mechanisms in cancers. Various immune escape mechanisms in cancer have been proposed. Certain cancer cells may secrete immunosuppressive factors to modify the host immune responses. In addition, anaemia is a common complication of malignancies. Cancer related anaemia may occur as a direct effect of the neoplasm, it may be due to products of the cancer, or it may develop as a result of the cancer treatment itself.

(*b*) *Antiinflammatory Effect of Tea Plays a Role in Cancer Prevention* The induction of inflammation in skin mediated by TPA is believed to be governed by cyclooxygenase (COX), lipooxygenase and ODC. These markers of inflammatory responses are important for skin tumor promotion. It was demonstrated that pre-appliation of black tea polyphenols to that of TPA resulted in significant inhibition of TPA-caused induction of epidermal ODC and of COX enzyme activities. Nitric oxide (NO) radical has a wide biological role in modulating physiological and pathophysiological process.

Conclusion

Based on the results of numerous laboratory studies, including ours, it can be reiterated that tea consumption might reduce the risk of certain cancers. This review leads us to conclude that tea, the popular beverage, may directly act as an anti-cancer agent by killing tumor cells, or it may act as a "rescue drink"

that strengthens the defense mechanism of the host, which otherwise may get suppressed due to developing cancer (Fig. 4). The knowledge of tea and its polyphenols adds a new dimension to our understanding of the use of dietary constituents either during therapy of cancer patients or as a preventive measure in high-risk individuals who work in a polluted environment containing carcinogenic/toxic chemicals.

# Oxidative Degradation of Protein

Cigarette smoking is a leading caused of preventable death in the world. The combination of a highly addictive pharmacologically active substance nicotine and an array of noxious chemicals - drastically affect the health. Cigarette smoke (CS) damages all parts of the body, gradually and insidiously, in a number of different ways. CS Cause lung cancer and other malignancies, chronic bronchitis and emphysema, coronary heart disease, stroke, cerebrovascular accident, peripheral vascular disease, peptic ulcer disease, macular degeneration, cataract, damage to foetus and many other harmful effects. One of the prominent hazardous effects of CS is the oxidative damage of biological macromolecules including proteins and DNA. The oxidative damage is produced by stable oxidants present in the aqueous extract of. The stable oxidants are very probably long-lived free radicals present in tar. We reported before that the stable oxidants in CS cause oxidation of plasma proteins and extensive oxidative degradation of guinea pig lung tissue microsomal proteins.

Materials and Methods

*Reagents* Unless otherwise mentioned, in all experiments, CTC black tea was used. The source of both black and green tea was West Bengal Tea Development Corporation, Kolkata, India. CT, epigallocatechin gallate (EGCG), BSA and tea extracts were purchased from Sigma Chemical Co., St. Louis, Missouri, USA. Tea extract containing about 80% TF was used as a source of TF. TR was prepared by the method described below. All other chemicals were of analytical grade.

*Preparation of Tea Infusion* One gram black or green tea was added to 10 ml of boiling water, brewed for 5 min, cooled to room temperature and filtered. The filtrate has been designated as BT or GT infusion.

Results

*Prevention of CS-induced BSA Oxidation by Black Tea (BT) and its Constituent Polyphenols* Figure 1 (lane 2) shows that after incubation of 1 mg of BSA with 50 µl of CS-solution followed by reaction with DNPH and immunoblotting, extensive formation of the DNP derivative occurs, which is a measure of the extent of carbonyl groups produced by oxidation of the side chain amino acids of BSA. Spectroscopic assay of the DNP-derivative shows that under similar conditions the amount of protein carbonyl formed is 10±0.5 n moles. When BSA was incubated with CS-solution in the presence of 50 µl of BT, the oxidation of protein was inhibited about 70% (Fig. 1, lane 3), as evidenced from the comparative scanning of the blots. Incubation of BSA with BT alone did not produce any oxidation of protein.

Discussion

Oxidative damage has been projected as a prominent mechanism of the deleterious effects of CS. There have been attempts to find suitable antioxidants that can prevent CS-induced oxidative damage and the consequent degenerative diseases. We have reported before that CS-induced oxidative damage of proteins is markedly inhibited by ascrobic acid both *in vitro* and *vivo.* In this volume we demonstrate that CS-induced protein oxidation is almost completely prevented by BT infusion. The antioxidant effect of BT has been found to be similar to that of GT. This indicated that although BT contains oxidized and complex condensation products of CT, the antioxidant properties are not reduced. HPLC and spectrophotometric analyses show that the sample of BT (CTC) used contain about 1% TF, 17.8% TR and 6% CT.

# Biological Effect of Polyphenols

Majority of human cancers are attributed to environmental factors including pollutants in the air and water, work place exposure, radiation and personal habits such as smoking/tobacco chewing and dietary patterns. Further identification of specific causative factors and evaluation of their relative importance have proved to be rather difficult since a majority of cancers result from complex interactions between environmental and host factors. Efforts to eliminate known human carcinogens from the environment and current cancer treatment approaches have met with limited success. Based on the experience with some infections diseases and the recent progress in cardiology, prevention of diseases appears to be one of the attractive approaches. Similarly, based on experimental and epidemiological evidence, chemoprevention or dietary intervention, especially employing plant-derived antioxidants, is receiving increasing attention. A number of plant-derived antioxidants have shown anti-initiating and/or anti-promoting activities in experimental systems.

Biological Effects

Different types of tea vary from each other in respect of the nature and amounts of flavonoids present and many of the biological activities of tea appear to be related to its flavonoid content. Flavanols and flavonols are groups of related, naturally occurring chemicals in plants. A number of components in these classes act as antioxidants which may protect against oxidative strees. Catechins are flavonols predominating in tea leaves viz. (-) epicatechin (EC), (-) epicatechin gallate (ECG), (-) epigallocatechin (EGC) and (-) epigallocatechin gallate (EGCG). It is mainly to preserve the catechins that green tea is typically panfried to inactivate polyphenol oxidase (PPO) as a result 60-80% of total flavonoids in green tea are catechin monomers (Fig. 2a and b).

The biological effects of green tea and its individual polyphenols have been reviewed extensively. Various studies employing different *in vivo* and *in vitro* models suggest that green tea and its constituent-free-catechins possess anti-oxidative anti-inflammatory anti-mutagenic as well as anti-carcinogenic activities.

Chemoprevention

As mentioned above, the chemopreventive efficacy of green tea has been attributed to the presence of free catechins. However, during the manufacture of black tea, there is a marked reduction in the amount of free catchin mononers due to oxidative polymerization, catalyzed by the enzyme polyphenol oxidase (PPO), to form a new set of compound(s), viz., oligomeric theaflavins (TFs) and polymeric thearubigins (TRs), which constitute almost 13% and 47%, respectively, of total black tea polyphenols

Since the discovery by Robertset al., of TFs and TRs in black tea, a lot of information has been generated with regard to the chemical structures and biological effects of TFs, but TRs, due to their high matrix reactivity, have been very difficult to isolate and characterize till date, and very little information is available about their biological activity.

As would be clear from the above tables, that though a large database of information has been and is being generated with regard to the various biological activities of either crude black tea extract, decaffeinated black tea extract, TFs or caffeine, a similar stride is not seen in case of TRs, despite the fact that they are the most abundant group of compounds present in black tea. This is partly due to the difficulties encountered during isolation of TR fractions as mentioned earlier.

# Preventing Bone Loss

It has been speculated that by the year 2010, the number of patients suffering from osteoporosis will be even greater than it is today, based on current assumptions. The average life span of the elderly segment of population worldwide will increase, and simultaneously the incidence of osteoporosis in this segment will be relatively greater, more so in Southeast Asia and the Pacific Rim.

It is difficult to foresee whether the drugs presently being used for the treatment of osteoporosis will continue to be as efficacious in the next couple of years or which improved drugs will be used by physicians

at that point of time. To review evidence for current therapies for postmenopausal osteoporosis and to establish practical guidelines for management of osteoporosis by family physicians, "medline" was searched from January 1990 to January 2003. According to this report, osteoporosis is treatable. Early diagnosis and intervention is recommended. Approved pharmacological therapies still include alendronate, risedronate, raloxifene, calcitonin and hormone replacement therapy.

## Inhibitors of Bone Resorption

According to their major effects, drugs in the class have been classified on the basis of inhibition of bone resorption and stimulation of bone formation. Drugs in bone resorption class are used primarily for prevention of further bone loss and maintenance of existing bone structure. The most widely used inhibitors of bone resorption are oestrogen, calcitonin and biphosphonates. Continuous efforts have been made to improve the efficacy of current bone resorptions inhibitors and to develop new inhibitors of osteoclast action.

## Oestrogen

It was first clearly documented about twenty-four years ago that oestrogen is a very effective inhibitor of the rapid phase of bone loss associated with increased bone turnover, which occurs for 5-10 years following menopause. The mechanism by which oestrogens exert their effects on bone resorption has still not been confirmed. It is possible that apart from receptor mediated action, oestrogens exert their effects by modulating the production of local factors in bone like transforming growth factor b (TGFb) and bone resorbing cytokines such as interleukin-6 (IL-6), interleukin-1 (IL-1) and tumour necrosis factor (TNF).

## Calcitonin

This probably is equally effective as oestrogen as an inhibitor of osteoclastic bone resorption in the postmenopausal period. However, its widespread use may be fairly limited because of its high cost, effects on inhibition of bone resorption is transient and its effects to increase bone mass are modest.

## New Approaches to Inhibition of Bone Resorption

During the last decade, efforts have continued to improve the efficacy of current bone respiration inhibitors and to develop new inhibitors of osteoclast action. Like, for calcitonin, there has been continued improvements in the mode of administration for its better efficacy; for oestrogen, introduction of oestrogen patches to avoid hepatic first-pass metabolism and reduce oestrogenic side-effects; and for biphosphonates, introduction of oral types which are more potent and widely accepted. All the currently available agents (other than calcitonin) have unknown modes of action. Their beneficial effects on inhibition of osteoclastic bone resorption were discovered by serendipity rather than by rational investigation.

## Osteoporosis and Phyto-Oestrogens

In India, we do not have any national health monitoring bureau for prompting and evaluating osteoporosis research. However, according to a recent estimate in the United States, 44 million men and women, in the age group of 50 years or above, have low bone mass or osteoporosis. The most devastating consequence of this disease is bone fractures. The assessment of osteoporosis risk includes determining risk factors, conducting laboratory and physical examinations, and measuring bone mineral density (BMD) and bone-turnover markers. When pharmacological therapy is warranted, biphosphonates and oestrogen-like compounds have shown the greatest benefit in preventing bone loss and lowering fracture rates. Nevertheless, there has been an increasing demand for agents for the treatment of postmenopausal symptoms in women with less toxic effects because the currently available agents mentioned in the earlier paragraphs for the treatment of osteoporosis are not fully divided of adverse effects. Of particular interest in relation to human health, are the class of compounds known as the phyto-oestrogens, which embody several groups of nonsteroidal oestrogens including isoflavones and lignans that are widely distributed within the plant kingdom.

## Concluding Remarks

There has been an unabated search for an alternative of currently available inhibitors of osteoporosis with less side-effects. BTE, from that point of view, may be therapeutically assessed as a phytoestrogenic compound for prevention against oophorectomy-induced osteoporotic damages. The development of BTE or its individual polyphenols as inhibitors of hypogonodal osteoporosis will need further detailed studies, as also its dose and human efficacy extrapolation. Nevertheless, it is an exciting challenge full of promising prospects without any possible side-effects.

# Green Tea Processing

Tea is a caffeinated beverage, an infusion made by steeping the dried leaves or buds of the shrub *Camellia sinensis* in hot water. Tea is grown primarily in mainland China, India, Pakistan, Sri Lanka, Taiwan, Japan, Nepal, Australia, Argentina and Kenya. Green tea originates from China and has become associated with many cultures in Asia from Japan and South Korea to the Middle East. Recently, it has become more widespread in the West, where black tea is traditionally consumed. Many varieties of green tea have been created in countries where it is grown.

The benefits of green tea and its effects were discovered 4,700 years ago and since then have been considered a wonder drink. High quality green tea is pale yellowish-green in colour and has a delicate taste. Different green teas exhibit their unique taste- varying from "grassy", "weedy", or even "fishy".

Green tea acts as an antiviral agent. This beverage contains am mineral called fluoride that prevents cavities as well as strengthens tooth enamel. This is because this beverage acts as anti-inflammatory agent. Therefore, it maintains a healthy, active metabolism and circulatory system on the body. The green tea ingredients are the ones responsible for its amazing health benefits. They are called catechins. Catechins are considered the most effective of all antioxidants and the amounts as well as the effects are far higher compared to black tea. This is because green tea has less processing compared to other teas.

Green Tea Ingredients

The main green tea ingredients are caffeine (formerly called theine), tannin (flavonols), theophylline, theobromine, fat, wax, saponins, essential oils, polyphenols particularly catechins, carotene, vitamin C, vitamins A, B1, B12, K and P, fluoride, iron, magnesium, calcium, strontium, copper, nickel, and zinc. It also has trace elements such as molybdenum and phosphorus, as well as 300 additional substances.

It is important to know that the quantitative proportions of these active green tea ingredients vary according to the area of cultivation (altitude, climatic region) and the growth stage of the leaf.

The caffeine content in the younger leaves and buds are more in compared to older leaves. Older leaves, however, have correspondingly larger amounts of tannin.

Green Tea Processing

Green tea is mainly produced in Japan and China, although increasingly, the Indian estates are producing high quality green tea to supply to the increasing connoisseur demand in Japan and other markets. Green teas may or may not be withered, but steamed immediately after they are harvested. This softens the leaves for rolling and keeps the cell sap from oxidizing. The main difference when making green tea is that the oxidization process is omitted, which allows the tea to remain green in colour, and very delicate in flavour. In order to ensure that the freshly picked leaf does not oxidize, before the tea is rolled, the leaf is either pan fried, or steamed. This will prevent the interaction of the enzymes in the leaf, and so no oxidization can take place.

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