Chapter 1

Introduction

1.1. Introduction

Tea is a gift of nature and has become the most gracious of temperance drinks and is one of the chief joys of life. In the long history of human civilization, man has selected and improved three important non-alcoholic beverages from nature's rich storehouse of plant resources – the extract of tea-leaves, the extract of coffee-beans and the extract of cocoa-beans. Of the three beverages, tea is the oldest known and is now the most popular beverage. It leads the other two in the total amount of beverage consumed and it is less expensive compared to coffee and cocoa.

Initially, in China the tea was manufactured from the leaves of the wild bushes through domestic process. But the worldwide demand of this health drink has forced to shape the domestic process to an organized industry. Different techniques for processing coupled with consumer acceptance have led to the development of a wide variety of tea which varies in appearance, colour, briskness, aroma etc. to satisfy every consumer taste within and outside the country of origin.

The introduction of tea cultivation in India was initiated through seeds obtained from China, although the tea plants were found wild in India. The native Indian population seems to have known tea from time immemorial. The investigation of Dr. Nathaniel Wallich at the Botanical Garden, Calcutta for identifying tea plants from different parts of India were fairly well documented [1].

The saga of commercial development of tea in India is both aweinspring and fascinating. The plantation on a large scale was introduced in 1788 by Sir Joseph Banks, the English Botanist. He recommended Bihar, Rangpur in Assam and Cooch Behar as the localities in which cultivation was most likely to be successful.

In 1823, Major Robert Bruce discovered tea plants in upper Assam. This discovery virtually laid the foundation of the tea industry in India. The first experimental plantations were established on the Gabroo Hills in Assam in 1835 [2]. With the emphasis on indigenous tea in Assam, the first commercial effort in organized tea growing was started by the Assam Tea Company in 1839.

The pioneering efforts to manufacture tea were made by George Williamson. He literally gave the first direction in the development of tea technology in India. By 1856, major production centres bigan in Darjeeling and Cachar, in the Terai in 1862 and in Dooars in 1874. There was followed by rapid growth in the Nilgiries, Travancore-Wynnad and the Annamalais of South India. There are also some cultivation in Himachal Pradesh in North India.

Tea, whether it is 'Black" or 'Green", is made from tender shoots of the plant, botanically known as *Camelio Sinensis* (L) O. Kurtze, a species which includes three widely different varieties, namely Assam, China and Combod. From the top of the bush the tender shoots, consisting usually of two leaves and a bud are plucked at regular intervals of about a week. The plucked shoots may be processed in several ways in tea factories to produce 'Black" or "Green" teas.

Tea is a multidisciplinary field with wide and diverse concepts. Since the introduction of tea for commercial cultivation in India, it has spread over a large area (about 437867 hectares) from Darjeeling Himalayas to the Assam Valley along with the South India, with significant growth in production.

The cultivation, maintenance, harvesting and processing of tea are labour-intensive and provide a direct and regular employment to millions of 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 related to tea such as tea machinery, packing, agricultural chemicals, transportation, etc. 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. Tea industry is one among the top ten foreign exchange earners for India.

Tea is nutritive and provides carbohydrates, proteins and several Vitamins. The carbohydrate content of unprocessed Assam tea is 30% (dry weight), mostly contributed by crude fibre, sugars, starch, pectins and pentosans. But only 4-5% of the solids are extracted by hot water allowing tea to be used in low-caloric diets. Proteins constitute about 20% of the dry weight of black tea but less than 2% is in soluble form. With a daily intake of 5-6 cups of tea, the protein may exceed 70 mg/day. Tea is fairly rich in some of the B-group Vitamins. The leaf contains carotene, nicotinic acid, pantothenic acid and ascorbic acid. The quantity of riboflavin is appreciable. However the riboflavin is significantly lowered during processing. Green tea in general contains a higher amount of riboflavin than black tea. One cup of tea per day can contribute 1% of an individual's daily requirement of niacia. The folic acid and the pantothenic acid are in higher quantities in Darjeeling black teas than in green tea. Indian green tea contains 0.07 mg Vitamin-C (ascorbic acid) per gram of tea, though it is significantly reduced during manufacture of black tea. Vitamin-E (α -tocophenol) and Vitamin-K occur in the lipids of black tea. It occurs at a level of 300-500 IU/gram. β–carotene (precursor of Vitamin-A) content is comparable to that of carrot, spinach and cabbage. Tea contains traces of various inorganic constituents like copper, fluorine and manganese.

Besides the economic and nutritional contributions, tea has some therapeutic values. The fresh tea leaves contain the well-known stimulant, caffeine. The low sodium content in tea infusion makes it an ideal drink for patients of hypertension. In addition to these, the tea leaves contain fluoride and a number of poly-phenols, especially Epigallo-Catechin-Gallate, which have many beneficial effects on human body. Regular use of tea improves hypertension and the effect is mediated through lowering of serum Angio-tension Converting Enzyme (ACE). Green tea reduces serum cholesterol, elevates High Density Lipoproteins (HDL), decreases platelet aggregation and reduces plaque formation in blood vessels. It is also likely to have an anti-obesity effect and may play a significant role in prevention of coronary heart diseases. Studies carried out in Japan indicates that the use of green tea after meals bring down the fasting blood sugar levels and glycosylated hemoglobin values of diabetic patients [3]. It also takes a vital role in the conservation of nature in an indirect way.

The bi-products of tea are also very important. During black tea manufacture 2-4% of waste is produced which cannot be processed for human consumption. The quantity of waste is about 10,000 tones per year in India. It includes micro-fine tea dust, floor sweepings, stalks, fibres and others. The tea waste contains caffeine (1.5-3.5%), pectin (5%) and cellulose (20%) and can be used as raw material for their extraction. Polyphenols and pigments of waste mainly comprise theaflavins, thearubigins and catechins and these constitute about 10-15% of the extractives. The waste contains 29.3% crude protein, Vitamins and minerals. Thus it has been found to be a potential feed source for livestock. The waste contains a significant quantity of n-triacontanol, a plant growth regulator. The Central Food Technological Research Institute, Mysore, India has developed a technology for the extraction of triacontanol from tea-wastes at a cost substantially lower than the international price. Its trials in tea field have shown that the harvested yield can be increased by 25-30%. The waste can be used as a cultural medium for industrial purpose of various fungi such as *Penicillium Aspergillus*. Tea waste is also useful as a constituent of fertilizer composts.

The twin objectives of the tea industry are to achieve a high productivity besides maintaining a good quality. There is an interplay of a number of factors affecting both the yield and quality. A thorough understanding of the crop plant such as its range of adaptability, selection of site, genetic potentials of the bush, appropriate methods of propagation, training of plants, management of cultural inputs to achieve optimum results, maintenance of bush, plucking techniques and processing is imperative for successful tea growing and manufacturing. It is the industry in which the productivity depends on the proper management of agriculture, technology and human resource.

The production of tea should continue with a steady progress in order to keep pace with raising domestic demand (fig. 1.1) as well as earning foreign capita. From fig. 1.2, one can find export picture of tea from India. Total productivity should meet up both domestic and export quantities. Although the tea industry of India had targeted its annual production of 1000 million Kgs made tea by 2000 AD [4] but the actual production lagged far behind the target. The total yearly production of tea in India is presented in fig. 1.3. The yield (production/hectare) is shown in fig. 1.4.

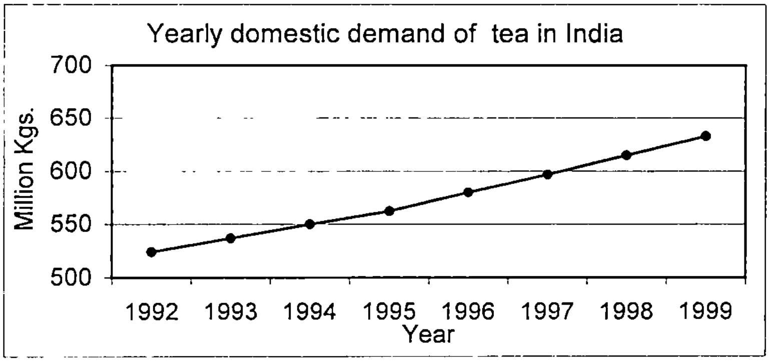

Fig.1.1. Total yearly domestic demand of tea in India [5].

Fig.1.2. Total export of tea from India [5].

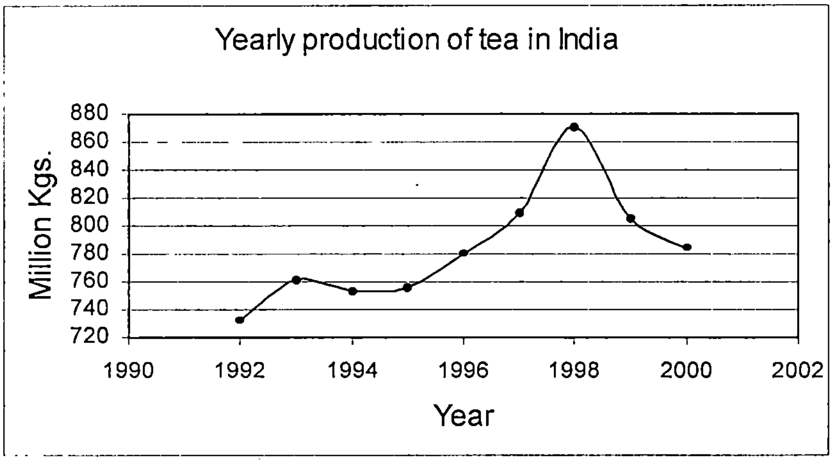

Fig.1.3. Total yearly production of tea in India [5].

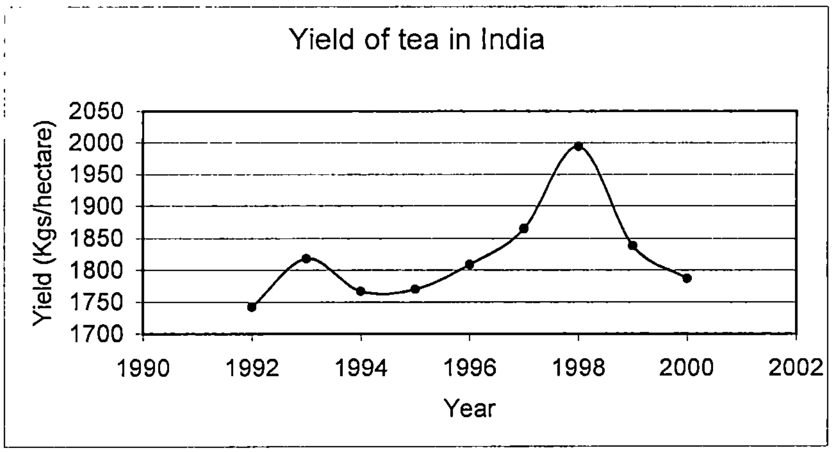

Fig.1.4. Yield (production/hectare) of tea in India [5].

It is evident from the above four figures figs. (1.1–1.4), that if the production of tea continues to decline further then the total tea produced will be consumed in domestic market and ultimately export will be ceased.

On the other hand, the major Asian competitors of India in production of tea are gradually improving their productions as shown in figs (1.5 – 1.8).

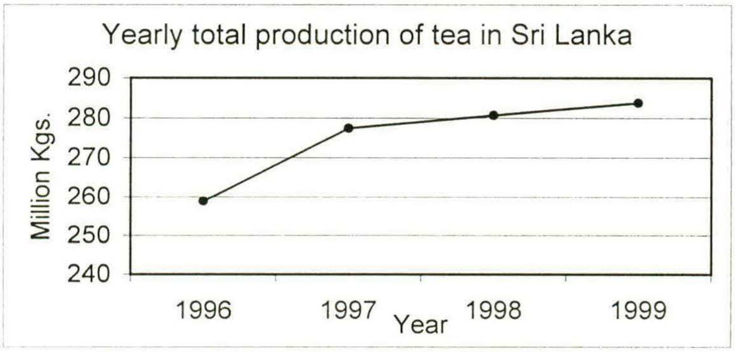

Fig.1.5. Yearly total production of tea in Sri Lanka [5].

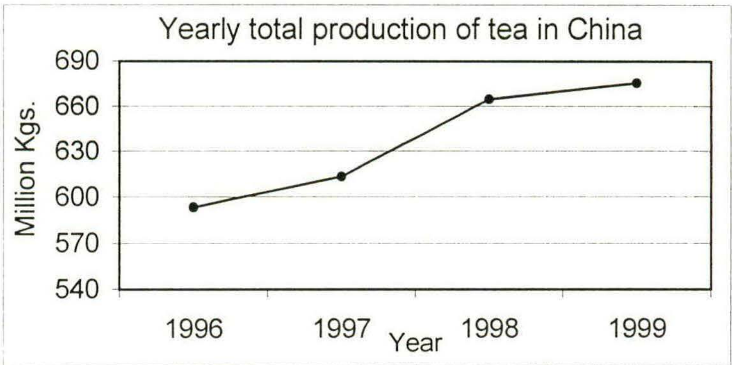

Fig.1.6. Yearly total production of tea in China [5].

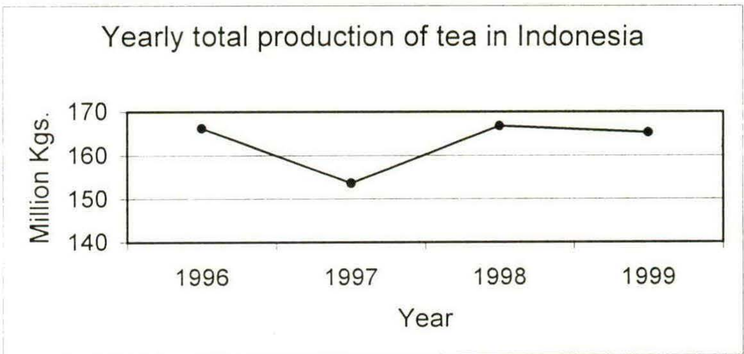

Fig.1.7. Yearly total production of tea in Indonesia [5].

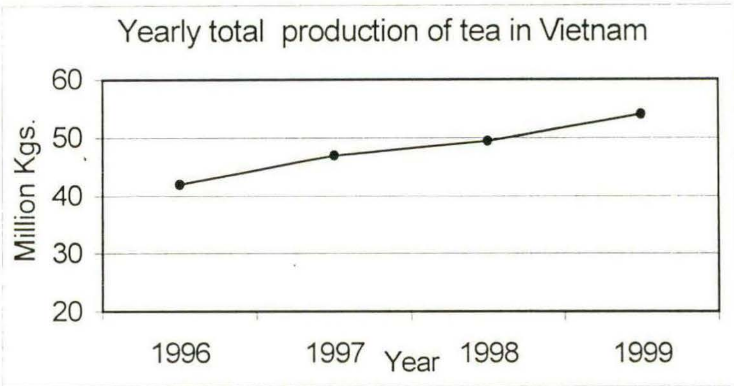

Fig.1.8. Yearly total production of tea in Vietnam [5].

Several factors such as soil, water, human resource, pruning, shade, insect pests, diseases, age of the bushes, and natural calamities are responsible for such decline of production as shown in fig. 1.3. Two of the major factors responsible for crop loss are insect pests and diseases throughout the year [6].

Appropriate measures are to be taken to improve the discouraging scenario shown in figs. (1.2.-1.4). The management practices need to be improved to tackle the situation. The next section presents the current management practices in tea at least in Indian environment.

1.2. Management practices in tea

The productivity, quality and the development of this industry depend on the proper management of agriculture, technology and human resources. Like all other agricultural fields, the parameters like soil texture, rainfall, temperature, sunlight, humidity etc. are very vital to increase the quantity and quality of tea. The field conditions are not static parameters. So to proceed with the sustained productivity even with odd and fluctuating climatic conditions, some instant and prolonged management practices are found to be very essential for better productivity.

To obtain desired productivity and profitability, two types of approaches are effective (i) upliftment of harvested crop by judicious blending of field practices and (ii) protection of harvested crop, mainly from insect pests and diseases. The present field management practices in tea cultivation can be classified as: (i) crop production management and (ii) crop protection management. The components of crop production and protection management are presented in a block diagram in fig. 1.9.

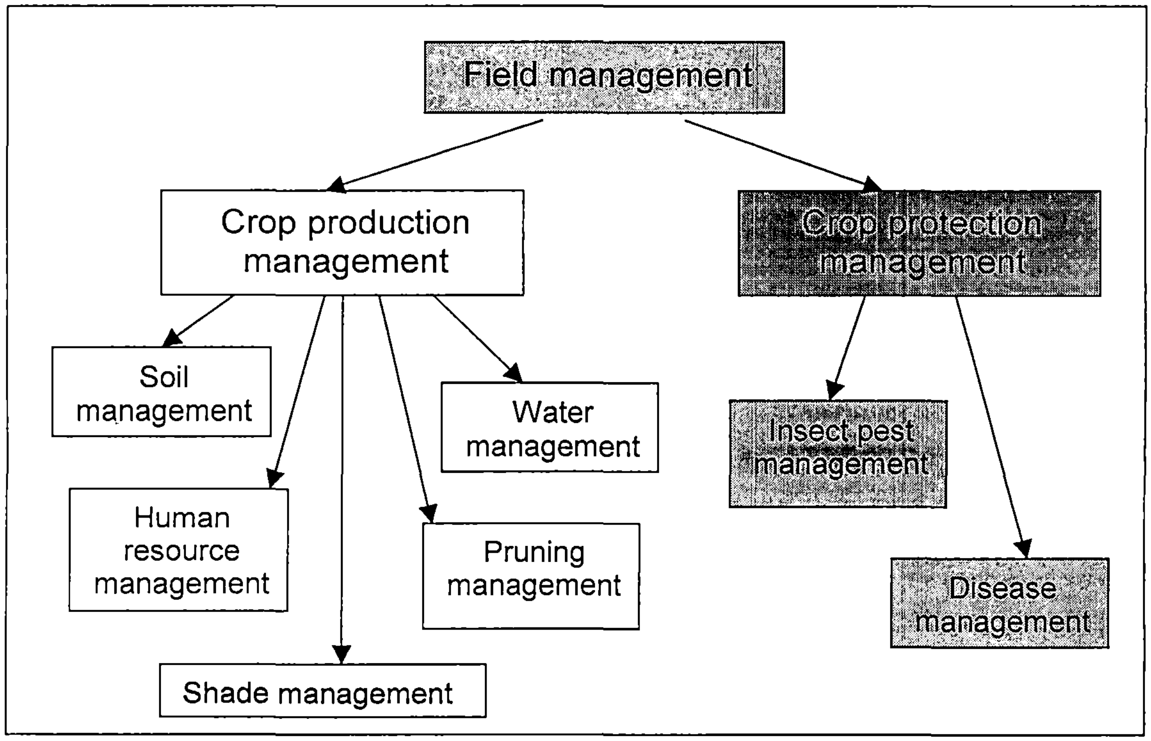

Fig.1.9. Block diagram of field management practices in tea.

1.2.1. Soil management

Physical properties of the soil like texture, structure, clay minerals and soil colloids largely determine the availability of inherent or applied nutrients. An well developed root system can only ensure maximum utilization of nutrients. Poor soil conditions like poor structure, inadequate drainage conditions need to be attended first for making a fertilizer policy economic and efficient.

A very fertile soil may not continue its fertility for a long period if proper and systematic practices are not done at the right moment. A productive soil should contain all the essential plant nutrients in sufficient quantities and in balanced proportions. The nutrients should also be present in available form before plants can use them. The fertility status of cultivated soils declines with progress of time affecting crop productivity. Experiences dictate that no cultivated soil can supply the nutrients in sufficient quantity beyond a point of time depending upon the original fertility status, intensity of cultivation and climatic conditions.

Two important natural laws viz. law of limiting factors and law of diminishing return govern response of a nutrient. The 1st law signifies that normal growth activity can be resumed only after removal of limitation imposed by restricted supply of particular nutrient(s), while the 2nd defines that response in turn of economic yield decreases with increasing level of supply of nutrients and beyond a certain point the overall situation is also influenced by climatic changes, bush management practices as well as factors like soil type, planting material, irrigation and possibly the age of the bushes.

There are two ways to predict fertilizer needs, deductive and inductive approach. These two approaches essentially differ in that the former attempts at averaging the results under application while the later seeks site specific information and extends it to similar situations. It may be possible to determine potential deficiencies before they occur to take remedial measures preventing acute deficiency and cause seasons short fall in yield. So for a sustained and good productivity, a long-term master management policy is very essential.

1.2.2. Water management (Irrigation & Drainage)

Roots absorb water and plant nutrients from the soil. When the leaves loss turgidity due to insufficient moisture, the stomata are usually closed and transpiration rate decreases, which affects production of tender shoots.

The other factor affecting the transpiration rate is the climate, which includes sunlight, temperature, humidity and wind. The amount of intensity of sunlight is most important. In general, high temperature increases transpiration very markedly if accompanied by low air humidity. On a calm day transpiration may be lesser than that on a windy day.

The water is absorbed by plant roots and must be periodically supplied by rain or irrigation for the sustained production of crop. On the other hand, the heavy concentration of rain fall during monsoon months combined with high seepage water causes the water table to rise enough and requires an adequate drainage system with proper outlet and maintenance at proper time.

Distribution of rainfall in North-East India is slightly uneven. During the period from October to February rainfall is saintly and it mainly varies from 5 to 10% of the average evaporation exceeds average precipitation by 8 to 357 mm. So conservation and supplementation of soil moisture by irrigation becomes necessary during this period of moisture stress. That is why a good water management is useful.

1.2.3. Human resource management

Human resource management is one of the most vital issues in tea industry. The industry deals with a large number of workers having various types of work skill. So it is very vital to optimise the distribution of the particular type of workers in the appropriate nature of work. Not only the type of workers but the selection of number of workers depending upon the volume of work is also very vital. Along with the above, the seasonal work distribution should be kept in mind. For example, a large number of workers are required in the peak season of plucking but there is no scope to provide workers for pruning, because pruning and plucking are not the simultaneous events. So pruning workers can then be shifted for plucking to meet up the demand but the same is not true for the factory workers. Likewise, a plucking worker can not be shifted to nursery. Most of the works in the tea industry are seasonal. The type of work, volume of work and the urgency of the work largely depend on the agro-climatic conditions of the cultivation. So unskilled planning may lead to an overall deterioration to the quality and quantity of the made tea which is a common fact in most of the tea cultivations. An overall planning is very essential for sustained productivity. An optimisation between the human resource and the specific work can lead to an industry for better productivity. Human resource management deals with the better implementation of human skill.

1.2.4. Pruning management

Commercial tea production needs tender shoots. Hence a tea bush needs to be maintained continuously in its vegetative phase of growth. Pruning is a cut made by a saw or knife and is an essential requirement for it. With increase in years away from pruning, growing apices of the tea bushes gradually loss vigour and finally reach to a stage when they loss the capacity to produce sufficient quantity of tender shoots. After certain years of cultivation, severe pruning may be necessary to reduce the bad or unproductive wood and also to eliminate the disease and pest ridden branches from the bushes. Though the pruning results in the loss of crop in the pruned year but there is a steady increase in productivity afterwards.

Time of pruning not only affects the total yield but also influences the distribution of the crop. In general the optimum time of the year to prune / skiff is when the plant is dormant or its growth rate is low and carbohydrate reserves are high. The exact time of pruning depends on the local climate, crop and quality requirement, seasonal crop distribution, susceptibility to pest and disease etc.

An analysis of the above factors may help the management greatly in making a round pruning program for the industry. Pruning and skiffing can be profitably utilized to obtain increased crop from the existing field. By careful logical admixture of various forms of prunes and skiffs in any tea estate, it is possible to increase yields and even out the crop distribution. Pruning management is a prolonged practice in tea cultivation.

1.2.5. Shade management

Importance of shade in tea was realized long ago and its organized planting in tea started from the very beginning of plantation. The primary function of a shade tree is merely to prevent excessive heating up of tea leaves by trapping some of the heating infrared rays from the sun before they reach the tea bushes.

Photosynthetic activity in tea declines rapidly above 35^{o} C leaf temperature and between 39^{o} C to 40^{o} C, there is no net photo-synthesis. The respiration continues up to 48^{o} C and leaf temperature above 48^{o} C damages leaf tissues. So provision of some form of shade by planting shade trees is a must in the plains of North-East India and as well as in South India.

The main reason why exposed leaves in North-East India become excessively hot is that in general the wind speed are very low during the hottest times of the year. Wind is very effective in removing excess heat. There are no hard and fast rules about species, spacing or admixture of the shade trees, as growth of the same species in different areas can vary considerably. Good management practices will decide the species best suited to the estate conditions and the most suitable spacing likely to provide as near optimum shade as possible at maturity. The only guide, therefore, for the optimum spacing of different species is local agro-climatic experience combined with the complete knowledge of various species of shade trees. So the shade management is in practice.

1.2.6. Insect pest management

Insect pest management is a challenging problem for the experts associated with the cultivation of tea. Tea is a perennial plantation crop spread over a large area under varying climatic conditions. So it provides a favourable breeding ground for a variety of insect pests. Several species of insect pests attack both young and matured tea plants and often cause considerable damage in localized area within a short time. Loss of crop due to the damage by the pests varies according to the severity of attack(s). A loss of 10% due to the overall pest attack is a generally observed figure though it could be 40% in devastating attacks by the defoliators [7].

Insect pests are common and vital problem of all the tea gardens. It is one of the productivity barriers which require a systematic, intense and experienced management. Insect pest management deals with the identification and control of insect pests in tea. In present practice, the identification of insect pests and any decision regarding their control measures are taken primarily by the human experts.

1.2.7. Disease management

The diseases of tea plant have been found from the very beginning of plantation for over 150 years [8]. The tea plant is susceptible to attacks by diseases under varying climatic and soil conditions. For a mono-culture, abundance of disease is not uncommon but diseases of tea are rather numerous. The diseases attack different parts of the plant such as leaves, stems and roots and ultimately cause a major crop loss.

Primary root diseases cause extensive damage to tea, resulting not only an immediate crop loss but functional physiology of the bushes is also affected [7]. Seedlings in the nurseries are also being affected by the diseases. Loss of crop from section damaged by diseases varies according to the severity of attack. Some diseases persist in the same area for years if not controlled properly, causing gradual deterioration in the health of the tea plants and causes loss in crop.

Disease of tea plant is another major productivity barrier which demands a considerable attention and an adequate management practice for protection of crop. There are evidences that in many tea gardens managers are paying bitterly for the neglect of root diseases by past management. For an example, a garden which adopted incorrect method in the past, lost 20 to 30 thousand bushes, representing between 7 to 10 acres of cultivation per annum [9]. Disease management is concerned with the identification and control of tea diseases.

In tea cultivation, the insect pests and diseases are being controlled mostly by the use of chemical pesticides and fungicides respectively. To reduce the crop loss by the insect pest and disease, application of some chemicals play a vital role undoubtedly. But their application invariably leaves toxic residues in made tea. Too much dependence on chemicals and their indiscriminate use lead to high deposition of toxic residues beyond the permissible Maximum Residual Limits (MRL) fixed by various international agencies like EPA, EEC, Codex, WHO etc.

In the recent years, there has been a greater dependence on the use of chemicals with little importance laid on the hazards of chemicals. The change in ecosystem contributing towards increased pests and diseases incidence has resulted in excessive load of chemicals on tea bushes [10]. Proper identification of pests and disease is also very essential because application of any chemical against non-target may have an adverse effect. In some cases, application of some chemicals tend to increase insect pests by affecting the natural parasites and predators of the pests and thus causing their resurgence [11].

So, it is evident that crop production management is concerned with identification and betterment of parameters such as soil, irrigation, drainage, pruning etc. to increase yield growth. It is a long-term practice and requires master planning for years even for decades. On the other hand, crop protection management is concerned with the identification and control of factors causing major damage to the harvested crop, mainly insect pests and diseases. Insect pests and diseases are the problems in tea cultivation throughout the year and throughout the cultivation irrespective of their geographical locations. The protection management should have the ability to suggest the prompt and rational actions to be taken for crop protection. This work mainly concentrates on the second issue i.e., protection management. This is usually done by human experts. But, however, they are really a scarce commodity at per the requirements of this wide-spread industry. To cover the complexity of the domain as well as mitigating the scarcity of domain experts one may consider an automated consultation system in an AI and ES framework as an alternative.

A good number of attempts (chapter 3) have been made to develop such expert systems / knowledge based consultation systems in agriculture with their relative success and failure. But, however, to the best of our knowledge not so much of the issues relating to tea garden problems, at least in Indian environment, have been addressed in this context. In this work an attempt have been made towards the development of a consultation system for the domain in an AI and ES framework to meet up the requirements, at least partially, of the domain. Attempts have also been made for the development of novel AI-based technological artifacts suitable for the domain.

1.3. Usage and benefits

For successful implementation of an expert system, the issues related to its usage and benefits should be considered before the development starts. Various aspects of the usage issues are particularly important such as (i) benefits of usage of the system to different potential users; (ii) who will use it and how; (iii) what problems users might face and how to overcome or minimise such problems and (iv) how the question-answer sequence should be tailored.

1.3.1. Levels of usage of a technical artifact

There are three levels of usage of a technological artifact as discerned by Hart [12]. The first level, the lowest level is concerned with technological features, the components that do not stand alone. The design of such features or components is concerned at this level. The middle level is concerned with whole entities rather than components and the actions or tasks they carry out. At the third level, the top level, we are concerned with the role of the entities rather than their actions or tasks. Tasks are reasonably well defined, even though there may be variants among the components of which they are made. They have little meaning in themselves and are carried out in fulfilment of rules, which give them their meaning. Hart characterised the difference between tasks and role by starting that tasks could be entered in a diary while roles (he gave the example 'Love thy neighbour') could not. Hart pointed out that the three levels are irreducible to each other.

On the other hand, Gillies [13,14] suggests that there are three levels of human computer interaction: physical, task, and organisational. The physical level concerns the user interface. The task level, the business tasks that the primary user undertakes while at the user interface. The organisational level concerns the organisational purpose of the tasks. This suggests that benefits which stem from such interaction can also be separated into three types, corresponding to three levels. Thus, for instance, speedier obtaining of a budget estimate would be a benefit at the task level; and speedier completion of the project proposal, of which a budget estimate is one part, would be a benefit at the organisational level.

The similarities between Hart's and Gillies' levels should be obvious, especially at the task level, but the differences are important. Hart's lowest level concerns any component of the whole entity and in the case of software, this means not just the user interface but also other features and facilities. While Gillies' highest level is differentiated from the task level by moving from the single user to the organisation, Hart's is differentiated by the addition of meaning or purpose. While it is often the case that the organisation does supply the purpose of tasks so that there is indeed a strong correlation between the two top levels, Hart's top level is not restricted to consideration of organisations. Hart's taxonomy seems more exhaustive and contains less ambiguity.

1.3.2. Usage of expert systems

The use of an expert system can be better understood by using Hart's taxonomy. At the lowest level, the modules such as answering questions, using the explanation facility or using the help facility are concerned. It is at this level that discussion of the features of an expert system becomes important – what type of explanation it gives, which types of reasoning it employs, etc.

The middle level is concerned with the expert system as a whole, rather than its components and features. We are concerned with the individual users and which takes the expert system supports. The classification of expert tasks by Stefik et al. [15] such as prediction, diagnosis, planning etc. are largely relevant at this level, while consideration of features is largely technology concerned or involves only the primary user's actions at the user interface and consideration of tasks involves the primary user's actions within their immediate organisation.

The top level is concerned with the role of the users play in, making use of the expert system and the purpose for which they carry out the tasks that are supported by it. Basden [16] proposed a list of roles such as consistency, checklist, program, communication, knowledge refinement, training and demonstration which the expert systems might fulfil regarding their applications. But, one can observe that this list was ill formed and is confusing, since it focuses on the roles the software plays rather than the roles of the human actors. Some of the list are true roles, if translated to the perspective of the human user. For example, by 'communication' it was meant for the clarification and spreading of expertise; and by 'consultancy' it was meant for enabling a person to solve a problem by the provision of expert advice. Both these are examples of roles. But by 'program' it was meant that the expert system shell could be used simply as a language in which to write programs and this is not the role: writing a program is a task.

It is a fact that an automated knowledge-based consultation system should be useful for improved protection of tea crop. It might not be feasible to provide an entomologist / plant pathologist for each tea garden whereas the proposed system can be operated by the general tea garden workers. This happens to be the primary benefit of such a system expected to mitigate such expertise. Worthwhile to note here that tea management trainees work with the expert guidance at training centres, this system should certainly work as a companion of theirs. Even, the system may be used by a management personnel for a second opinion. The overloading problem of an expert is expected to be relieved to some extent by the use of this system. It may also be used by the tea management trainees as 'training kit'.

From the above discussions, it is evident that the common users of the system will be the general workers of the tea gardens who may not have the exposure to AI and expert systems technology. Even, they may not have any basic training of computers. However, such types of introductory ideas on computers are now being introduced in school levels in different institutes. Possibly, the by-product of the above situations is the lack of motivation and/or a kind of inertia to maintain the traditional systems. The situation should certainly be improved by the co-ordinated efforts from the tea garden authorities and the Tea Board of India. One-week intensive course would be adequate. In the initial phase of such use, an easy developer-user interaction should certainly be encouraging to minimise such problems.

The question-answer sequence should be tailored: (i) to the needs of the region and (ii) to the users' level. As the users are the field supervisors or the common workers of the tea garden, obviously, question-answer sequence should not have any knowledge from the intimate area of entomology or plant pathology. It should only be concerned with the associated terms of usual cultivation field.

1.3.3. Benefits

If there are three levels at which usage of an expert system can be discussed then it is not surprising if there are three levels of benefits, each pertaining to a different usage level. Basden [16] proposed three levels at which benefits accrue: (i) feature benefits, (ii) task benefits and (iii) role benefits.

Feature benefits are those advantages that arise from technological features of functionality and user interface. Ease of manipulation can arise, for instance, from graphical user interfaces. An example found in DTI [17] is 'critical items are highlighted'. Task benefits are those which arise from using the expert system to support a task. Examples in DTI [17] include 'fewer changes to schedule' and 'improved visibility of requirements'. Role benefits arise from the effect the expert system has on the roles the user fulfils by carrying out the supported task, such as 'improved supplier relations', which in DTI [17] is seen to arise from the two task benefits above.

While it is useful to be able to classify benefits into three sets, there is indication of some form of causal, or at least enabling, link between them. Feature benefits can lead to task level benefits, which can in turn lead to role level benefits as shown in fig. 1.10.

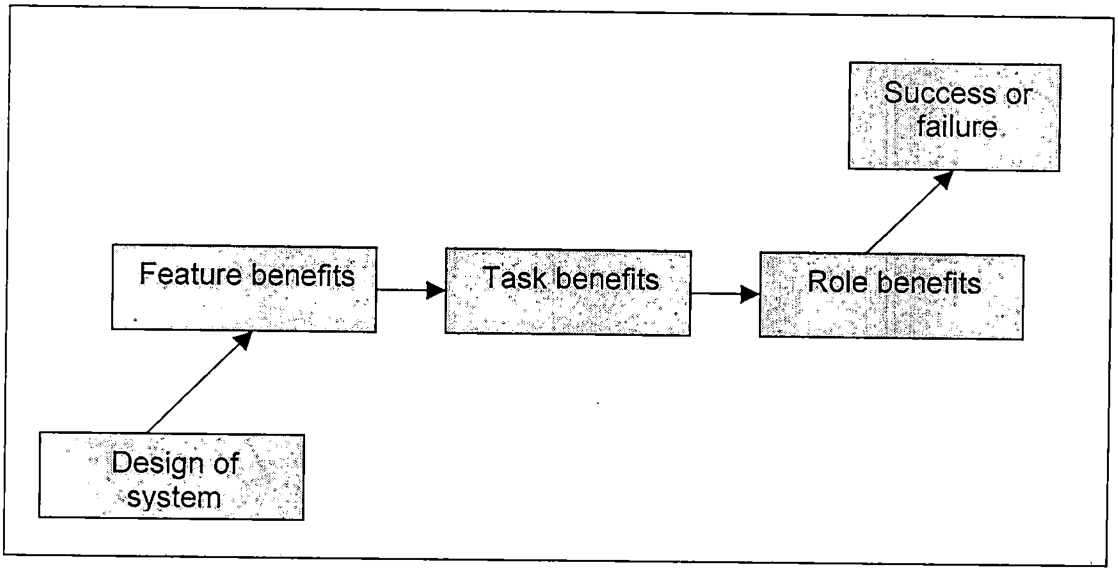

Fig.1.10. Three levels of benefit.

It is role benefits, rather than feature and task benefits, that are a determiner of the success or failure of a system since, as discussed above, tasks and features find their meaning only in the context of a role. It is now easy to view the expected benefits of the proposed system at per the tripartite division: feature benefits, task benefits and role benefits as shown in fig. 1.11.

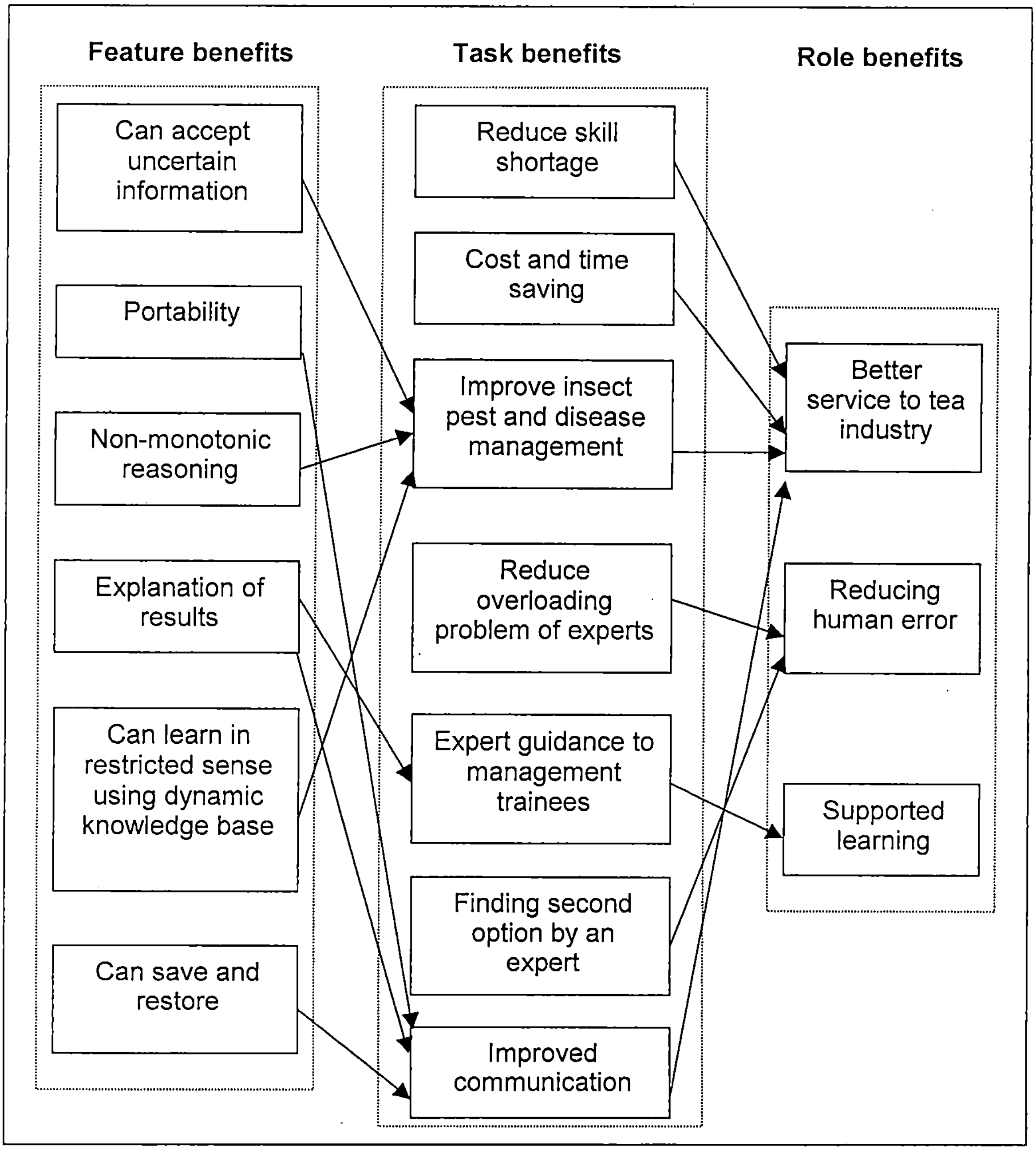

Fig. 1.11. The levels of expected benefits in use of our proposed system.

From the above fig. 1.11, it is seen that the links are many-to-many rather than one-to-one. Thus, a feature benefit can enhance a number of tasks and a given task may require several feature benefits. Moreover, though there is some causality of the links, while others are merely enabling. Further, there are other factors which influence the operation of each link, such as working practices, organisational norms and attitudes of users or others around them.

1.4. Aim of the work

The aim of the present work is to apply AI techniques in tea garden management. This we intend to do in steps. We initially have tried to explore the present status of the domain which helped us in understanding the needs of the domain. This work considers two management issues: Insect pest management; and Disease management. To meet up the needs of the tea domain, at least partially, an attempt has been made to develop expert systems or knowledge based consultation systems. Emphasis has been given on different potential issues concerned with an expert system development. Potential issues such as (i) required expert system architecture, (ii) knowledge acquisition and representation, (iii) uncertainty management, (iv) expert system tool selection, (v) user interface / usage issues, (vi) performance evaluation etc. have been considered.

Initially, we have developed the conventional expert systems for tea insect pest and disease management on the single user (PC based) platform. They produced impressive results when compared with that of the human experts. Being inspired with the performance and to solve the problems such as (i) availability, (ii) software distribution and (iii) communication, associated with the conventional expert systems [18], we have extended our efforts to develop Web-based versions of these expert systems so that they can be globally accessible.

The process of building an expert system is inherently experimental [19]. The applicability of different potential issues pointed out above has been studied in different steps of the development. Moreover, expert system development is the first and foremost software engineering [20] and therefore, there has been an attempt in the study to consider some software engineering issues.

Lastly, in this study, an attempt has been made to design and implementation of an alternative approach for classification type of problems using case-based model. This model is then tested for insect pest management for tea gardens. As a method of building intelligent reasoning systems, case-based reasoning has appeal because it seems relatively simple and natural. A big problem in reasoning in expert domain is the high degree of uncertainty and incompleteness of knowledge involved. Case-based reasoning addresses those problems by having the reasoner rely on what has worked in the past. Case-based systems also provide efficiency.

1.5. Summary of the work

The scheme of the presentation is as follows:

Chapter 2 of this thesis contains a brief survey on major insect pests and diseases active in tea cultivation. The symptoms of damage observed on tea plants and the morphological characteristics of insect pests have been studied. The identification symptoms of diseases are also studied in details. Moreover, an attempt has been made to give an account of loss due to pest and disease infestation in different gardens of Dooars region, India.

Chapter 3 contains two important issues: (i) why it is an expert system domain; and (ii) what requirements the domain lays on an expert system. This chapter initially discusses, in brief, what is artificial intelligence and expert systems, categories and application areas of expert systems, components of a typical expert system, general desirable features of an expert system, different stages of an expert system development, rule based vs. model based systems etc. and lastly, the above mentioned two important issues (i) and (ii) have been presented.

In chapter 4, we have presented the issue of knowledge engineering with two aspects: (i) knowledge acquisition and (ii) knowledge representation. Under the first issue, levels of knowledge and knowledge categories have been discussed. Next, we have explored different issues of knowledge acquisition – their merits and demerits. Here we have also pointed out the prime sources of knowledge acquisition used in the current research. Under the second issue, we have discussed different schemes for knowledge representation – their merits and demerits. We have also discussed the relative suitability of the methods in context to the present problem domain.

Chapter 5 deals with the issue of selection of an appropriate expert system tool. A detailed study has been provided here among three types of tools: AI-languages, tool kits and shells.

Chapter 6 deals with the issue of uncertainty management. The sources and nature of inexactness have been identified and discussed with examples. A suitable analysis of different methods of handling inexactness which seem(s) to be most sympathetic to the problem domain at our hand have been provided.

In chapter 7, we have presented *TEAPEST:* a rule-based object-oriented expert system for insect pest management in tea. The issues of knowledge engineering, GUI, system design, implementation and performance evaluation have been presented.

Chapter 8 presents *TEADISEASE*: a rule based object-oriented expert system for disease management in tea. The issues of knowledge engineering, GUI, system design, implementation and performance evaluation have been presented.

Chapter 9 presents the Web-accessible consultation systems of *TEAPEST* and *TEADISEASE* namely *TEAPEST/ WWW* and *TEADISEASE/ WWW*. Initially, the benefits of using expert systems through the Internet have been discussed. Next, the technological artifacts for transference of stand-alone PC-based consultation systems to Web-accessible consultation systems have been discussed. The implementation details and the performance evaluation have been placed. One can visit the Web-site: **http://samanta_rk.tripod.com/homepage.html** for accessing our systems.

In chapter 10, we present a model for case-based learning as an useful technique for developing knowledge-based systems. This model is then tested for insect pest management for tea gardens.

Chapter 11 presents the design and implementation of a case-based classifier approach. Performance evaluation has been presented taking cases from tea gardens.

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