PROCEEDINGS OF THE WORKSHOP ON TEA PRODUCTION TECHNOLOGY UPDATED

Proceedings of the workshop on
Tea Production Technology Updated

Held on 24 December 2014

Sponsored by
Krishi Gobeshona Foundation
Farmgate, Dhaka-1215

Organized by
Bangladesh Tea Research Institute
Srimangal-3210, Moulvibazar

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Edited by
Dr. Mainuddin Ahmed
Director, BTRI

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Contents of the Proceedings

PREFACE

Bangladesh Tea research Institute organized a Workshop titled T**ea Production Technology Updated** at its main campus, Srimangal on 24 December 2014 which was sponsored by Krishi Gobeshona Foundation (KGF), Farmgate Dhaka. A total of 126 participants attended the workshop at which four technical papers were presented by the concerned subject experts of the Institute.

The workshop focused attention to adopt scientifically proven technologies which are environment friendly in order to augment field productivity as well as to enhance the quality of end product. The deliberations include agro- techniques such as pruning, tipping, plucking etc., inclusion of mycorrhizal fungi in tea cultivation to enrich plant nutrition; integrated management of pests in tea cultivation in order to minimize cost as well as to protect environment and finally ideal procedure of black tea manufacturing, quality improvement and machinery management.

This publication incorporation the papers presented at the workshop after minor editing wherever felt necessary with the consent of the authors concerned. The questions raises by the participants and the answers given by the authors during discussion are also included in the publication. The articles suggest possible strategies and line of actions that could be implemented at the estate level in order to enhance productivity, control pests economically without harming much to the environment and manufacture quality tea.

Considering the interest shown by the participants at the workshop the institute is confident that the publication will serve as a useful reference for those who are related to tea industry particularly who are working at the field and factory level.

(Dr. Mainuddin Ahmed)
Director, BTRI

Inaugural Address
Chairman, Bangladesh Tea Board

Distinguished Special Guest,
Director, BTRI,
Director, PDU,
Executives of different managements,
Senior planters,
Participants of the Workshop
Scientists of BTRI & Officials of PDU

Assala-mu-alaikum,

You might have known by the time that I joined Tea Board only few days back. I am very pleased to be with you for the first time at the inaugural session of the workshop on **'Tea Production Technology Updated.'**

It is a matter of great pride that the institute has been conducting such an important workshop for the management personnel of the tea estates.

I understand our tea industry has great potential to increase production and earnings by elevating the yield as well as quality. This is reflected in the dedication, zeal and firm commitment of all concerned for which our tea production has increased from 31 mkg to over 66.26 mkg and yield has been raised to 1325 kg from 735 kg slightly over four decades of our Liberation. In spite of increased production, our export volume is shrinking every year due to the increase of domestic consumption @ 4% against growth of production grossly @ 1% per annum.

The average yield of tea estates varies widely from management to management, highest average being 1800 kg and the lowest being 680 kg. The statistics reveals that this is not a healthy growth scenario for a small tea growing country like ours where variation of land and soil conditions is negligible. But now-a-days unfavorable climatic condition is after disrupting the harmony pr our production. We must have to narrow down the difference in order to raise our national average further by adopting improved technologies already available. The best source may be BTRI which is close to your door.

I am pleased that BTRI is organizing such a workshop which is sponsored by the Krishi Gobeshona Foundation, Farm Gate, Dhaka.

I believe the technology offer package which BTRI has evolved so far can boost up our production and enhance the standard of our tea. These technologies are the outcome of tenacious research works which are supposed to be adaptive to our environment. The tea industry needs to harness full potential of it.

Efficient technology transfer system in the field is equally important. Linkage with the researchers and planters' for better understanding will ease implementation and sustainability in the field. I am sure this workshop will provide the opportunity where the technology innovators and the technology users of the tea industry will be able to interact closely and discuss freely all aspects of tea husbandry. I am confident that if the scientists and management personnel will march forward in this direction, tea production will be increased.

I wish you all success.

Allah Hafez

Major General Md. Enayet Ullah, *ndu, psc*
Chairman
Bangladesh Tea Board
24 December, 2014

Welcome Address
Director, Bangladesh Tea Research Institute

Hon'ble Chief Guest, Maj. Gen. Md. Enayet Ullah, *ndu, psc,*
Chairman, Bangladesh Tea Board
Special Guest – Mr. Harun-or-Rashid Sarker, Director, PDU
Special Guest – Mr. Golam Mohammad Shiblee, DGM, Finley Tea Co. & Chairman, BCS, North Sylhet Valley Circle
Distinguished Executive of the tea estates
Scientists of BTRI & Officials of PDU
Members of the press
Good morning

Assala-mu-alaikum,

In this august occasion, I would like to express my sincere gratitude to our Chief Guest and Chairman, Bangladesh Tea Board who showed keen interest on this workshop. We are also thankful to you for making time to attend this gathering.

Today's workshop on **'Tea Production Technology Updated'** is organized by BTRI and sponsored by Krishi Gobeshona Foundation (KGF).

As you know BTRI is a research institute and the technologies evolved by BTRI are adaptive to our agro-climatic conditions. So, the tea industry needs to harness full potential of the innovated technologies to overcome the constraints confronting our tea industry. The aforesaid workshop covers various topics of scientific management with updated information of pruning, tipping, plucking, pest & disease management and tea manufacturing and quality improvement.

Our goal is common, that is higher productivity, better quality and reduction of COP. If we work together, it is not impossible to achieve. I do hope you will actively participate in the discussion session to make the workshop a lively and successful one.

Today's topics are very much related to our tea and tea productivity. I hope this will help you.

Once again I express my sincere thanks to you all.

Allah Hafez

Dr. Mainuddin Ahmed
Director
Bangladesh Tea Research Institute
24 December, 2014

PRUNING, TIPPING AND PLUCKING FOR ENHANCING OF TEA CROP PRODUCTION

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Abstract

Tea is a vegetative and long standing perennial crop. Pruning make active vegetative phase of tea bush and help re-grow more and more lateral branches. It is also important to make a permanent frame at 45 -50 cm height in young stage. De-centering at 15 -23 cm and pegging at 23cm response better for erect and horizontal bush habit of tea plant respectively. Time of young tea pruning depends on practical observation of permanent plant anchorage in the ground and climatic condition. In mature tea, 4 years pruning cycle combination with LP-DSK-MSK-LSK has proved better for higher yield. It may not be same for all clones. Best time for LP is before ending December. 20% 30%, 30% and 20% of net area of plantation would be better to allocate for LP, DSK, MSK and LSK respectively. Every year 10% of scheduled LSK area would be adjusted in DSK. Adjusted section should not be readjusted in near future. Tipping and plucking are the harvesting process of young tender leaves as tea crop. Non-judicial practice of tipping and plucking make tea bushes weak and decrease yield. Retardation of growth of tea bush is due to prevailing of less active LAI (leaf area index). Longer tipping round in skiff sections is attributed more banjhi and plucked shoots with full stub. For better crop and good bush health effective leaf area and canopy covered land area ratio (LAI) 5:1 is utmost site of photosynthesis. The tea bushes after recovery from LP, DSK, MSK and LSK 5, 3, 2 and 1 layers of maintenance leaf above the cut mark respectively will help maintain this ratio and improve bush health and maximize yield. When growing shoots of 10 -15% bushes reach the tipping height in pruned or skiffed bushes that would be the high time to start tipping. Timely tipping and 7 days plucking round are beneficial to increase number of generations and enhance crop production. A handsome amount of crop is lost due to unwanted creep height. Pruning type and system of plucking are directly related to creep-height. Janam and fish plucking system are more effective to control creep height in the sections of different type of pruning. Quick increase of creep height and less number of lateral developments are associated in light plucking. Janam plucking system is more helpful to control creep height in the light pruning and deep skiff sections. Fish leaf plucking system is more beneficial for medium and light skiff areas. Seven days plucking round is better for obtaining highest yield and crop quality in the peak cropping season only. Soft three leaves and a bud ($3^1/_2$) during peak season are considered fine leaf but in early and later parts of plucking season it will be coarse. At the time of plucking immature growing shoots ($1^1/_2$) should be left off which will get physiological maturity and gain maximum weight for next plucking. A shoot with physiological maturity gain 40% weight than its physiological immature stage.

Key words: Tea, Pruning, Tipping, Plucking, Crop Production

Introduction

Pruning provides the bush organs which mainly are the leaves, while plucking removes them. It stimulates the production of a new set of vigorously growing leafy branches in replacement of the old set from which most of the leaves would have dropped off. There are other reasons necessitating renewal of branch system from time to time. Pruning is a great stress to tea bushes and activity against natural growth and development of tea bushes. Still then pruning is one of the vital cultural practices in the tea husbandry for keeping the bush at vegetative phase. As the age from pruning increases, shoots become smaller, increasing number of banjhi shoots appear at the plucking table as well as more and more buds fail to grow. Occasionally drastic pruning may become necessary for the elimination of diseased and pest-ridden branches, renewal of moribund frames and reduction of the load of unproductive wood.

The height of the plucking table has to be kept within easy reach of pluckers for manual plucking. It is practiced since the tea cultivation started. In Bangladesh, every year pruning or skiffing of the tea bushes are done due to geographical location and environmental fluctuations. But many of the tea growing countries prune once after 3/4 years interval. Because tea bushes of those countries receive well distributed rain throughout the year with minimum fluctuation of temperature. So, they have no fixed pruning time. They can prune their tea bushes as their requirement. In our country, practically tea is harvested 9-10 months only in a year. There is no crop in Bangladesh condition from the 3rd week of December up to 2nd week of March. It is considered as lean period of Bangladesh tea and that is the best time of pruning. Low temperature and longer rain free period (moisture stress) at that time restrict the normal growth of shoots. Pruning of the tea bushes in this time restrict transpiration loss. Simultaneously, the pruning litters cover up the soil surface and reduce evaporation loss. After getting favorable condition, the bushes recover with newly growing shoots. For these reason, pruning has to be done in our country to keep the bush at vegetative phase as well as to keep within convenient height.

There are some basic differences of objectives in young and mature tea pruning. The main objectives of young tea pruning are to make a permanent frame, to develop quick canopy coverage, to increase the number of effective branches quickly etc.

Ali (1970) stated that considering the quality and growth of tea bushes 3 -4 year pruning cycle could be followed. Three year pruning cycle might be adopted successfully in case of vigorously growing plants. Otherwise four year pruning cycle could be followed. He further opined that longer pruning cycle with lighter form of skiff resulted in reduction of crop quality. Barbora (1994) suggested 4 year pruning cycle LP-UP-DS-UP for N.E. India. Zaman (1988) observed that in Bangladesh condition, 4 year pruning cycle combination with LP – DS – MS –LS gave higher yield. Barua (1989) stated that a three year pruning cycle has proved most satisfactory for plain districts, subject to proper adjustment of various skiff combinations. He further mentied that in higher elevations and in case of growing chinery bushes, pruning cycle may be extended up to six years. Biswas (1977) observed that at lower elevations longer than three year pruning cycle appeared to be less productive.

Tipping and plucking are the harvesting systems of tea crop. It is the most expensive and labour intensive operation in tea cultivation. Hudson and Sarma (1991) observed that 60% of the field cost and 20% of the total cost of production involved with these activities. Young and tender growing vegetative parts /shoots from the tea bushes are harvested as good raw materials for processing quality tea in the factory at the expense of the metabolites supplied by the mature maintenance foliage remaining below the plucking table. It is reported that the young and tender leaves of tea bushes are highly capable to take part actively in photosynthesis. But these highest capable leaf areas for photosynthesis do not get opportunity to take part to produce metabolites due to tipping and continuous plucking for tea crop. As lost of such pragmatic leaf areas by tipping and plucking sufficient active photosynthetic leaf areas should be kept at the time of tipping time.

Sufficient carbohydrate production and more partitioning towards growing buds could lead maximization of yield in tea. The tea bushes produce maximum carbohydrate, synthesize essential organic compounds and liberate energy when optimized effective leaf area in the tea bushes. The opportunity of normal physiological functions of tea bushes will be restricted or limited by limiting maintenance leaf during tipping and continuous plucking. Barua (1989) reported that the peak photosynthetic efficiency of a leaf lasts for about six months after full expansion. Whereas leaf persists to the tea bushes up to 18 months. In his views an average LAI of a tea stand will be 5 for good growth and development of tea bushes as well as maximization of crop production. He also mentioned that leaf area is affected by cultural treatments and plant jat or clone. Under prolong drought condition and high temperature cause scorch and defoliation of leaves reducing LAI. High infestation of pest and disease can reduce LAI. In TES annual report (1981-82) it is mentioned that the capacity for photosynthesis gradually decline but the aging leaf still retains some activity until its abscission. Manivel and Hussain (1982) observed that the fish leaf was photyosynthetically more active than a foliage leaf. Manivel (1980) reported that the top layer of maintenance foliage contributed maximum towards the growth of new shoots. Photosynthesis declines from the top to the bottom layers of maintenance foliage due to obstruction to the passage of light through canopy.

It is understood from TES annual report (1978-79, 1983-84) that the crop production system of tea bush is sink limited. The area of production of photosynthesis (LA, leaf area) is the source and the growing parts where photosynthetase are used is known as sink. The successive shoots developing at the plucking table are the strongest sinks on plucked bushes. It was also mentioned that within the shoot, the growing bud is the strongest sink. Sink capacity drops to 70% of the bud in the first leaf below the bud, to 40% in the second leaf below and 30% in the third leaf. Tanton (1979) suggested that sink capacity in tea could be enlarged by harvesting $3^1/_2$ instead of $2^1/_2$ shoots. This suggestion appears to have overlooked that the third leaf on a growing shoot is old enough to produce more than 50% of photosynthates required for its own development. It also mentioned there sink capacity is increased by inducing the growth of more number of shoots. However, by using sustainable technology of tipping and plucking it is possible to provide sufficient maintenance foliage in tea bush within the tolerant limit of normal bush physiology.

Tipping will be initiated first after recovery from pruning and when growing shoots attain at prefix height. It takes around three to four months from pruning in Bangladesh condition. It varies with the depth of pruning, time of pruning and type of skiff. Sarker (1988) opined that higher yield was obtained when 20cm tipping allowance was given and that was tipped at the banjhi horizon on a pruned bush. He also stated that the tipping height might vary between 15 cm – 30 cm for maintain 5 leaves into the height of tipping allowance after pruning, which depending on type, vigor-ness and thickness of stick wood of tea plants.

The active leaf area, age of the maintenance leaf and time of tipping are important factors for lateral growth and development. They play an important role to produce maximum crop of tea. It is estimated that age of 1st leaf (lower leaf) at tipping allowance / height is about 3 or 3.5 months at the time of tipping. Gradually younger leaves are arranged at tipping allowance from top to down. Comparatively upper layer of leaves more actively take part in photosynthesis more actively.

Young tea pruning: Young tea pruning is done to produce a low spreading frame for ground coverage to check soil erosion, weed control and to develop a sturdy framework in early stage of tea. Grice and Rahman (1973) showed that the height of permanent frame formation depends on spacing, topography and jat or clone. Ali (1978) observed that pruning of sapling at 15 cm in nursery at the age of 10 to 12 months was effective to produce of new shoots. There are different methods which are used in young tea pruning such as de-centering, breaking, de-budding, ring barking and pegging. Barbora *et al.* (1984) observed that pegging produce a wider frame than de-cenetring. They also stated that de-centering before pegging produced more branches. Syam (1995) reported that thumb pruning or breaking at a height of 15 - 20 cm produced better configuration of tea by spreading of lateral branches. He further suggested that after about 8 - 9 weeks the new shoots could be tipped at a height of 60 – 65 cm. Tamang and Sarker (1977) observed that the young tea spread could be made either by de-centering or pegging. Further they mentioned that for spring planting, plant with good health response better when de-centre at 10 – 15 cm from the ground in December. Different types of formative pruning; de-centering, breaking, pegging and de-budding were studied on the clones BT2, BT5, BT6 and BT8 (BTRI annual report 1996, 97, 98, 99 and 2000). Bush architecture of BT2 and BT5 are of erect habit. On the other hand bush habit of BT6 and BT8 is horizontal. From the yield data presented in Table – 1 showed that the clones having erect bush habit (BT2 and BT5) gave better response in pegging method. On contrary the clones BT6 and BT8 having horizontal bush habit significantly produce highest yield in De-centering method. Yield difference is significant for different clones.

Table 1. Highest production of young colonel tea (BT2, BT5, BT6 and BT8) in under different pruning types

Name of Clone	Recorded highest production in young tea made tea kg /ha in different pruning system.			
	De-centre	Breaking	Pegging	De-budding
BT2	-	-	774.00	-
BT5	-	-	1038.80	-
BT6	1499.20	-	-	-
BT8	1499.20	-	-	-

In order to find out easy and compatible young tea pruning method in Bangladesh the above four methods are being tried in the field. It is understood that young tea pruning method is clone specific. Though pegging promotes more yield in young age for erect habit bush but in the long run this trend does not continue. Considering the present circumstances of plantation and convenience of pruning work, BTRI recommended de-centering for multi-stemmer plant and thumb breaking system for single stem plant which are presented in table-2.

Table 2. BTRI recommendations of young tea pruning

Age of young tea	Pruning type	Pruning height (cm)	Tipping height (cm)	Pruning time
1st year	De-centre/ breaking	15-23	50	Incase of spring planting late January- early February is the best time. Incase of winter planting late April- early May is the best time.
2nd year	Pruning	35-40	55	
3rd year	Skiff	50	52-55	
4th year	Pruning	45-50	70-75	
5th year	Skiff	68-73	72-75	

Time of young tea pruning depends on weather condition, time of planting, soil moisture and status of growth prevailing in the plant.

Mature tea pruning: Keeping tea bushes at vegetative phase by changing old sets of sticks and placing new sets of active productive branches is the main objectives of mature tea pruning. Five types of pruning with different depth are practiced in Bangladesh tea namely light pruning (LP), deep skiff (DSK), medium skiff (MSK), light skiff (LSK) and medium pruning (MP). Height of the plucking table when become inconvenient for the pluckers the height of the tea bushes is reduced by adopting medium pruning (MP). Some times MP is also called a height reduction pruning.

Pruning and yield relation of tea bushes: Relative depth of pruning and skiff are directly related with crop and quality. Higher the depth of pruning from plucking table, better the quality of tea but lower the yield. Lower the depth of pruning or skiff from the plucking table higher the yield but lower the quality of crop. Depth of pruning from the plucking table should be within tolerant limit of tea bushes. Otherwise, the risk of death of the tea bushes will be higher. BTRI recommendations of pruning height and time are presented in table 3.

Table 3. Recommended pruning height and time in tea cultivation of Bangladesh

Type of pruning	Height of pruning (cm)	Time of pruning
LP	55-80	Finish by the end of December
DSK	65-90	Better by first half of January
MSK	70-95	Finish by the end of January
LSK	72-97	Better by first half of February
MP	45-60	Best by December

Pruning and tea bush physiology: Rhythmic growth of tea bush is centrally located. During pruning, cleaning of unproductive infested and snags wood in centre place would help diverting more carbohydrate (photosynthetic product) in productive branches present in the peripheral region of tea bush canopy. It also makes the plants healthier hence increase yield. In the lower pruning, bud breaking takes longer time from the brown wood present in the lower part of the thickened sticks. Pruning the plants unnecessarily below the bush frame height, crop production will go down drastically.

Pruning sample: Traditionally one or two healthy tea bushes are taken for giving pruning samples in a common place of the section. Without keeping proper attention to bush health at the time of giving pruning sample, some time leads to reduction of number of productive sticks per bush. This situation may cause abnormal crop loss.

Pruning programme: Pruning is a hard work in tea cultivation which is directly related with crop production. Degree of hardness of pruning and skiff are responsible for quality and quantity of crop harvested. Judicious allocation of pruning and skiff area following four year pruning cycle will balance crop and quality of a tea estate. Timely pruning and tipping encourage maximizing production, number of shoot generation in a plucking point. Pruning programme helps minimizing cost of pruning. It should be prepared based on back calculation for time bounding related with available labour and resources for pruning. BTRI recommends 50% of net production area will be under LP and DSK and rest 50% for MSK and LSK. It could be followed as a guide line. 60% allocation to DSK and MSK together might be another turning point for higher balance production of a tea estate. Adjustment of allocation is always better from LSK to DSK.

Pruning Cycle: Pruning cycle is denoted as the sequential combination of pruning and skiff of successive years regulated as cyclic order. In Bangladesh and N.E India, four year pruning cycle is practiced with different combination of skiff. The cycles are LP-DS-MS-LS, LP-UP-DS-UP, LP-MS-DS-MS and LP-OS-DS-OS. From 12 years of study, it was found that four year pruning cycle combination with LP-DS-MS-LS is more suitable for higher production of tea. Shahiduzaman (2002) stated that 4 year pruning cycle combination with LP-UP-DS-UP produced 4.8% higher yield in BT2 clone over the recommended 4 years pruning cycle LP-DS-MS-LS. It indicates from his study that a particular pruning cycle may not be suitable for all cultivars rather it is cultivar specific.

Some technical points of pruning: Pruning should not be done at the same height of previous pruning mark. Present pruning height should be fixed above three to four cm of the previous pruning mark. Otherwise there is every possibility to form odd knot in the bush and yield will decline gradually.

Four years cycle with the combination of LP-DSK-MSK-LSK should be followed for better quantity and quality crop.

Cut should be clean, smooth and a bit slanting towards the center of the bush growing in the flat land. It is something like bottom shaped. Incase of sloppy land, cut should be parallel to the ground. Center of the bush should be kept clean.

Pruning litter should be removed from the tea bushes, specially incase of MSK and LSK sections. If it is not removed, horse hair thread blight, black rot etc diseases may be invited to the tea bush.

Banjhi, diseased and lacerated branch should be cut and clean properly. Within 24 hrs of pruning, fungicide should be sprayed as the dose mentioned in the table below:

Name of the fungicide	Nature of fungicide	Per ha. dose of fungicides and water	
		Fungicides	Water
Knowin 50 WP	Systemic	750 g	1000 L
Syrazim 50 WP	Systemic	750 g	1000 L
Calixin 75 EC	Systemic	1.12 L	1000 L
Copper 50 WP	Contact	2.8 Kg	1000 L
Champion 77 WP	Contact	2.24 Kg	1000 L

BTRI circular no. 138

Pruning litter is one of the main sources of organic matter in tea cultivation. It could be added in the soil at the time of pruning by keeping these *in situ*. It is better to slashing down the green parts before light pruning and medium pruning.

Tipping: Standard tipping practice is a possible way to keep bushes healthy when other growth factors remain constant. Timely tipping will encourage growing more number of laterals and thus increasing generations towards crop maximization. Tipping time and tipping allowance should be fixed through field observation. When 10-15% newly growing primary shoots of the bush in a field attain the tipping height it will be the time to start tipping. There is no definite interval of tipping. Closer round helps quick formation of smooth and even plucking table and help improve crop production. If any un-avoiding circumstances forced to increase tipping round it should be restricted only in LP and DSK section not in MSK and LSK or un-pruned areas. Tipping should be started from the center of a bush in the flat land but in the tillha land it should be started from the lower peripheral side of bush canopy. Tipping allowance should be fixed by sampling method on the basis of leaf layers. Tipping of LP, DSK, MSK and LSK bushes are shown in the figure 1, 2, 3 and 4 respectively

Tipping allowance: It is found that after light pruning, 5 layers of full leaves from pruning cut mark should be considered an ideal size of maintenance leaf area of tea bush for good health and maximizing yield in LP area.

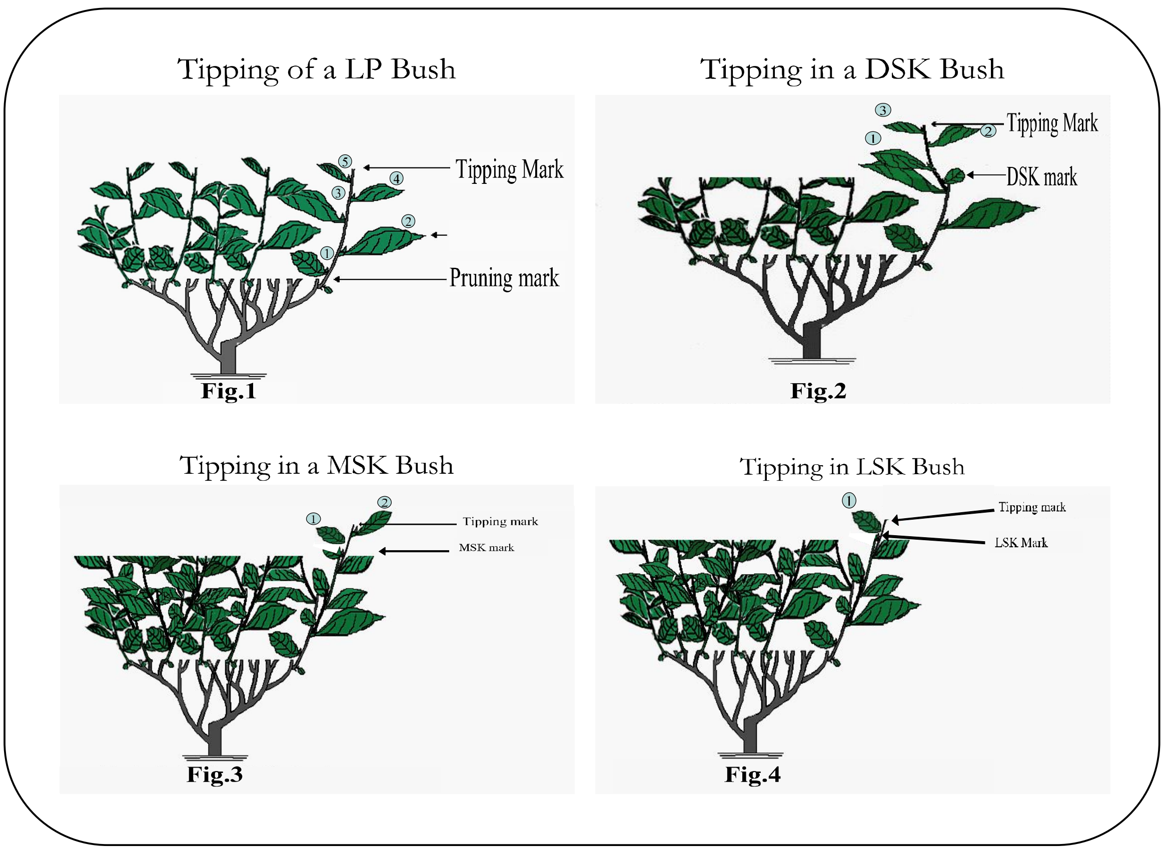

Fig. 1-4 Tipping allowance and maintenance leaf in different type of pruned & skiffed bush

Tipping stimulates the bud on the axils of the leaves to grow by the primaries, but the stimulus becomes weaker at increasing distance from the point of tipping. It was informed the top most axillary buds of all tipped primaries produce lateral shoots, which decline to 50% in the case of second axillary bud and 25% in the third.

Traditional tipping practices in Bangladesh Tea cultivation:

A little attention is taken to optimum maintenance foliage surface at the traditional tipping practice in Bangladesh. Most of the cases it is concentrated only height of tipping allowance of growing shoots after recovery of pruning bushes. The way of tipping may not be provided optimum maintenance leaf area for maximization of yield.

Traditionally tipping gets more attention in LP and DSK sections than MSK and LSK sections. As we harvest more crop in MSK and LSK sections, it should be more emphasized to keep uphold sufficient effective maintenance leaf for maintaining better bush health and maximization of yield. There is an understanding of many planters that the skiff sections already grip more than required maintenance foliage from previous year. So they think, there is no need to further addition of leaf area in those sections. On the basis of this idea, the growing shoots are tipped / plucked leaving janam or fish leaf only in MSK and LSK sections without adding any new leaf layer to the tea bushes. In the early cropping season, tipping is generally practiced with longer round. Because of longer interval, growing shoots become hard and causes of recognizable numbers of shoots is plucked with stub. Sometimes pilling up the bark or brushy of stem retaining to bush. The situation is very detrimental to maximize yield and some time create ideal situation of infestation of fungal diseases through pleated spot or wound.

As tea is a commercial crop, planters start tipping on the basis of factory renovation. Such idea may encourage going little late /delaying in tipping, which help growing more banjes in the field particularly in MSK, LSK or un-pruned sections.

Plucking: Collection of crop shoots is called plucking in tea cultivation. It is an anti natural activity against natural growth and development of tea plants. It is estimated that good maintaining tea bushes produce crop economically for 50 years. Any un-judicious and non-scientific plucking leads to short the economic life of tea bushes. Simultaneously crop loss will happen because of creation of uneven plucking table, un-expected creep height, cut up the opportunity of initiation maximum number of laterals. For harvesting maximum crop and maintaining standard quality the principle of plucking 'keeping the tea bush healthy and plucked maximum crop by practicing scientific plucking method with minimum cost of production' should be followed **.**

It was observed that continual plucking to a mother leaf leads to the retention of excessive maintenance foliage on the bush at the expense of productivity. It was reported that fish leaf plucking leads to excessive creep but janum and level plucking enhanced productivity. In addition hard plucking encouraged shoot number and has negative effect on unit wt. of shoot. Wettasingghe *et al*. (1991) reported that fish and janam plucking increased shoots per bush but decreased shoot size than combination of fish leaf plucking and single leaf plucking. He stated that fish and janam plucking gave significantly higher yield in the first year from pruning. Standard plucking based on shoot growth and leaf extension rate should be ideal practice in tea harvesting. Shahiduzzaman and Eunus (2010) reported that the number of shoots and shoot weight were higher in Janam plucking system. They recorded 16.68% more yield over fish plucking. The leaf growth varies with plant type or nature of the cultivars, conditions of growing and general environmental conditions particularly temperature, rainfall and relative humidity.

Plucking Round: The time interval between two successive plucking is called plucking round. The interval is ideally determined by the rate of leaf un-folding. In north-east India and Bangladesh, to keep a balance between crop and quality, normally 7 days plucking round is practiced. On the assumptions that by this time the levels of various biochemical constituents necessary to make tea of quality would reach their optima. Any increase or decrease in plucking interval could significantly influence the dynamic metabolic system, even leading to alteration in leaf physiology. Therefore plucking round at shorter intervals with fine plucking can reasonably assure a better quality of made tea than teas plucked at longer plucking intervals. Shahiduzzaman and Eunus (2010) reported that 5.46% more crop was harvested in 7 days plucking round than 10 days round. Probably it might be the cause of specific clone. Generally up to 10 days plucking round, crop is increasing but quality of crop decline than shorter plucking round over10 days. Nyirenda and Mphangwe (2013) reported that plucking round varies from clone to clone and place to place because of a big variation in optimum shoot age (OSA) between cultivars ranging from 35 to 54 days at two different locations. In our Bangladesh condition, variation in optimum shoot age would be 21 -28 days in peak season but in early and late cropping season it would be extended up to 40 - 56 days.

It was observed that the time required for unfolding of successive leaves from a growing bud vary from 3 – 6 days depending on climatic variation. This is called leaf period. The mean leaf period of seed jat plant of N.E India is 4 days during the main flushing season and the leaf should be plucked a day earlier than twice of the leaf period (2 x leaf period – 1= 7 days). The type of shoots left out during previous round in peak season determines the size of harvestable shoots in the next round, as is evident from table 4.

Table 4. Type of shoots available on different plucking round in the tea bushes

Type of shoots left in the bush	Type of shoots harvested after		
	4 days	8 days	12 days
Only bud	$1^1/_2$	$2^1/_2$	$3^1/_2$
One leaf and a bud ($1^1/_2$)	$2^1/_2$	$3^1/_2$	$4^1/_2$*
two leaves and a bud ($2^1/_2$)	$3^1/_2$	$4^1/_2$*	$5^1/_2$ *

It is seen from the table 1 that one leaf and a bud ($1^1/_2$) which was left in previous plucking round produce $3^1/_2$ standard shoots in the next 8 days plucking round. If two leaves and a bud ($2^1/_2$) left during plucking within next 4 days the shoot become $3^1/_2$ standard shoots beyond that it will be coarser.

Shahiduzzaman (2002) mentioned that 7 days plucking round produce higher yield. It is seen from the yield data in table 5 that comparatively longer round (10 days) produce higher yield by the compensation of quality. In skiff area shorter round (6 – 7 days) is not out yielder but maintain standard quality (table 6). Shorter round (6 days) in LP area produce highest number of generation but in skiff areas no definite trend was observed

Table 5. Yield kg/ha in different length of plucking round

Pruning type	Length of plucking round				
	6 days	7days	8 days	9 days	10 days
LP Year	1022	1087	997	1027	1112
DSK Year	1720	1782	1756	1747	1786
MSK Year	1694	1889	1845	1794	1894
LSK Year	2363	2321	2271	2097	2092

Experimental data on number of laterals initiation (Generation number) showed in table 6.

Table 6. Average number of generation at different plucking round

Pruning type	Length of plucking round				
	6 days	7days	8 days	9 days	10 days
LP	7	6	5	4	5
DSK	5	5	4	3	3
MSK	4	3	4	5	4
LSK	5	6	4	4	3

Plucking System: Plucking system plays a vital role towards maximization of tea crop. It is directly related to creep-height and initiation of more number of generations to harvest. Longer creep height is responsible for crop loss due to development unwanted creep. It also reduces the number of generation or restricts initiation of more laterals because of longer time requirement to dry up the green long stick remaining on the plucking surface. Plucking system is determined on the part of harvesting shoots persist or retain in the tea bushes. It is generally known as stub. Plucking system is broadly classified into two categories. One is called light plucking and other is hard plucking. When growing shoots are plucked leaving one full leaf or more in the tub refers as light plucking (Fig 5). First full leaf of a growing shoot some time called mother leaf and 2nd full leaf is treated as first leaf. Both mother and first leaves plucking are light plucking. When plucking height goes up leaving more and more leaves plucking become lighter and create un-control creep height. Harvesting selective growing shoots at the height above fish leaf on the plucking table is called **fish plucking (Fig. 5)**. Similarly plucking done at the height just below the fish and above the janam (scaly leaf) is known as **janam plucking (Fig**. **5**).

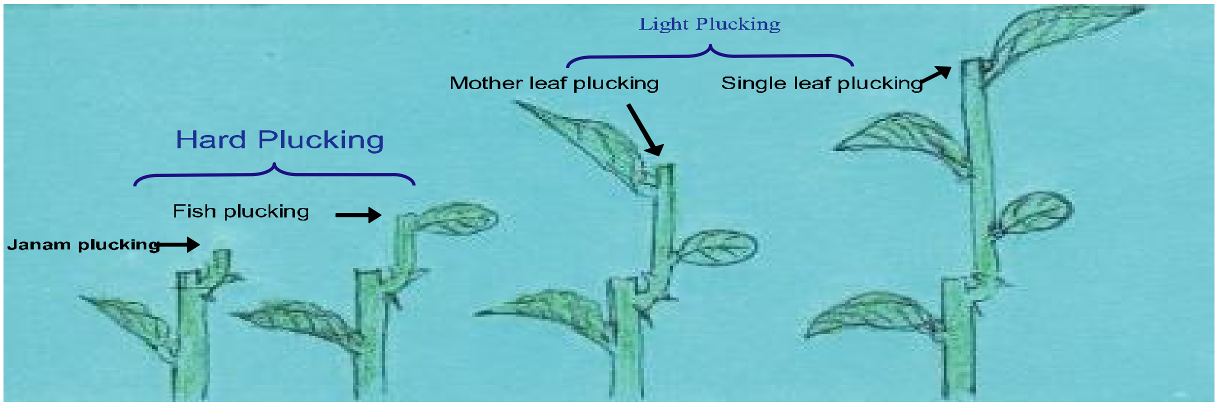

Fig. 5. Plucking System

Both fish and janam plucking are considered as hard plucking.

Plucking systems has great impact on tea yield. Data presented in table -7 indicate that highest yield is associated with janam plucking system in pruning and all type of skiff areas.

Table 7. Effect of plucking system on yield (kg/ha) and mean shoot weight (g/shoot) at different pruning type

Pruning Type	Number of shoots / bush		Weight (g) of shoots / bush		Yield (Kg/ha)		Green weight (g) / shoot	
Plucking System	Fish	Janam	Fish	Janam	Fish	Janam	Fish	Janam
LP	1343	1236	0.860	0.864	2902	2916	0.64	0.70
DSK	2431	2480	1.446	1.648	4880	5562	0.59	0.66
MSK	2447	2498	1.493	1.626	5038	5837	0.61	0.65
LSK	2919	3113	1.425	1.694	4809	5717	0.49	0.54

The term **black plucking** is frequently used in tea culture. Black plucking is also one kind of hard plucking. It is done only at the eve of long vacation. In this case growing shoots at all growth stages on the plucking table present are plucked without any selection. If it is practiced regularly great negative impacts put on the yield and abnormally increase the plucking round decreasing yield. Hence it would be a great challenge to maximize yield of tea.

Plucking shoots standard: Standard of plucking shoots refers the type of shoots harvested. Standard of plucking shoots depends on pruning type, plucking round and types of growing shoots leaving for next plucking round and leaf extension rate of the clone / jat of the plucking area. Plucker's efficiency also has a great impact on maintaining plucking shoot quality. Adjusting leaf growth rate with plucking round would be a great tool for maximizing yield. Such type of immature shoots should be left for next plucking round that will gain maximum weight and get physiological maturity by next round of plucking. Changing one stage to next stage of under growing shoots would take three to four days. By this time the growing shoots store energy and accumulate food to the growing parts especially to the top bud. It was reported that during this time, shoot gain 40% weight i.e. increase biomass without compensation of quality of shoots.

Leaf growth also depends on temperature, soil moisture, soil nutritional status and genotype of tea bushes. In the peak cropping season, by 3 to 4 weeks a growing bud become two leaves and a bud ($2^1/_2$). In the early and latter part of cropping season it takes longer time to grow a two leaves and a bud ($2^1/_2$). It takes 5 to 6 weeks in the early and 6 to 7 weeks in late cropping season. Practicing standard 7 days plucking round help grow more number of plucking shoots (generation). 5 to 6 generations were recorded at BTRI in clones and in seedling population. Eight generations were reported in north east India (Barua, 1989) Standard physical leaf composition in the bulk of plucking shoots is directly related to plucking round (table 5), labor efficiency and system of plucking. Harvested leaf quality is divided into four categories i.e.

a) Fine: One leaf and a bud ($1^1/_2$) and two leaves and a bud ($2^1/_2$) together.

b) Standard: Standard quality of leaves is contained large one leaf and a bud ($1^1/_2$), all two leaves and a bud ($2^1/_2$), soft three leaves and a bud ($3^1/_2$) and single banjis.

c) Medium: All two leaves and a bud ($2^1/_2$), all three leaves and a bud ($3^1/_2$), single and double banjis.

d) Coarse leaf indicates all three leaves and a bud ($3^1/_2$) heard or over $3^1/_2$ and all banjis.

To maintain a blance between quality and yield, 80% fine and 20% coarse leaf in the harvest is judicially acceptable in Bangladesh tea. Under a good plucking system breaking back is not required. However, this becomes necessary when rounds are very long and supervision is improper cause's crop loss. Leaving banji shoots on the plucking surface causes loss of crop, which could be as high as 90 kg/ha. This loss is attributed to; uneven plucking surfaces, restricted lateral growth and hindrance in the metabolic activity of tea bush.

Table 8. Average physical leaf composition by shoot number and there percentage at different plucking intervals of a year

Item of leaf composition	Number of physical leaf composition in different plucking round (Percentage shows in parenthesis)				
	6 days	7days	8 days	9 days	10 days
$2^1/_2$	2899 (45.34%)	2020 (43.34%)	1326 (36.72%)	981 (33.73%)	702 (28.02%)
$3^1/_2$	2032 (31.78%)	1478 (31.71%)	1273 (35.25%)	1040 (35.76%)	825 (32.93%)
Over $3^1/_2$	243 (03.80%)	177 (03.80%)	232 (06.43%)	257 (08.83%)	267 (10.66%)
B_1 (Banji one)	208 (03.25%)	-	-	-	-
B_2 (Banji Two)	587 (09.18%)	549 (11.77%)	417 (11.54%)	272 (09.36%)	359 (14.33%)
B_3 (Banji Three)	425 (06.65%)	437 (09.38%)	363 (10.06%)	358 (12.32%)	352 (14.06%)
Total	6394	4661	3611	2908	2505

In TES Ann. Rep. 1974 – 79 it was reported that bio-chemical quality of made tea gradually decrease from bud to different components of plucked shoots downward to total crop and value of made tea. Results of the experiment are presented in table 9 a.

Table 9 a. Contribution of different components of plucked shoots to total crop and value of made tea

Components	Percent by wt. of the harvested crop	Relative value of made tea	Percent contribution of components to value of tea
Bud	11.5	100	18.1
1st leaf	20.5	79	23.8
2nd leaf	28.9	52	21.9
3rd leaf	9.8	49	7.8
Stem	15.8	64	17.4
Banjhies	13.6	55	11.1
Weighted average	-	65	-
Control (whole shoots)	-	69	-

Chowdhury (2001) stated that from his in-house trial report on plucking quality shoots and their value (estimated and sale) of made tea that highest contribution of sale value associated within $2^1/_2$ (table 9 b).

Table 9 b. Quality leaf manufacturing and its effect in market price in auction sale

Quality of green leaf manufacture	Brokers estimated value Tk. /kg		Sale value Tk./kg in Chittagong auction		HPLC test value of TF Count	
	clone	Seedling	clone	Seedling	clone	Seedling
Fine plucking (2 1/2)	95/-	75/-	115/-	78/-	Above 4000	3500
Normal plucking	-	64/-	-	66/-		
Difference Tk,/ kg	-	11/-	-	12/-		
Difference in %	-	17/18	-	18/18		

Result presented in table 9b clearly demonstrates that manufacturing of tea from quality leaf always has premium value. Fine plucking should be targeted always for quality tea manufacturing in a factory.

Creep height and crop loss: Creep height is related with plucking system, length of plucking round and skill of pluckers. It was observed that unwanted creep height on the plucking table made irreparable loss of crop. It was reported that one inch un-wanted creep height may causes 100 -120 kg made tea loss / hectare/year. Under hard plucking system with shorter length of plucking round keep the height of creep within tolerable limit. Type of pruning and skiff also influence the creep height. The result presented in the table 6 shows that the highest creep (6.3 cm) was recorded in LP with longer plucking round and the lowest (2.5 cm) in LSK with shorter plucking round. Creep is gradually increased with the advance of plucking round and season (Table – 10, 11a & 11b). The creep height increment rate is highest from peak to late cropping season. How the creep height developed is shown in Fig-6.

Table 10. Average creep height (cm) at different plucking round at the end of cropping season

Pruning type	Length of plucking round				
	6 days	7days	8 days	9 days	10 days
LP Year	5.8	6.1	6.0	6.2	6.3
DSK Year	4.4	4.3	4.5	4.4	4.3
MSK Year	3.2	3.4	3.3	3.4	3.3
LSK Year	2.5	2.4	2.7	2.6	2.7

Table 11a. Accepteable level of creep height (cm) in different pruning type relation with different parts of cropping season

Type of pruning	At the end of July	At the end of August	At the end of November
LP	2.5 cm	3.5 cm	5 – 6 cm
DS	2.5 cm	3 cm	4.5 – 5 cm
MS	2.5 cm	3 cm	4 cm
LS	2.5 cm	3 cm	4 cm

Table 11b. Effect of plucking system and pruning types on increasing creep height of clone and seedling tea.

Clone / Seedling	Plucking system	Creep height (cm) in different pruning type				Mean Creep Height (cm)
		LP	DSK	MSK	LSK	
TV1	Fish Janam	11.5 5.12	12.5 3.85	8.95 3.11	3.62 1.96	9.61 **3.61**
BT1	Fish Janam	9.6 4.9	10.50 2.95	5.67 3.20	3.46 1.88	7.31 **3.23**
B207	Fish Janam	10.67 4.85	11.68 3.38	5.49 2.90	3.18 1.95	7.75 **3.27**
Seedling	Fish Janam	10.50 4.84	9.53 3.31	6.89 2.39	3.69 2.23	7.65 **3.19**

It is observed from table – 11a that janam plucking system will help control creep height in LP section. It helps maintain a smooth and even plucking table also. Fish plucking or mixture of fish and janam plucking could be better in skiff sections for keeping control creep.

Crop regulation: Heavy rush of crop are observed almost every year in July, August and September. During this time plucking rounds become longer and coarse components increase in the harvested shoots. For manufacturing improperly weathered excess shoots, factory becomes over loaded and slacking the standard of manufacture. Therefore crop regulation can be weaving out the heavy rush of crop by dispersed the crop early and later part of rush time.

The traditional method of dealing with the situation is by suspending plucking for one or two rounds and skiff the bushes before recommencing plucking. Regulation of crop by this way would be more harmful towards maximum crop harvest. With a view to avoid skiff and loss of crop, in Tockli Experimental Station various chemicals have been tested for suppressing crop during the period of heavy rush without reducing the total output of crop shoots (TES Ann. Rep., 1981-85). Dose and chemicals used in the experiment are presented in table 12. It was claimed that the chemicals suppressed growth for 2 – 3 weeks followed by vigorous growth of the bushes during the following 4 - 6 weeks. It was reported that there was no loss of crop and the chemicals had no adverse effect on quality of crop. It is not tested in Bangladesh tea yet. It could be experimented in our tea in near future.

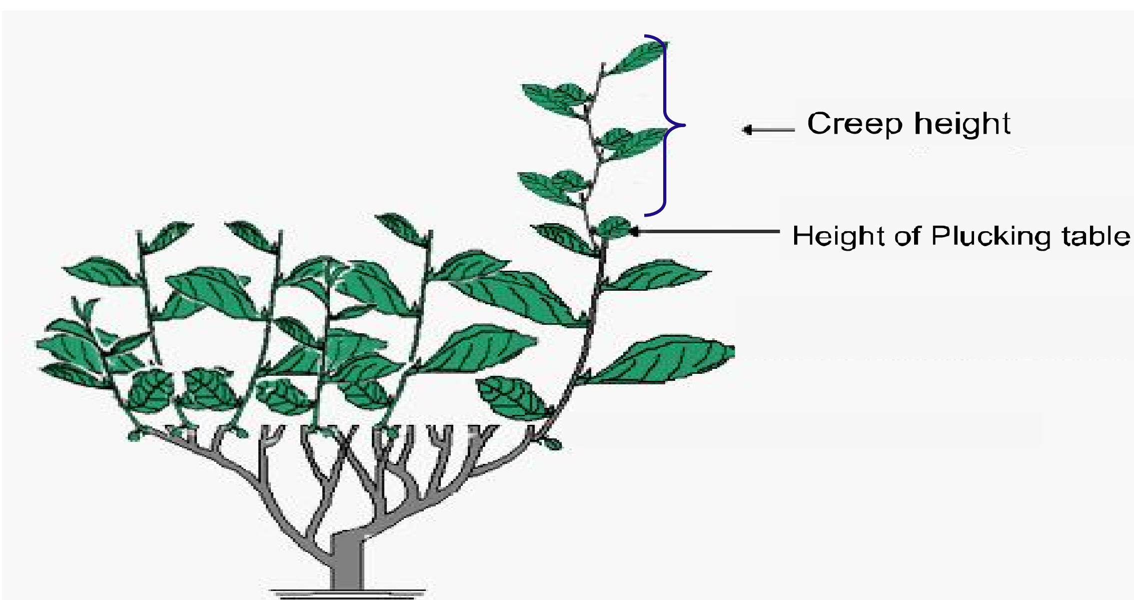

Fig. 6 Creep height in a LP Bush

Table 12. Temporary growth suppressor and their dose in the period of heavy rush of crop

Name of chemical	Dose / ha (Single spray)	Chemical composition	Time of application	Effect
Ethephon	100 ppm	2-chloroethyl phosphonic acid	Peak growing season (June to September)	Suppressed growth for 2 – 3 weeks followed by vigorous growth of the bushes during following 4 -6 weeks without loss of crop.
Morphactin	50 ppm	Chlorflurenol methylester		
Paclobutrazol	200 ppm			
chlormequat	200 ppm			

It might be possible also to distribute crop of heavy rush period to early and late end of rush time by adjusting time of pruning by regulating the pruning cycle.

Plucking programme: Effective plucking programme is helpful to harvest maximum crop produced by the bushes with maintaining a standard balance between yield and quality. It would be a great way of means to maintain plucking round which could help maintain quality of harvested leaves and bush health. It also helps smooth and continuous supply of standard quality of fresh leaves for processing tea in the factory without over or under loading capacity of factory. As plucking is more costly among the field activates, an effective programme can create an opportunity to justify judicial deployment of labour for plucking. Around 60-70% of field cost is associated with labour payment for harvesting tea crop in the field. Therefore any inefficient labour management for plucking contributes higher cost of production. Effective plucking program might be a way of improving the situation of traditional deployment of labour for plucking.

For the preparation of an effective plucking program the following information are needed-
Area and pruning based section wise estimated crop target,
Monthly crop estimation and distribution,
Available pluckers and average crop out tern / labour / day of a garden,
Estimated green leaf to be plucked daily on the basis of yield and quality balancing,
Estimated daily plucker requirement,
Determination of plucking round and system of plucking.

Pruning type wise crop estimation techniques: Pruning area wise yield data of Bilashcherra Experimental Farm are analyzed and presented in table 13 and 14 for understanding of crop estimation techniques.

Table 13. Crop estimation in different parts of cropping season in relation with pruning types based on crop distribution

Type pruning in cropping area	Estimated number of plucking round and green leaf production (kg) / round / bush									Expected made tea kg/ha
	Early season			Peak season			Late season			
	Number of estimated Plucking round	production (g) / round / bush	Yield (kg/ha)	Number of estimated Plucking round	Prod. (g) / round / bush	Yield (kg/ha)	Number of estimated Plucking round	Prod.(g) / round / bush	Yield (kg/ha)	
LP	5 - 7	13 -14	910 (9.47%)	15 -16	33 - 34	6930 (72.16%)	7-8	18 - 20	1764 (18.37%)	2160
DSK	6 -7	15 - 17	1260 (11.92%)	15 -16	35 - 36	7350 (69.54%)	7 -8	20 - 22	1960 (18.54%)	2378
MSK	8 - 9	18 - 20	2016 (18.60%)	15 -16	38 -39	7980 (73.64%)	6 -7	10 - 15	840 (7.75%)	2438
LSK	8 -9	21 - 23	2352 .59%)	15 -16	40 - 42	8400 (73.53%)	6 - 7	08 - 10	672 (5.88%)	2570
Average crop distribution of seasons			15.14 %			72.22%			12.64%	

It is revealed that in the mature tea highest proportion of production is obtained from skiff sections than pruned area. In Bangladesh condition, tea crop can be harvested not over 10 months in a year. Cropping season start from March and early cropping season may extend up to May. June- October are considered main (peak) and November – December are late cropping season. Highest crop (over 70% crop) is harvested in peak season in all type of pruning areas. Highest crop is harvested according to depth of pruning or skiff upward direction. But quality of plucking leaf is gradually up graded in downwards depth of pruning or skiff. So that it can be said that lower the pruning higher the quality and higher the pruning lower the quality. During the preparation of plucking programme this idea has to implement for balancing quantity and quality of daily crop production and distribution adjusting with factory loading capacity.

Table 14. Month wise crop distribution from 2009 -2013 of Bilashcherra experimental farm

Month	Monthly crop distribution percentage (%) of the production years					Mean (%) of crop distribution
	2009	2010	2011	2012	2013	
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	0.30	0.34	0.21	0.14	0.12	0.22
April	4.24	3.66	4.95	4.84	2.99	4.06
May	7.13	10.16	3.45	12.34	7.84	8.19
June	12.00	12.93	13.00	10.94	13.44	13.06
July	15.84	14.37	13.95	16.44	18.36	15.79
August	17.75	16.76	14.16	15.96	16.75	16.28
September	12.22	16.44	19.61	13.25	13.87	15.08
October	17.34	8.85	16.40	14.16	12.83	13.92
November	8.80	11.05	9.74	8.97	8.35	9.37
December	4.38	5.44	1.53	3.32	5.45	4.03

Source : Bilashcherra Experimental Farm, BTRI Annual Report 2009 – 2013

Optimum population is maintained especially in high yielding young mature sections of well managed tea gardens of Bangladesh.. Yield of the areas under different pruning types are directly related with the age of bushes and depth of pruning & skiff. Pruning and age wise yield data of Bilashcerra Experimental Farm were analyzed. In young mature sections yield was obtained 1800, 2200, 2300 and 2400 kg per hectare for LP, DSK, MSK and LSK sections respectively. In old (over 40 years) teas yield were be estimated 1000, 1100, 1200 and 1300 kg per hectare for LP, DSK, MSK and LSK respectively. Simultaneously crop also is being estimated of young tea 150, 400, 700, 900 and 1000 kg per hactor for 1, 2, 3, 4 and 5 years aged new plantation respectively. Average crop harvested by pluckers per round was calculated and it was 35 – 40 kg /round. Length of standard plucking round is practiced 7 – 8 days in Bangladesh. Number of plucking rounds was generally estimated 28, 30 -32, 32 -34 and 34 – 36 in LP, DSK, MSK and LSK sections respectively.

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INTEGRATED APPROACHES IN TEA PEST MANAGEMENT FOR SUSTAINABLE TEA PRODCUTION

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Abstract

Tea is a popular beverage in the world, produced from the leaves of evergreen shrub *Camellia sinensis* L (O Kuntze). It is a perennial crop and grown as a monoculture on large contiguous areas. Tea plant is subjected to the attack of several pests such as insects, mites and nematodes. Tea mosquito bug, red spider mite, termite, nematode, thrips and looper caterpillar are the major pests of tea in Bangladesh. Enormous crop loss was incurred due to the attack of these maladies. Tea crop protection is an essential component of tea husbandry to safeguard of the tea plants from the ravages of pests, diseases and other maladies. Extensive use of chemical pesticides began only a few decades ago with tremendous immediate economic gains but its abuses were not foreseen or ignored. As a consequence there arose the development of resistance to pesticides, pest resurgence and secondary pest outbreak as major problems. Critical studies on crop loss due to pests and establishment of economic threshold levels of major pest species are prerequisites for minimizing the use of pesticides. Many different tactics of IPM strategies including cultural practices, physical, mechanical and biological control agents, pest-resistant varieties and chemical pesticides are used in tea plantation. In tea husbandry, cultural control measures such as plucking, pruning, shade regulation, field sanitation, fertilizer application, host plant resistance, manipulation or destruction of alternate hosts and selection of pest resistant/tolerant varieties and mechanical mechanisms like manual removal, heat treatments, light traps, use of bio-pesticides, bio-control agents and sex pheromone trap need to be given more importance in pest management programme in tea. Since pesticides will continue to play a vital role in pest management in tea, urgent investigations need to be taken up on the effect of pesticides on predators, and parasites active in the tea ecosystem, on pesticide residues in tea and also on the newer technologies of pesticide application. The various components of the IPM practices are discussed in this paper with a few specific examples, since the success stories with the use of IPM practices are numerous and increasing day by day. Thus the recent integrated approaches for tea pest management should help tea industry for successful long lasting plantations.

Key words: Tea, Integrated Pest Management, Sustainable Tea Production

Introduction

Tea is a popular beverage in the world, produced from the leaves of evergreen shrub *Camellia sinensis* L (O Kuntze). It is a perennial crop and grown as a monoculture over large contiguous areas during the last 160 years had formed a stable tea ecosystem for widely divergent endemic or introduced pests. Moreover, a characteristic feature viz. the permanence of shade trees, ancillary crops, forests, an uniformity of cultural practices such as sequential pruning cycles, weekly plucking rounds, weeding, mulching etc. have a greater impact on the subsequent colonization, stabilization and distribution of pests. Since the dawn of tea culture, a wide range of pests have been associating with tea plantations. Tea pests and tea productivity are two antagonistic factors.

Each tea growing country has its own distinctive pests. Globally 1034 species of arthropods and 82 species of nematodes are associated with tea plants (Chen and Chen, 1989). Among them, 25 species of insects, 4 species of mites and 10 species of nematodes are recorded from Bangladesh (Ahmed, 2005). Only a few of them have become major pests while most of them are minor and localized which cause occasional damage. In tea, a major pest of today may be minor of tomorrow. Of the production, about 10-15% of its crop could be lost per year by various pests particularly insects, mites and nematodes if adequate control measures are not taken. Moreover crop losses to the extent of 50% or more may be inflicted by the advent of an epidemic or outbreak of specific pests in a particular season or a tea estate. Most of the pests are polyphagous, but all the pests infest throughout the year and complete their life cycle in the tea fields. Tea pests may be classified into three categories on the basis of the site of attack/infestation viz. *root pests* like nematode, termites, cockchafer grub; *stem pests* like red coffee borer, stem borer and *leaf pests* like tea mosquito bug, thrips, jassid, aphid, flushworm, looper caterpillar, leaf roller and all mite species (Mamun and Iyengar, 2010).

Major insect pests of tea recorded in Bangladesh are shown in fig. 1.

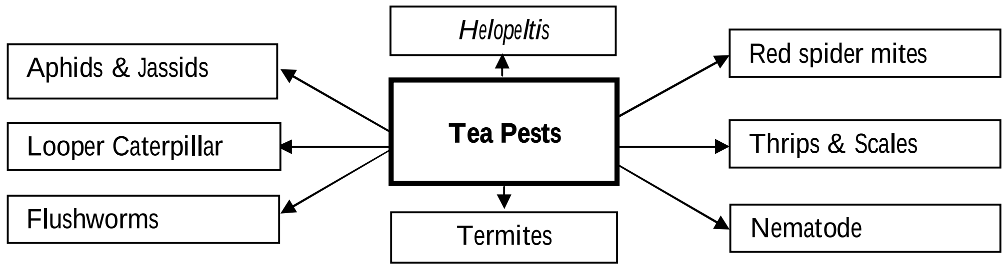

Fig. 1. Major insect pests of tea in Bangladesh

Tea Pest Spectrum

Tea mosquito bug, *Helopeltis thievora* Waterhouse is one the most important sucking pests of tea in Bangladesh. It is also widely distributed in India, SriLanka, Vietnam, Indonesia, Malaysia and in African countries. From the economic point of view, the pest is considered to be the major one causing damage to tea both in respect of quantity and quality. It has assumed considerable significance in the last few years due to its widespread occurrence in all the six valleys in Sylhet Zone. The damage is caused by both adults and nymphs of the insect which are most active during early in the morning and late in the afternoon daily. The insects suck sap from terminal twigs, buds and leaves by piercing the plant tissues with their mouth stylets besides injecting toxic substances present in their saliva. As a result of this injury, the leaves become curled up and deformed. The feeding punctures on leaves appear as reddish brown spots. The attacked shoots may present dieback symptoms. Each female bug can insert as many as 500 eggs in soft plant tissues. The eggs hatch in about a week's period by releasing the nymphs. The entire life cycle is completed in about a month. In a year there may be several generations. Adults hibernate during winter. These insects are active from January to September. Their damage is predominant in moist and shaded areas especially after monsoon showers.

The red spider mite, *Oligonychus coffeae* Neitner causes serious damage in India, Sri Lanka, Bangladesh, Taiwan, Kenya, Malawi, Uganda and Zimbabwe (Gotoh and Nagata, 2001). Now-a-days, it is a serious pest of tea in Bangladesh. Hundreds of spider mites are found on the upper and undersurface of every tea leaf, together with thousands of eggs and the white skin casts by the mites as they grown. Tea red mites are of major economic importance in the tea industry of Bangladesh and are responsible for depredation of yield and debilitation of tea plants. Crop loss by the pest is 9.57% (Ali *et al.,* 1994). The larvae, nymphs and adult mites cause the damage. When large numbers of mites are present, sucking one leaf cell after another and sucking out the contents, the whole leaf eventually changes to a bronze colour and finally dries up. Population of red spider mites reached in peak in March/April during drought period. The life cycle from the egg to adult is completed in 10-14 days depending on weather condition.

Termites are usually known as white ants. The great majority of termites live in tropical and subtropical regions. They are polymorphic social insects which live in nests (termitaria) of their own construction. Many termite species are responsible for considerable damage to tea bushes and shade trees. In Bangladesh tea, both live wood termites as well as scavenging termites are present in the field. Among the termite castes, worker caste is very dangerous to tea. Crop loss by this pest is 22.56% (Anonymous, 2007-08). Fecundity of high performance queen is 84,000 eggs/day.

Nematodes or Eelworm is a serious pest of tea in the nursery level. They are non-arthropod pests, microscopic, resembling round worms. Infected saplings become weak and unthrifty, plant loose their freshness, become flaccid, gradually turns reddish and ultimately dries up and finally damage the root systems. Root knot nematodes (*Meloidogyne* sp.) and root lesion nematode *(Pratylenchus* sp.*)* are the major in Bangladesh tea. Root knot infestations are easily recognizable from their characteristics tumor like galls they produce on infested plant roots. Adult males are always slender and females are saccular with a distinct neck. A single female eelworm is capable of laying 300 to 600 eggs. Life cycle is simple, and requires 20-60 days to complete.

Thrips & Looper caterpillar are the emerging pests of tea in Bangladesh condition. They normally infest the tea plant during recovery after pruning or when young and as nursery. Both adults and nymphs of thrips make slits in the upper leaf surface by inserting the styles and sucking the juice. On the under surface of mature leaves, two longitudinal *sand papery lines* form along the mid-rib. Affected leaves may be corky and curl up. The looper caterpillar is also a serious pest of tea, shade trees and green crops. Young caterpillars feed on tender leaves, making punctures along the margin while the mature larvae prefer older leaves. In a severe attack, tea bushes are completely denuded. The female deposits her eggs in batches of about 200 eggs, mostly during night. Young caterpillars are dark brown with pale greenish white lines on the back and sides. Hence, it loops while walking. The larval period is about 3 weeks and pupal period is 3-4 weeks. The life cycle is completed in 8-10 weeks.

Tea Pest Management

Tea crop protection is an essential component of tea husbandry to safeguard of the tea plants from the ravages of a multitude of pests, diseases and other maladies. The development of a specific pest control programme depends on many factors, such as the nature of pest spectrum, type of crops to be protected, economics of pest control technologies available, etc. In view of tea ecosystem and diversity of pest complex, a multiple approach of pest management is adopted for Bangladesh tea. At present, the control of insect pests of tea tends to depend on insecticide spraying. Over the past few decades, the application of organosynthetic pesticides has resulted in the resurgence of primary pests, secondary pest outbreaks, and resistance development, as well as the presence of environmental contaminants including residues in made tea. To reduce these problems, IPM tactics have emerged as an alternative solution. Today it is realized that an integrated pest management programme (IPM) involving biological and cultural methods with judicious use of chemicals alone will help reduce the pest pressure. IPM is a cohesive system of selection, integration and implementation of pest control strategies/methods based on the predicted, economic and socio-ecological consequences. According to FAO definition, "*IPM is a system that in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury*". IPM is recognized as the most robust construction to arise in the agricultural science during the second half of the twentieth century. Concern research efforts have been made to develop various control techniques (cultural, biological and chemical) which could be harnessed for integrated management of important pests of tea in Bangladesh.

Pest forecasting and pest monitoring

Pest forecasting and pest monitoring is an important approach, which can be employed by extension officers, field officers and supervisors to analyze field situations with regard to pest defenders, soil conditions, plant health, influence of weather factors and their inter-relationship for growing a healthy crop.

Economic Threshold Level

One of the basic requirements of pest control is the economic threshold levels (ETL) at which control measures are justified. The ETL is a matter of judgment, giving time for the farmer to take action for the control measure before economic injury level itself is reached. Without this information it is not possible to decide whether an insect is indeed a pest in a particular situation. Critical studies on crop loss due to pests and establishment of economic threshold levels of major pest species are pre-requisites for minimizing the use of pesticides. In choosing the kind and amount of pest control, one should establish the ETL first.

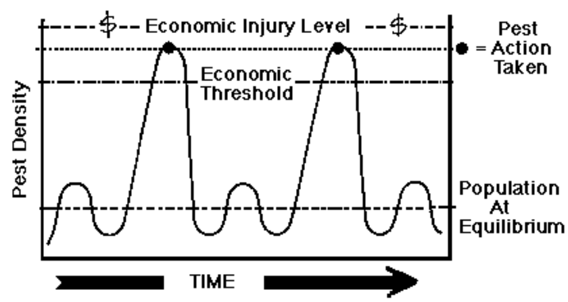

Fig. 2. Showing Economic injury level (EIL) and Economic Threshold Level (ETL) of pests of tea

The economic threshold Level (ETL) is the population density at which control measures should be determined to prevent an increasing pest population from reaching the Economic injury level (Fig. 2). EIL is the lowest pest population which will cause economic damage. EIL is very low for the pests infesting the new shoots since their injury directly affects both yield and quality of tea. On the other hand, EIL is high for the pests infesting other parts of the tea plants because their injury affects the growth of the new shoots of the next crop and light injuries do not affect the yield and quality. An action threshold for *H. theivora* in Bangladesh was determined through population modeling studies (Ahmed *et al.,* 1992). The ETL of the major pests of tea in Bangladesh is given in Table 1.

Table 1. Economic Threshold Level (ETL) of major pests of tea in Bangladesh (Mamun and Ahmed, 2011a)

Name of the Pest	Economic Threshold Level (ETL)
Tea Mosquito Bug	5% infestation
Aphids	20% infestation
Thrips	3 Thrips per shoot
Jassids	50 nymphs per 100 leaves
Looper caterpillar	4-5 Lopper per plant
Flushworm, Leaf Rollers	5 infested rolls per bush
Red Spider Mites, Pink and Purple Mites	5 mites per leaf
Termites	10% infestation
Nematodes	7 nematodes per 10 g soil

Component of Integrated Pest Management in Tea

Many different tactics are used in IPM strategy in tea plantation. Of all standard control strategies such as natural control like- Climatic factors, Topographic features, Predators and Parasites, etc.; applied control like- Cultural control, Physical control, Mechanical control, Biological control, Microbial control, Regulatory control, Breeding of resistant agrotypes, Ionizing radiation, Chaemosterilant and Chemical control etc. have been incorporated and still to be continued because of immediate protection of tea and various constraints to employ with different control methods (Muraleedharan, 1991). The various components of the IPM practices are enumerated below with a few specific examples, since the success stories with the use of IPM practices are numerous and increasing day by day.

Cultural control

Cultural control apparently is the most economical and widely applicable method of pest control. This involves the intelligent manipulation of all aspects of crop husbandry. In tea culture, certain routine cultural practices such as plucking rounds, adjustment of pruning cycles, the modification of shade trees and timely weed control may be effectively employed as pre-emptive measures of pest control (Sasidhar and Sanjay, 2000). This approach of pest control is cheap, risk free and often effective for a long period without adverse effect on the environment.

Plucking: Plucking is one of the common phenomena in tea culture. This process has a significant impact on the removal or reduction of many foliar pests, viz. tea mosquito bug, aphid, jassids, scales and leaf folding caterpillars such as flushworms and leaf rollers. Tea mosquito bug lay eggs on the broken ends (stalks) of plucked shoots. The shorter the plucking rounds, the more removal of eggs, larvae and juvenile stages of pests from the bushes. Intensive removal of stalks during plucking will reduce the incidence of this pest (Mamun, 2011a). However, plucking intensity is important; the higher the intensity, the greater the reduction in pest population (Satake *et al.*, 2006). So, plucking round should be maintained at 7-8 days for the removal of eggs, larvae and juvenile stages of *Helopeltis*.

Pruning: Pruning is one of the important cultural operations in tea husbandry. It is an essential agronomic practice implemented in winter in Bangladesh condition for renovating vegetative growth at the expense of reproduction, to increase crop productivity in subsequent years. Pruning removes a large part of the pest populations present on the foliage and stems. Most of the foliar pests like tea mosquito bug, flushworm, aphid, jassid, thrips, red spider mite, scarlet mite and purple mite are removed during light pruning (LP) operation (Mamun, 2011b). Three years pruning cycle is preferred in severe pest infested areas. Light Skiff (LS) helps remove unproductive shoots and eggs of *Helopeltis* and thrips (Rabindra, 2012). Prune the badly affected sections by *Helopeltis* before ending December. When an attack by *Helopeltis* becomes unmanageable the affected bushes may be skiffed to reduce the damage.

Shade regulation: The culture of shade trees and many ancillary crops in the tea ecosystem is considered to be a necessary evil. In tea, shade regulation plays a predominant role in pest suppression. Infested by mites and thrips is seen more in tea fields devoid of shade. Proper shade establishment is necessary to minimize the infestation of these pests. Dense shaded areas are prone to the attack of *Helopeltis* (Ahmed *et al.*, 1993). As tea mosquito bug is a negatively phototropic pest, over shaded plantation should be thinned to allow sufficient sunlight and better aeration. The pest cannot tolerate the sunlight and ultimately reduce the infestation. Certain shade trees like *Indigofera* and *Albizzia* are the alternate hosts of several caterpillar pests. So, the recommendation of shade management will help preventing the excessive build up of thrips, mites and *Helopeltis*.

Field sanitation: Field sanitation assumes significance in the management of several pests. Weeds offer excellent hiding places and serve as alternate hosts for *Helopeltis* and Red spider mites. Weeds like *Mikania cordata, Bidens bitrnata, Emillia* sp., *Polygonum chinese, Oxalis acetocella, Malastoma malabethricum, Lantana camara,* Cinchona, Cashew, Cocoa, *Tephrosia*, Guava, Jackfruit, Coffee, Mango, Sweet potato, Rangan (*Ixora coccinea*) offer excellent hiding places and serve as alternate hosts for the Tea mosquito bug. *Malastoma malabethricum* and *Urena lohata* weeds act as alternate host of Red spider mite. Weed free cultivation and preventing trespassing of cattle, goat, and other animals from RSM-infested fields reduce its spread. *Ageratum conizoides, Borreria hispida, Commelina bengalensis, Pouzolzia indica* and *Oxalis corymbosa* are alternate host of Root knot nematode. So, growth of host plants in and around tea fields should be controlled and this will help reducing the growth of pest population. Besides, improved drainage system helps minimize the pest infestations.

Fertilizer application: Fertilizer produces nutritious plant for human being but many insects may also benefit. Chemical fertilizers have to be judiciously applied, as excessive application of nitrogenous fertilizers is known to result in the outbreak of sucking pests as well as live wood termites (Sivapalan, 1999; Sudoi *et al.,* 2001). Tea mosquito bugs have been found to breed or develop rapidly on plants given good nitrogenous fertilization. Phosphorus is known to induce resistance in tea to *T. kanzawai* (Cranham, 1966). Application of potash enhanced nematode resistance in plants (Kamunya *et al.,* 2008).

Planting of rehabilitation crops: As an ecofriendly pest management concept, recent research findings showed the nematode population in soils could be contained remaining below critical level (7.00/10g soil) by planting and lopping the green crops named Guatemala and Citronella. Nematode population in Guatemala and Citronella field were 2.98 and 4.56 respectively which were below the critical level. So, Guatemala and Citronella can be planted before establishing tea nursery for improving soil properties as well as suppressing the nematode population in tea soil (Mamun *et al.,* 2011).

Trap crop: Studies related to the use of trap crops in tea are scarce. A trap crop also manipulates the habitat in an agro-ecosystem, which can be included under the ecological engineering approaches for the purpose of IPM (Gurr *et al.,* 2004). However, Marigold is an ornamental plant and in tea it can be used as a trap crop of red spider mite. One row of marigold can be planted at the outer periphery and also in the vacant area of the section. Border plantings of *Adhatoda vesica* serve as a barrier for red spider mite, *Oligonychus coffeae* (Watt and Mann, 1903). As such, susceptible tea clones such as Tocklai vegetative clone TV1 to *H. theivora* may be utilized as the trap crop (Hazarika *et al.,* 2009).

Host plant resistance

Host plant resistance is perhaps one of the least expensive, safest and most practical ways of integrated pest management in tea plantation. The mechanism of pest resistance in plants is generally *physiological* (i.e. plant toxins inhibit pest) or *mechanical* (i.e. plant morphology leaf structure, pubescence, distastefulness of sap, vigour or antibiosis, etc.) which may be controlled by single gene or multiple genes. Tea being a perennial crop, research on clonal selection and breeding is primarily aimed at the resistance to pests. However, another type of pest-resistance, that is, tolerance in which plants may sustain a high level of pest attack without an economic damage, may be successfully incorporated in the pest control strategy for tea.

Different tea clones show varying degrees of susceptibility to *Helopeltis.* However, at present there is no clone with a high degree of resistance to *Helopeltis.* It is clear that the dark leaved varieties are more prone to damage by tea *Helopeltis* than the light leaved ones. (Barbora and Singh, 1994) found that TV1, TV9, TV12, TV14, TV16, TV18, TV19, TV20, TV22, TV23 & TV24 to be highly preferred by *Helopeltis* and TV11, TV17, TV21, TV25 & TV26 are moderately susceptible. Chowdhury *et al.* (2008) classified clones released by BTRI as "Fairly resistant", "Resistant", "Susceptible" and "Very susceptible" to *Helopeltis* by feeding method with 4^{th} instar nymph for 7 days. Based on the findings, 7 clones (BT1, BT2, BT7, BT8, BT10, BT12 & BT16) appeared fairly resistant, 8 clones (BT4, BT5, BT6, BT9, BT13, BT14, T15 & BT17) with two seed jats bi-clonal seed and general seed showed susceptible reaction while two clones (BT3 & BT11) were found to be very susceptible to *Helopeltis.*

Xu *et al.* (1996) found that China varieties are more susceptible to the attack of red spider mites because of their higher rhodoxanthin and l-arginine content and lower tannin content; while Assam cultivars are apparently more susceptible to the attack of pink mites as those have less pubescence, stronger cuticularization on the undersurface, lower stomatal density, and low sugar, but are rich in total antioxidant activity, theamine, gibberellic acid, and caffeine.

Ahmed *et al*. (1994; 1999) stated from the view point of termite resistance that B207/39 and B233/39 (Munipuri type); BT4, BT6, BT7, BT8 & BT9 (Munipuri-China hybrid) and Tingamara seedlings (broad leaf Assam hybrid) were the best while AN1, TV9, BT1, TV18 & BT2 (hybrids or Camboid type of small to intermediate leaf size) may be in the second preference and BT10 & BT11 had been found to be the most susceptible clones to termite attack.

Physical control

Physical control is one of the important approaches to the integrated pest management programme. Such controls aim to reduce pest populations by using devices which affect them physically or alter their physical environment. The only method in this category which has really stood the test of time is hot water treatment of plant organs like roots to kill concealed pests such as eelworms.

Manual removal: Collection and destruction of Lepidopteran caterpillars are economical and useful either for small plantations or for plantations with a large labor force. Population of foliage feeding caterpillars such as looper caterpillar, faggot worms, flush worms and leaf roller can be reduced to a great extent by manual removal of larvae and pupae.

Heat treatment and soil solarisation: Soil is the medium for growing tea plants. Many insects like eelworm, cockchafer grubs, termites, root mealy bugs live or hibernate in suitable temperature and humidity conditions relatively under or near the soil surface. Soil used in the nursery may be heated to 60-65°C for killing the infective juveniles of soil nematodes.

Use of light traps: Light traps are an important component of physical control methods and have significance in tea pest management. The behavior of certain species of insects being attracted to light could be advantageously used in their management. Light trap is a cost effective and environment-friendly monitoring tool of Lepidopetran pests in tea plantations (Ahmed *et al.,* 2010). Fluorescent light traps and yellow pan traps are useful in attracting the moths of caterpillars and other insects. They can be set up in the seasons of moths' emergence. These traps are useful for monitoring the activity of the pests and as a means of control.

Mechanical control

Mechanical methods are manual devices utilized for pest suppression. There have only been a few attempts to utilize this method for tea pest management. However, a few methods have been developed and practiced in tea plantation in Bangladesh for the control of termites.

Mound digging process: Termitaria (Termite mound) are architecturally designed dome-shaped close system earthen mounds that provide natural protection from adverse environment. '*Queen*' lives inside the mound and reproduce infinitesimal progenies to build up the population. The mechanical control method to destroy the termitaria seems to be a plausible solution for termite control. The destruction of isolated termitaria is widely practiced in tea plantation in Bangladesh (Ahmed, 2011). To minimize termite population destruction of colony and the queen is a very good practice. It is apparent that mound digging process is very effective to reduce the termite density in the plantation because supplementary queens could not develop within three years and thereby the termite population will obviously decline.

Destruction of termite colony by cocktail mixture: Experiment on integrated control aspect of termite colony show that insecticide like Dursban 20EC and Calixin 75EC could be used with an injecting rod having 0.95 cm diameter and 94 cm length directly inside the termite colony having effective results. It is understood that the Dursban 20EC is a broad spectrum non-selective contact insecticide and has a direct action on termite whereas Calixin is used as a systematic fungicide which is used to prevent the fungal combs of the termitaria. Consequently, termite present in the soil surrounding the dug hole will be drastically reduced by the application of cocktail solution. The above method of controlling termite colony is very simple and less expensive in comparison with other methods such as Dig out method.

Use of food traps: In order to monitor termite population and determine the damage matrix on those variable food materials in plantation areas or in rehabilitation areas and subsequently to control the invading termites, simple field testing device using food traps was constructed. Six types of food traps, such as 1) Saw dust, 2) Tissue paper, 3) Dried tender bamboo splits, 4) Jute sticks, 5) Susceptible soft timber, and 6) *Bogamedeloa* branch were selected. It was observed in the practical field that the use of food traps especially bamboo splits and or soft timber induce termite infestation in derelict redundant tea sections and subsequent use of proper pesticide to control them might provide an environmentally sustainable control method for termite. So, food traps like bamboo splits, soft timber and *Bogamedeloa* are considered to be a suitable tool for destruction and management of termite (Ahmed, 1999).

Regulatory control

Almost all countries, including Bangladesh & India, have legal enactments, called quarantine laws, to prevent the entry of foreign pests and pathogens. Quarantine measures are advocated for the introduction of tea germplasm either as seed material or vegetative propagule in the form of scion and rooted cuttings (Venkata, 1983). Only healthy, pest and disease free planting materials should be procured.

Biological control

Biological methods of control involve the conservation, preservation and introduction of natural enemies like predators, parasitoids and pathogens for suppression of pests within tolerable levels. More than hundred species parasitoids, predators and pathogens have been recorded from the tea estates. The minor status of several pests such as aphids, scale insects, jassids, flushworms and leaf rollers is due to the action of these natural enemies. Efforts towards the conservation and augmentation of natural enemies in the tea ecosystem, could offer significant advances in biological control programme in tea. The effects of artificial management including insecticide application are negligible on the bush below the plucking surface. The bush below the plucking surface is very important as refuge for natural enemies. For example, the population densities of several natural enemies of *Oligonychus coffeae* are high at the bush below plucking surface.

Predator: Several predatory mites, mostly belonging to Phytoseiidae, Stigmaeidae and Tydeidae, mainly prey upon phytophagous mites infesting tea. *Oligota flaviceps* is identified as a predator of Red spider mite in tea (Babu *et al.,* 2008a). *Amblyseius herbicolus* and *Euseius ovalis* are the two main common predators of *Acaphylla theae* and *Calacarus carinatus*. Anthocorids belonging to *Anthocoris* and *Orius* and the predatory thrips, *Aelothrips intermedius* and *Mymarothrips garuda* are important natural enemies of thrips. Recently, *Chrysoperla carnea* has been identified as a predator of thrips and *Helopeltis*. Several species of coccinellids and syrphids exert tremendous influence on the population of *T. aurantii* (Muraleedharan *et al.,* 1988). Tea aphids may be controlled effectively by the lady bird beetle, *Hippodamia divergens* (Ahmed *et al.,* 2009). Preying mantids are identified as the potential predator of *Helopeltis theivora* and *Verania vincta, Verania discolor* are identified as the potential predator of red spider mite.

Parasitoid: Leaf rolling caterpillar, *Cydia leucostoma* is parasitized by nine species of braconids, two ichneumonids and one encyrtid in addition to a pupal parasitoid belonging to *Ascogaster.* Among the larval parasitoids, *Apanteles aristaeus* is the most common species on flushworms. The leaf roller, *Caloptilia theivora* is heavily parasitized by the eulophid, *Sympiesis dolichogaster*. *Apanteles fabiae* and *Apanteles taprobanae* parasitise the looper caterpillar, *Buzura suppressaria*. The egg parasitoid, *Erythmelus helopeltidis* was found effective against tea mosquito bug, *Helopeltis theivora* (Sudhakaran and Muraleedharan, 1998). Percentage parasitism in the field varied between 52% and 83% and this is the first record of this species attacking *H. theivora.*

Pathogens: Use of entomopathogenic fungi is a new arena of research for integrated pest control in tea. Several microbes are pathogenic to tea pests. Formulations of the bacterial insecticides, *Bacillus thuringiensis* have been effectively used for the control of looper caterpillars, cutworms, flushworms and other lepidopterous pests (Muraleedharan and Radhakrishnan, 1989). Certain entomopathogenic fungi, *Verticillium lecani, Paecilomyces fumosoroseus* and *Hirsutella thompsonii* were evaluated and found effective against pink, purple and red spider mites (Babu *et al.,* 2008b). *Cladosporium* sp., *Aspergillus niger, A. flavus* found to be the potential entomopathogenic fungi for the management of *Helopeltis* in tea (Bordoloi *et al.,* 2011). Sana (1989) stated that an entomopathogenic fungus, *Cephalosporium* sp. is reported to be parasitic on the nymph of tea jassid. *Metarhizium anisopliae* is the commonest entomopathogenic fungi that reduced the population of red spider mites, thrips and live wood termites in tea (Ahmed and Mamun, 2013).

Use of botanicals

Botanical products are environmentally safe, less hazardous, economic and easily available. Certain products derived from indigenous plants are used for tea pest control. Recently, Mamun and Ahmed (2011a) reviewed some works on botanicals and their usage in tea pest management. Products containing azadirachtin, an oxygenated triterpenoid obtained from the seed kernel of neem, *Azadirachta indica* is now being evaluated against certain tea pests and has been found effective against *Helopeltis,* Red spider mites, flushworm etc. Application of neemcake @ 2kg/bush was found to be effective for the plants suffering from the attack of root knot nematodes, *Meloidogyne brevicauda* (Radhakrishnan, 2006). Besides, Mahogany, Karanja, Datura, Tobacco, Bishkatali, Katamehedi, Lantana, *Xanthium* and *Clerodendrum* extracts may also effective against major pests of tea such as tea mosquito bug, red spider mites etc (Mamun and Ahmed, 2011b). Neem and Mahogani cake reduced the nematode population in the soil significantly (Mamun *et al.,* 2013). These cakes can be used in soil treatments for the management of nematodes to get nematode free soil or safe soil with less nematode for establishing tea nursery. The use of plant extracts should be incorporated in the IPM programme in the tea industry of Bangladesh. The indigenous plants are available in and around the estates as well as elsewhere in the country. Tea planters may use these plants for the management of pests of tea.

Use of sex pheromone

Sex pheromones have been utilized extensively in IPM programme in field crops but their use is rather unknown in plantation crops like tea. Sex pheromones could be integrated into the pest management programme in tea (Noguchi *et al.,* 1981; Hiyori *et al.,* 1986). Sex pheromone traps obtained from Japan were successfully used for monitoring the populations of leaf roller moths in South India (Selvasundaram, 1990). The components of sex pheromone of *Cydia leucostoma,* the flushworm of tea have identified. Sudhakaran *et al.* (2000) carried out an experiment in the laboratory and in the field to determine the presence and activity of sex pheromone in the tea mosquito bug, *Helopeltis theivora.* The study revealed that the homogenized solution of the test insects with dichloromethane attracted more males when compared to other solvents like n-hexane and heptane. Communication disruption using sex pheromones of *Helopeltis,* flushworm, looper caterpillar, leaf roller may be effective and this technique would be incorporated in IPM strategy in the tea plantation of Bangladesh.

Chemical control

Pesticide will continue to play a vital role in pest control programme in the foreseeable future. Pesticides have been considered to be one of the most essential agricultural inputs for increasing crop production. The correct choice of pesticides, dosage, timing and method of application are of paramount importance for the successful control of insects and mite pests of tea. Over the years, the pattern of pesticide usages on tea in India has followed the world trend. Insecticides ranging from DDT to the most recent synthetic pyrethroids do find a place in the schedule of pest control programmes in tea. The recommendation on chemical control on tea pests in Bangladesh is presented in the Table 2.

Table 2. Approved pesticides for the control of major tea pests in Bangladesh (Mamun *et al.*, 2014)

Chemical	Target pest	Dosage	Spray volume
Sulphur 80WP	All mites	2.25 kg/ha	1000 lit/ha
Propargite 57EC	All mites	1.00 lit/ha	1000 lit/ha
Fenpopathrin 10EC	All mite	1.00 lit/ha	1000 lit/ha
Ethion 50EC	All mites	1.25 lit/ha	1000 lit/ha
Fenproximate 5EC	All mites	300 ml/ha	1000 lit/ha
Fenazaquin 10EC	All mites	600ml/ha	1000 lit/ha
Hexythiazox 10EC	All mites	500ml/ha	1000 lit/ha
Thiacloprid 240SC	Thrips, Aphids, Jassids, *Helopeltis,* scale insect	375 ml/ha	500 lit/ha
Quinalphos 25EC	Caterpillar, thrips, *Helopeltis*, aphids, all mites	750 ml/ha	500 lit/ha
Deltamethrin 2.8EC	Caterpillar, *Helopeltis,* thrips	500 ml/ha	500 lit/ha
Cypermethrin 25EC	Caterpillar, *Helopeltis,* thrips	250 ml/ha	500 lit/ha
Chlorpyrifos 20EC	Termites	10.0 lit/ha	1000 lit/ha
Imidacloprid 200SL	Termites	1.5 lit/ha	1000 lit/ha
Fipronil 50SC	Termites	1.5 lit/ha	1000 lit/ha
Carbofuran 5G	Nematodes	165 gm/m^3	-
Fipronil 3GR	Nematodes	165 gm/m^3	-

Spraying calendar is prepared, viewing the trend of seasonal occurrence of pests and economy of spraying, to synchronize pest control measures with farm management practices. The spraying calendar may be different in different crops having different pest spectrum. Majority of pests are found to be prevalent during mid season, June-September, while a few pests become active in localized area during the onset or tail end of the cropping season. Therefore, it is necessary to assess the degree of incidence by a sequential survey before the application. Having considered the seasonal trend of invasion by various pests, a synchronized pest control strategy is adopted so that a balanced and timely action is exercised according to the spraying calendar (Table 3). Barrier spraying has been found to be effective against *H. theivora* (Ahmed, 2005).

Table 3. Tentative spraying calendar against major insect pests of tea in Bangladesh

Month	INSECTICIDE		ACARICIDE	
	Spray	Insects	Spray	Mites
January				
February	Spot spray	Flushworm, Aphid, Jassid, Thrips	General spray	Red spider, Pink, Purple & Scarlet mite
March	Gen/spot spray	Flushworm, Aphid, Jassid, Thrips	Gen/spot spray	Red spider mite
April	Spot spray	*Helopeltis*		
May	Gen/spot spray	*Helopeltis*	Spot spray	Red spider mite
June				
July	Gen/spot spray	*Helopeltis*	Gen/spot spray	Red spider mite
August				
September	Gen/spot spray	*Helopeltis*		
October	Spot spray	*Helopeltis*	Spot spray	Red spider mite
November	Spot spray	*Helopeltis*		
December	General spray	Termites		

General spray   Spot spray   Gen/spot spray

Thus, before spraying any chemicals, the tea planters must consider i) the impact of pesticides on non target organisms, human health, wild life habitat and environment and ii) adopt IPM strategies to reduce the pesticide load to produce residue free tea, increase the exports and meet out the consumers' demand. Based on the ecological characteristics of tea fields and production system of tea, a tentative IPM system comprising all suitable control methods in tea cultivation in Bangladesh has been proposed (Fig. 3).

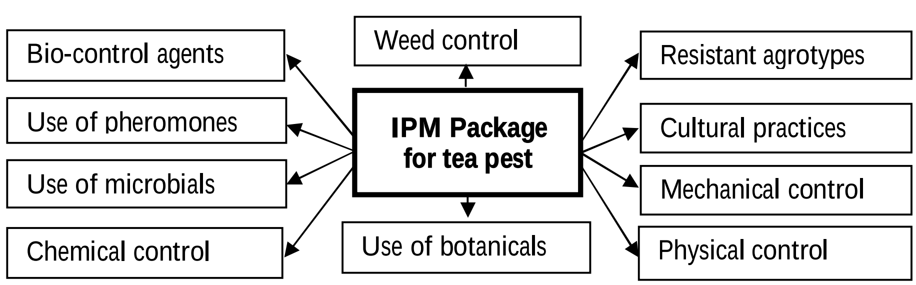

Fig. 3. Component of IPM package for tea pest

Conclusion

The future tea pest management lies in developing an information-based system in which prevention and therapy are combined to reduce the damage/loss caused by pests. As such, thresholds based on damage/loss will need to be established for many more key pests in near future. Because commodity value per land area is high in tea, emphasis on prevention may prove to be useful and may include advance planning with respect to the implementation of strategies. Need based, judicious and safe application of pesticides is the most vital aspect of chemical control measures under IPM strategy. It involves developing IPM skills to play safe with environment by proper crop health monitoring, observing ETL and conserving the natural bio-control potential before deciding in favor of the use of chemical pesticides as a last resort. Habitat management, exploitation of hitherto under used natural enemies such as predator, parasitoid & entomopathogen, use of the novel biorational pesticides, management of pesticides to extend their useful life, proper use of semiochemicals and the use of information technology are some major tactics to be employed in the IPM programme in tea in the coming years.

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PROSPECT OF MYCORRHIZAL APPLICATION IN TEA CULTIVATION

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Abstract

Tea (*Camellia sinensis* (L) O. kuntze) is grown in acidic soils, where low levels of available P (Phosphorus), Zn (Zinc), Mg (Magnesium) frequently limit its establishment. The arbuscular mycorrhizal (AM) fungi are well known to benefit plants in many ways. In such soils, an efficient mycorrhizal association can increase nutrients uptake and crop yield. Biodiversity of AM fungal colonization and spore population in the rhizosphere soils of tea and tea associated plants were studied. Effects of AM fungi and chemical fertilizers on the growth and development of tea were also investigated. The per cent colonization as well as spore population of AM fungi varied from tea agro-types to clones and tea associated other plant species. The range of AM fungal colonization was recorded as 40% to 55%, and the spore population was 130 to170 nos. per100 g of dry soil. Out of four tea agro-types, maximum root colonization (55%) and spore population (170) were recorded in Manipuri type followed by Assam type and Burma type. The minimum colonization (40%) and spore population (130) were found in China type. In clones, the highest root colonization (55%) and spore population (120) were found with BT6 and minimum colonization (20%) and spore population (60) was recorded with BT9. Among the tea associated plants, the range of root colonization (%) varied from 40% to 80%. The highest colonization was observed with *Calapogonium mucunoides* (80%) followed by *Albizzia lebbek* (70%), *Derris robusta* (70%), *Tephrosia candida* (70%), *Mimosa invisa* (70%) and minimum with *Cymbopogon citratus* (40%). The range of arbuscular and vesicular intensity were observed as 10% to 20% and 0% to 20% among the plant species, respectively. Out of six genera of AM fungi, four genera like *Glomus, Acaulospora, Gigaspora,* and *Scutellospora* were found in tea soils. Positive correlation ($r = 0.96$) was observed between root colonization and spore population in tea plantation. A mixture of *Gigaspora, Scutellospora* and *Glomus* along with infected roots of host plants was used as inoculum in searching the interaction of AM fungi. All parameters of tea saplings inoculated with AM fungi were significantly ($P_{0.05}=2.563$) greater than the control (non-inoculated). The result also revealed that 32%, 43%, 60% and 66% of shoot length, root length, plant weight and root weight of tea plant were increased with AM fungi inoculation compared to the control, respectively. Phosphorus was significantly increased (60%) in the mycorrhizal soils. Organic carbon (23%) and Magnesium (11%) were also increased compared to the control. So, arbuscular mycorrhizal association and its application technology can be applied in tea soil management.

Key words: Mycorrhiza, Colonization, Population, Nutrients uptake

Introduction

Tea (*Camellia sinensis* (L) O. kuntze) is an important cash crop of Bangladesh. In Bangladesh, four agro-types namely Assam, Burma, China and Manipuri types are popular in tea estates (Sana, 1989). For quality potentials and better yield, Bangladesh Tea Research Institute (BTRI) released 18 tea clones. Total land area for tea is only 1.16 lakh ha, of which about 57,210 ha of land has been brought under tea cultivation, distributed in 166 tea estates producing about 63 million kg of made tea per year. Tea sector contributes 0.11% of GDP and about 0.30 million people are employed in this industry which is about 0.22% of total national employment (Anon, 2014). The average production of tea in Bangladesh is only 1,245 kg of made tea per hectare, which is quite low compared to other major tea growing countries like India (1690 kg/ha), Sri Lanka (1684 kg/ha) and Kenya (2106 kg/ha). The reasons behind lower production of tea are mainly low soil pH and poor fertility and productivity of soils, shortage of soil-organic matters, erratic rainfall and drought in summer (Anon, 2014) etc.

The AM fungi are known to benefit plant growth by enhancing nutrients uptake (Gnekow and Marschner, 1989; Howeler *et al.,* 1987), mediating inter-plant nutrients transfer (Francis *et al.*, 1986; McNeil and Wood, 1990; Newman, 1988), reducing the severity of root diseases (Jalali and Jalali, 1991), protecting soil erosion (Bethlenfalvay and Schuepp, 1994) and increasing drought resistance (Levy and Kirkun, 1980). Occurrence of AM fungi in tea roots was recorded first by Tunstall (1930) in North-East India. Thereafter, many authors reported AM colonization and the application of AM fungi in the development of tea plants (Balasuriya *et al.*, 1991; Kumaran and Santhanakrishnan, 1995). Sufficient information is available on tea mycorrhiza (Barshed, 1997; Barua, 1998; Mridha *et al.,* 1995). Although tea is an important industrial crop in Bangladesh, the research in this regards has been received little attention (Barshed, 1997; Mridha *et al.,* 1995). Information on AM fungi in tea (Balasuriya *et al.*, 1991) and its activities on the growth of tea especially nutrient supply to tea (Rajagopal and Ramarethinam, 1997) and interaction with chemical fertilizers (Balasuriya *et al.*, 2000) are very limited. Detail work in this area has not been carried out in Bangladesh earlier.

It is very essential to deal in detail on the distribution of AM fungi in different tea agro-types, clones, tea ancillary plants in tea plantations, beneficial roles of AM fungi with special reference to nutrients uptake, influence of AM fungi on growth of tea and adverse effect of pesticides on AM fungi. Hence, the present program has been scheduled to assess biodiversity of AM fungi in tea and tea associated plant species along with its application for tea productivity.

Materials and Methods

Sample collection

Roots and rhizosphere soils of different tea and tea associated plants were collected for the assessment of biodiversity of AM colonization and spore population. Four tea agro-types, 15 tea clones and six shade species were selected for the present study. Replicated samples were collected at a soil depth of 0-15cm in all the cases. After collection, roots and soil samples were separated immediately. The separated roots were preserved in 5% formalin and soils were studied as soon as possible for spore population to avoid the loss of the spores.

Assessment of AM fungal colonization

Preserved roots were washed thoroughly with tap water to remove the formalin and then cut into approximately 1.0 cm long pieces and stained in aniline blue according to Phillips and Hayman (1970). The root pieces were boiled in 2.5% KOH solution for 30 minutes at 90^{0}C temperature. Then the root pieces were washed well in water and acidified with 1.0% HCl solution for 24 hours. Heavily pigmented roots were bleached in 10% H_2O_2 for 50 to 60 minutes. The segments were boiled in 0.05% aniline blue at a temperature of 90^{0}C for 30 minutes. Subsequently, the roots were destained in acidic glycerol. A total of 50 segments were examined from each sample. Root pieces were studied with a compound microscope at 10x10 magnifications. The presence of mycelium, arbuscules and vesicles were recorded and analyzed for determining the structural colonization. Mycelial colonization was considered as total colonization. The percentage of AM colonization was calculated by the following formula:

$$\text{\% Root colonization} = \frac{\text{Number of AM positive segments}}{\text{Total number of segments scored}} \times 100$$

Assessment of AM spore population

The collected soil samples were mixed thoroughly and sieved through 2 mm mesh to remove the gravels and other particles. AM fungal spores were extracted following the wet sieving and decanting method (Gerdemann and Nicolson, 1963). Spore population was counted on the basis of 100 g dry soils. Morphologically similar spores were picked up with the help of soft forceps and mounted in Melzer's reagent and PVLG separately. The spores were identified up to different genera (Schenck and Perez, 1990). Percentage of spore population of individual genus was calculated by the following formula:

$$\text{\% Genus} = \frac{\text{Number of individual AM genus}}{\text{Total numbers of AM spores}} \times 100$$

Preparation of tea cuttings and Primary bed

The tea cuttings were collected from BT5 mother bushes grown at Bangladesh Tea Research Institute (BTRI) farm. Each cutting consists of one full leaf with a stalk of about 2.5 to 3.0 cm in length. Hard red surface of the shoot is the indicative to the best cutting. The portion of the hard green wood of the shoot is first cut obliquely over the axillary bud followed by a second cut parallel to the first cut by means of a sharp blade. The cuttings were kept moistened in a water bowl till planting out in the nursery bed measuring 1.5 m x 10 m. Cuttings were planted at 6 – 7 cm spacing using triangular planting system. Leaves were not allowed to touch the soil surface. Low shades were provided on the bed with bamboo-split lathe-frame of 1.5 x 1.2 m with about 23 cm height. Cultural operations like weeding, forking and watering were done as and when necessary.

Preparation of secondary bed

The secondary bed measured 1.5 m X 10 m with slanting towards east at an inclination of 15 cm. The drain was prepared around the bed measuring 30 cm wide and 15 cm depth. A sand layer of 2 cm was spread on the bed to absorb excess water during watering. High shades were provided of 1.2 m on the beds with bamboo tarja. The soil (potting media) was collected from the Experimental Farm of BTRI. The soil was light textured. Chemical analysis of the soils was done in the Soil Chemistry Laboratory, BTRI.

Preparation of Inuculum

The indigenous AM fungal inoculum was obtained by collecting the propagules using wet sieving and decanting method (Gerdemann and Nicolson, 1963) from the soils of tea plantations. The crude inoculum (spores, hyphae and root bits) was multiplied and maintained in a small plot (1 m X 2 m) with sterilized soil. *Leucas aspera* were grown conjointly for 16 weeks, after which the tops of the plants were removed. The roots were finely chopped and the dried root-soil mixture was mixed thoroughly to obtain a homogenous inoculum. Before inoculation, per cent root colonization and number of spores with the plants were assessed.

Preparation of poly bags

The soil was sieved with 4 mesh sieve and mixed thoroughly with decomposed cow dung at the ratio of 7:1 (Soil: Cow dung) and was sterilized properly. The size of the poly bag (transparent) for the experiment was 23 cm in length, 9.6 cm in diameter (lay flat 15 cm and poly bag area was 7.235 X10^{-3} m^2) and 0.04 mm in thickness. Before putting the cuttings, the bags were filled uniformly with 1.6 kg of soils per bag and then watered regularly, and kept under shade for 15 days for settling of soils. Crude inoculum was placed 2 cm below the soil surface as a uniform thin layer containing about thousand infectious propagules per 100 g of the indigenous AM fungi, comprising spores of *Gigaspora, Scutellospora* and *Glomus* species, sporocarps, bits of hyphae and infected root segments per bag. One tea sapling was transplanted per poly bag. There were altogether 04 treatments with 3 replications. Watering and other intercultural operations were done properly. The plants were maintained for one year after transplantation.

T_1	= Control (Sterile soil)	T3	= T2 + Mycorrhiza
T_2	= Nursery mixture	T4	= Only Mycorrhiza

Data recording

Data were recorded after six months and one year of planting. Data on length of shoot and root, weight of shoot and root of the plants were recorded. Collected data were analyzed by means of a comparison test using DMRT. The percentage of AM fungi association in tea roots and population of AM fungal spores in rhizosphere soil were also recorded.

Results and Discussion

The maximum root colonization was recorded with Manipuri type (55%) and it was followed by Assam type (50%) and Burma type (50%). The minimum colonization was recorded with China type (40%). The range of mycelial colonization was recorded as 40-55% in different tea agro types (Fig. 1). The data of the AM structural colonization in different tea agro-types are presented in fig. 2. Arbuscular colonization was recorded maximum (15%) in Manipuri type and it was followed by Burma type (10%). Minimum arbuscular colonization was recorded in Assam type (5%). Vesicular colonization was not observed in tea agrotypes.

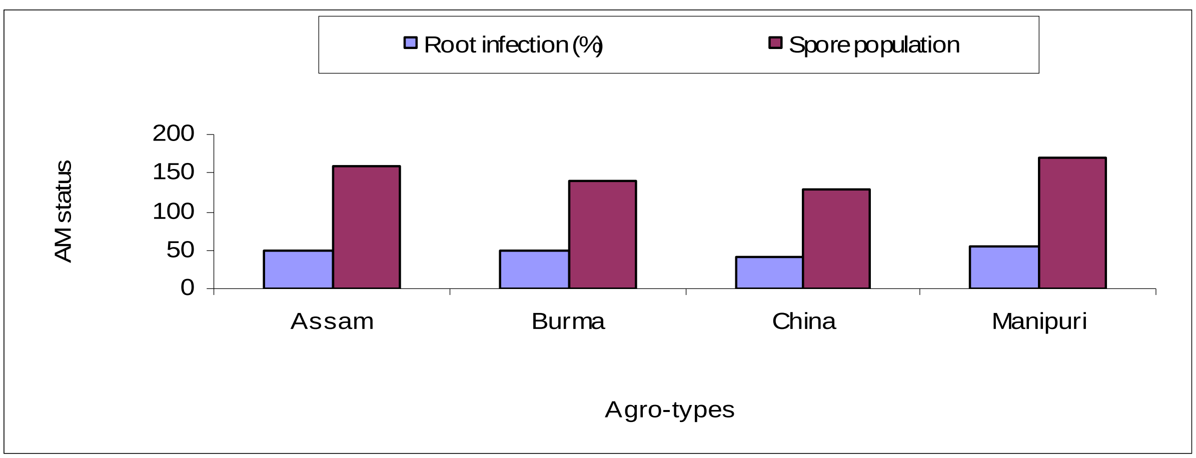

Fig 1. Total AM fungal colonization and spore population in different tea agro-types collected from BTRI farm.

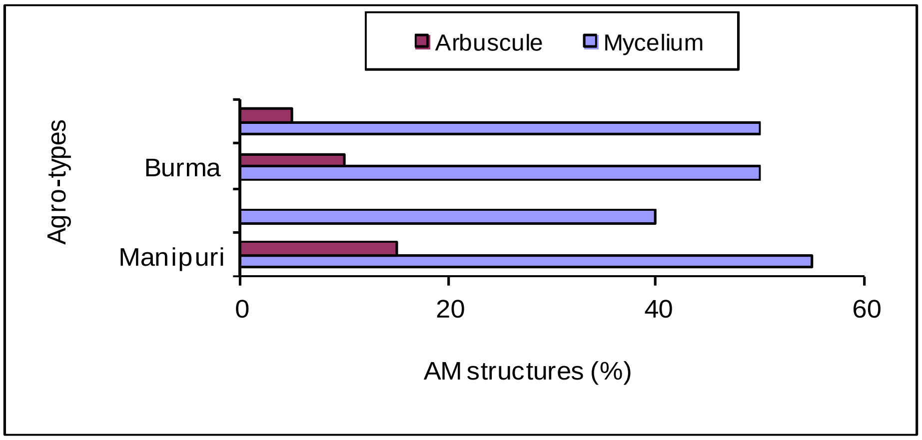

Fig. 2. Structural colonization (mycelium, arbuscule) of AM fungi in roots of different tea agro-types collected from BTRI farm.

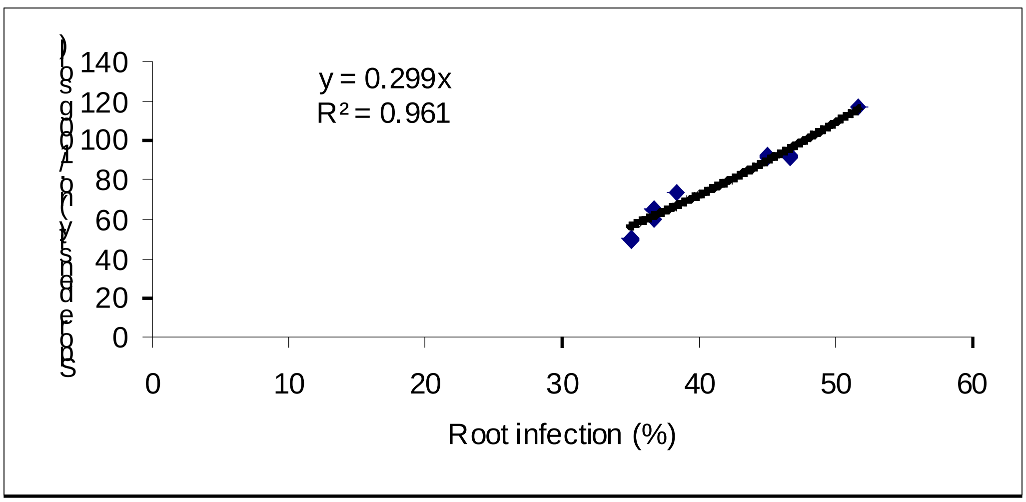

Fig. 3. Relation between average root colonization (%) and spore population (no./100 g soil) in tea of different agro- ecological zones

Table 1. Biodiversity of AM fungal genera in different tea agro-types collected from BTRI farm

Tea agro-types	Total spore population	Gig. (%)	Scu. (%)	Glo. (%)	Aca. (%)	Uni. (%)
Assam	160± 10	45	20	10	10	15
Burma	140± 10	35	30	10	10	15
China	130± 15	40	20	20	10	10
Manipuri	170± 15	40	25	10	15	10

Note: Mean ± SD of 3 samples. Gig.= *Gigaspora*, Scu.= *Scutellospora*, Glo.= *Glomus*,

Aca.= *Acaulospora*, Uni.=Unidentified.

The range of spore population was recorded as 130-170. The maximum spore population was recorded in the rhizosphere soils of Manipuri type (170) and it was followed by Assam type (160) and Burma type (140). The minimum was recorded in the soils of China type (130). Out of six AM fungal genera *Glomus*, *Acaulospora*, *Gigaspora* and *Scutellospora* were observed in the rhizospheric soils of tea agro-types (table 1). The maximum *Gigaspora* was recorded in the soils of Assam type (45%), which was followed by China type (40%) and Manipuri type (40%). In Burma type it was only 35%. There was a positive correlation (r= 0.96) between total colonization and spore population of different tea agro-types (Fig. 3).

Table 2. Structural colonization (mycelium, arbuscule, vesicle) of AM fungi in the roots of different tea clones collected from BTRI farm.

Tea Clones	Total root colonization (%)			Intensity of structural colonization (%)								
				Mycelium			Arbuscules			Vesicles		
	Mycelium	Arbuscule	Vesicles	P	M	A	P	M	A	P	M	A
BT1	30 ± 5	10	-	30	-	-	10	-	-	-	-	-
BT2	45 ± 10	20	-	40	5	-	20	-	-	-	-	-
BT3	35 ± 5	10	-	35	-	-	10	-	-	-	-	-
BT4	30 ± 10	10	-	30	-	-	10	-	-	-	-	-
BT5	45 ± 5	10	-	40	5	-	10	-	-	-	-	-
BT6	55 ± 5	20	-	50	5	-	20	-	-	-	-	-
BT7	30 ± 10	10	-	30	-	-	10	-	-	-	-	-
BT8	30 ± 10	0	-	30	-	-	-	-	-	-	-	-
BT9	20 ± 10	10	-	20	-	-	10	-	-	-	-	-
BT10	35 ± 5	10	-	30	5	-	10	-	-	-	-	-
BT11	35 ± 5	10	-	30	5	-	10	-	-	-	-	-
BT12	35 ± 10	0	-	35	-	-	-	-	-	-	-	-
BT13	35 ± 5	10	-	35	-	-	10	-	-	-	-	-
BT14	35 ± 5	10	-	30	5	-	10	-	-	-	-	-
BT15	35 ± 5	10	-	35	-	-	10	-	-	-	-	-

Note: Mean ± SD of 3 samples. P = Poor, M= Moderate, A= Abundant

Among the 15 clones, the maximum root colonization was recorded with BT6 (55%) which was followed by BT2 (45%) and BT5 (45%). The minimum colonization was recorded with BT9 (20%). The moderate percentage of root colonization i.e. 30 to 35% was recorded with BT1, BT3, BT4, BT7, BT8, BT10, BT11, BT12, BT13, BT14 and BT15. From the data of the arbuscular colonization in different tea clones, it was observed that the maximum arbuscular colonization was recorded with BT2 (20%) and BT6 (20%) and the minimum (10%) was recorded by BT1, BT3, BT4, BT5, BT7, BT9, BT10, BT11, BT13, BT14 and BT15. The arbuscular colonization was absent in BT8 and BT12. Vesicular colonization was not observed in all the tea clones studied (table 2).

Table 3. Biodiversity of AM fungal genera in different tea clones collected from BTRI farm

Tea clones	Total spore population	Gig. (%)	Scu. (%)	Glo. (%)	Aca. (%)	Uni. (%)
BT1	70± 5	40	20	15	15	10
BT2	110± 5	45	20	10	10	15
BT3	80± 5	35	30	15	10	10
BT4	70± 10	40	20	15	15	10
BT5	85± 5	35	25	15	15	10
BT6	120± 5	40	15	20	10	15
BT7	75± 5	30	20	25	15	10
BT8	60± 10	25	30	25	10	10
BT9	60± 5	30	20	20	15	15
BT10	95± 5	35	25	15	15	10
BT11	105± 5	25	25	20	10	15
BT12	65± 5	30	25	20	15	10
BT13	90± 10	30	20	20	15	15
BT14	80± 10	35	25	15	15	10
BT15	75± 10	35	25	20	10	10

Note: Mean ± SD of 3 samples. Gig.= *Gigaspora*, Scu.= *Scutellospora*, Glo.= *Glomus*, Aca.= *Acaulospora*, Uni.=Unidentified.

The rhizosphere soils of BT6 clone showed maximum spore population of 120, which was followed by BT2 (110), BT11 (105), BT10 (95) and BT13 (90). The minimum was recorded in the soils of BT8 (60) and BT9 (60). The moderate numbers of spore population from 65 to 85 was recorded in the rhizosphere soils of BT1, BT3, BT4, BT5, BT7, BT12, BT14 and BT15. Out of six AM fungal genera *Glomus, Acaulospora*, *Gigaspora* and *Scutellospora* were observed in the rhizosphere soils of tea clones (table 3). Biodiversity of root colonization and spore population of AM fungi in tea plants indicate that tea plants are mycotrophic in nature. Under natural condition, AM fungi colonize the tea roots (Barua, 1998; Kumaran and Santhanakrishnan, 1995).

Although, the range of root colonization of AM fungi was recorded from 20 - 55%, the intensity of colonization was poor as was found by Balasuriya *et al*. (1991). It was clear that the per cent colonization was variable among tea plants. These results are in consistent with the reports of Balasuriya *et al*. (1991), Barshed (1997) and Mridha *et al*. (1995). The range of root colonization of AM fungi was recorded from 30 - 65% with Bangladesh tea (Barshed, 1997) and from 6 to 45% in Indian tea (Balasuriya *et al*.,1991). Out of six genera of AM fungi, only four genera namely *Glomus, Acaulospora, Gigaspora* and *Scutellospora* were identified in the soils of Bangladesh tea plantations, where *Gigaspora* and *Scutellospora* were abundant and *Glomus,* and *Acaulospora* were found minimum. Species belonging to the four genera viz. *Glomus, Acaulospora, Gigaspora and Sclerocystis* have so far been recorded in tea (Barua, 1998). In the present study, the population of *Gigaspora* was found to be dominant. The findings were different in the report of Kumaran and Santhanakrishnan (1995) where they found *Glomus* sp. to be dominant in soils of tea plantation of India.

Table 4. Structural colonization (mycelium, arbuscule, vesicule) of AM fungi in the roots of different shade plants collected from tea plantations

	Total root colonization (%)			Intensity of structural colonization (%)								
				Mycelium			Arbuscules			Vesicules		
Shade plants	Mycelium	Arbuscules	Vesicules	P	M	A	P	M	A	P	M	A
Permanent												
Albizzia odoratissima	60 ± 10	10	0	40	10	10	10	-	-	-	-	-
Albizzia lebbek	70 ± 5	10	10	50	10	10	10	-	-	10	-	-
Derris robusta	70 ± 5	20	10	40	20	10	10	10	-	10	-	-
Temporary												
Crotalaria anagyroides	60 ± 10	10	10	40	10	10	10	-	-	10	-	-
Indigofera teysmanii	50 ± 5	10	0	40	10	-	10	-	-	-	-	-
Tephrosia candida	70 ± 10	20	10	50	10	10	10	10	-	10	-	-

Note: Mean ± SD of 3 samples. P = Poor, M= Moderate, A= Abundant

Table 5. Structural colonization (mycelium, arbuscule, vesicle) of AM fungi in the roots of different cover and green crops collected from tea plantations.

Cover and Green crops	Total root colonization (%)			Intensity of structural colonization (%)								
				Mycelium			Arbuscules			Vesicules		
	Mycelium	Arbuscules	Vesicules	P	M	A	P	M	A	P	M	A
Mimosa invisa	70 ± 15	10	10	40	20	10	10	-	-	10	-	-
Calapogonium mucunoides	80 ± 10	20	20	50	20	10	10	10	-	10	10	-
Tripsacum laxum	60 ± 5	10	0	50	-	-	10	-	-	-	-	-
Cymbopogon citratus	40 ± 5	10	0	40	-	-	10	-	-	-	-	-

Note: Mean ± SD of 3 samples. P = Poor, M= Moderate, A= Abundant

In case of shade, cover and green crops, maximum colonization (%) was observed with *Calapogonium mucunoides* (80%) followed by *Albizzia lebbek* (70%), *Derris robusta* (70%), *Tephrosia candida* (70%) and *Mimosa invisa* (70%). 60% colonization was observed with *Albizzia odoratissima*, *Crotalaria anagyroides*, *Tripsacum laxum* and 50% with *Indigofera teysmanii* (tables 4 & 5). The standard deviation (±) of root colonization was varied from ±5 to ±10. Mridha *et al.* (1995) reported 92% root colonization with both *Crotalaria* sp. and *Indigofera* sp collected from Oodaleah tea garden. Ravi *et al*. (1995) recorded 75% and Mohan and Verma (1995) reported

66% colonization with *A. lebbek*. Barshed (1997) recorded 80% with *T. candida* and 85% with *M. pudica*. These variations in root colonization can be attributed to the edaphic conditions and age of the plants. The lowest percentage of root colonization was recorded in the present study with non-leguminous species like *C. citratus* (40%), which supported the findings of Srivastava and Basu (1995) where they reported 50% root colonization in non-leguminous plants.

Table 6. Effect of AM fungi on growth parameter of tea saplings in the nursery

Treatments	Plant height (cm)	Length of roots (cm)	Weight of plants (gm)	Weight of roots (gm)
	Mean of five replications			
T_1= Control (Only soil)	47.80	16.30	4.80	2.08
T_2= Nursery mixture	51.40	17.30	6.14	2.40
T_3= T2 + Mycorrhiza	56.60	19.92	6.80	3.32
T_4= Only Mycorrhiza	63.00	23.30	7.70	3.46
LSD (0.05)	*2.563*	*0.246*	*0.344*	*0.203*
CV	*3.40%*	*0.93%*	*3.93%*	*5.23%*

Table 7. Effect of AM fungi on nutrient status of nursery soil

Treatments	OC (%)	N (%)	P (μg/g)	K (μg/g)	Mg (μg/g)
T1= Control (Only soil)	1.09	0.110	12.00	66.00	29.80
T2= Nursery mixture	1.28	0.128	12.07	60.20	31.60
T3= T2 + Mycorrhiza	1.29	0.133	18.60	66.60	31.80
T4= Only Mycorrhiza	1.34	0.130	19.20	39.60	33.00
LSD (0.05)	*0.020*	*0.010*	*0.061*	*0.052*	*0.052*

The effect of AM fungi on the growth and development of young tea plants like shoot length, root length, weight of plant and root weight and mycorrhizal status are illustrated in (table 6). Results reveal that 32%, 43%, 60% and 66% shoot length, root length, weight of plant and root weight of tea plant respectively were increased with AM fungi compared to the control. Phosphorus was tremendously increased (60%) in the mycorrhizal soils. Organic carbon (23%) and Magnesium (11%) also increased compared to the control (table 7) and it was supported by the findings of Guillemin *et al*. (1992). They reported that mycorrhizal symbiosis enhances growth of coffee plants (both roots and shoots) significantly. The role of AM fungi in enhancing plant growth and nutrition is well-documented (Smith and Gianinazzi-Pearson, 1988). P-deficient plants lacking AM fungi tend to have a high plant growth usually associated with nutrient-stressed plants (Pacovsky *et al*., 1986). It was observed that shoot length, root length, weight of plant and root weight of tea plant were increased with AM fungi as was observed by Chhabra and Jalali (1995), who reported that rock phosphate with mycorrhizal inoculation increased plant height and dry weight significantly. The result is similar to the finding of Fortuna *et al*. (1992). They reported the growth and height of plants were found to be increased rapidly by using AM fungi. A significant interaction was observed between the AM fungi and P fertilizers for sapling development.

Conclusion

From the present investigation, it can be concluded that tea (*Camellia sinensis* (L.) O. Kuntze) and tea-associated plants were mycorrhizal. Biodiversity of AM fungi was also recorded in tea soils of Bangladesh. Although, vesicles were not recorded but the intensity of mycelia and arbuscules were found in tea roots during the study. Out of six genera of AM spores, *Gigaspora* and *Scutellospora* were the most commonly distributed in tea soils followed by *Glomus* and *Acaulospora.* Tea plants were mycorrhizal dependence; its growth and development were directly or indirectly related to AM fungi. Mycorrhizal status influenced by edaphic factors and exchangeable soil nutrient status. Nonetheless, AM fungi were highly sensitive to chemical fertilizers and pesticides. So, judicious applications of chemical fertilizers and pesticides are urgently needed. Therefore, it is suggested that in future mycorrhizal technologies can be adopted in tea along with various safeguarding techniques and soil management practices for sustainable tea production in Bangladesh.

Recommendation

The world's agricultural lands are deteriorating as a result of improper management. The soil fertility and productivity are declining as well as soil erosion is wide spread. Because of economical and environmental constraints, it is necessary to develop least expensive and technologically simplest methods for immediate benefit. AM fungi have the potential to contribute significantly to the success of agro-ecosystems.

AM fungal technologies can be introduced with the existing tea cultural practices for improving soil fertility and productivity by allowing planters to reduce their input costs on indiscriminate use of chemical fertilizers. Appropriate AM fungi can be incorporated in nursery for raising mycorrhizal tea seedlings and transfer of those seedlings to the field is a simple inoculation technique which is suitable for tea and ancillary crops.

Mycorrhizal fungi appeared to have beneficial effects on plant growth by improving soil fertility. This technology can be added with available techniques to enhance soil conditions in tea plantations. Mycorrhizal research and its practical use as a low-input technology in tea culture for improving tea production is urgently needed to stop further deterioration of tea lands due to subsistence tea culture, excessive use of inorganic fertilizers, pesticides and several other adverse factors.

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TEA MANUFACTURE AND QUALITY IMPROVEMENT *VIS-A-VIS* TEA MACHINERY MANAGEMENT

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Abstract

Tea is the most popular non-alcoholic beverage next to water. Tea leaves are processed in the factories to produce an acceptable product for human consumption. There are various kinds of tea, such as black tea, green tea, oolong tea, flavoured tea etc. in the world tea market. Black tea occupies about 99% of the total tea production in Bangladesh. The salient features of black tea manufacture involves different operations *viz.* plucking and handling of tea shoots, withering, processing (CTC), Fermentation, drying, sorting and packaging. 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 made tea. The making of high quality tea depends very largely on the fineness of the plucked leaf, since the greatest concentration of ingredients, essential for making a good cup of tea is found in the first two leaves and a bud. Hence, the plucking standard has an important influence on the quality of tea. Any physical damage to plucked leaves, viz. bruise, distortion or overheating will instantly initiate chemical reactions which may impair the quality of the made tea prior to succeeding processes. Therefore, careful handling of green leaves from field to factory is pre-requisite to obtain good tea. The best tea is made by withering at the lowest practical temperature, and that sufficient time, 10-12 hrs minimum, should be allowed to elapse for physical and biochemical changes to proceed. An important step of tea manufacturing is the leaf distortion or maceration of the withered leaf by CTC. Several reactions are initiated during CTC, e.g. the breakdown of chlorophyll by chlorophyllase, the sequence of reactions leading to the formation of compounds responsible for flavor and colour of the liquors and other non-enzymic reactions. Fermentation of tea leaf is the process of oxidation of various chemical constituents of tea leaf through a series of chemical reactions. Colour, strength and briskness are developed in this stage. The meticulous care and cleanliness in the fermenting area or room is necessary. Otherwise, the inevitable bacterial contamination may result in taint in made tea. 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. The neutralization of harshness of liquor and destruction of microorganisms that play an important role in producing better quality, are also involved during drying. Grading and sorting are traditionally done using mechanically oscillated sieves fitted with meshes of appropriate size. Tea quality is assessed by the appearance of the leaf before and after infusion with boiling water and overall organoleptic impact of the resultant liquor. All the machinery should be maintained properly to keep running condition in peak season.

Key words: Tea, Manufacture, Improvement, Quality, Machinery

Introduction

Tea shoots contain 10-30% (dry weight basis) flavanol compounds. Oxidative transformations of these catechins take place during fermentation stage of black tea processing and forms theaflavins (TF) and thearubigins (TR), the prime quality attributes of CTC black tea.

Hence, quality of CTC black tea is dependent on the amount of flavanols of harvested shoots, activity of oxidase enzyme and also on the processing conditions (Obanda *et al.,* 1992*;* Thanaraj *et al.,* 1990; Millin, 1987). The tea shoots are subjected to undergo changes in various stages of processing such as withering, fermentation and drying. All the stages are associated with several chemical reactions which determine the quality of end product. The first step of black tea is withering. The foremost concept of withering of plucked tea shoots was to condition the shoots for subsequent stages of black tea processing. Chemical changes during withering play a pivotal role in determining aspects of quality. Normal wither of the plucked shoots for 16-18 h was practiced to achieve the required physical conditioning of the fresh tea shoots. Since respiration of the plucked tea shoots continues during withering, partial loss of moisture of the shoots is accompanied by catabolic process causing certain transformation in the chemical composition of the shoots (Bhatia, 1964).

Withering of the fresh shoots therefore pertains to two types of wither, namely "physical wither" causing loss of moisture and "chemical wither" involving chemical transformations associated with senescence of the shoots, both occurring simultaneously. Both these withers appear to be necessary for making good black teas (Ullah *et al.,*1984).

After withering CTC (maceration) is another important stage of black tea processing, where the basic requirement is leaf size reduction with a degree of cell disruption. Maceration machines i.e., rotorvane and CTC rollers operate most effectively within 70% moisture of withered leaf. Excessive moisture in the green leaf may clog both the rotorvane and CTC rollers (Tomlins *et al.,* 1996). Also, the quality of processed leaf depends upon the hardness of the shoots, withering percentage, closeness of roller setting, etc. These, in turn, have direct impact on the output of the machine, frequency of roller sharpening, power requirement and more importantly, quality of made tea. Moreover, the space requirement and energy consumption or in particular, the electrical wastage of the CTC machine is also very high (Mahapatra, 2002). CTC roller sharpening must be done after certain period of cutting.

Fermentation stage is also another most significant step in tea processing since the liquoring characters of tea are developed during this process. Upon disruption of the intercellular components during macerations, polyphenols present in the cell vacuole are oxidized by the tea oxidative enzymes, leading to the formation of TF and TR pigment characteristics of black tea (Robertson, 1992; Subramanian *et al.,* 1999; Muthumani and Kumar, 2007; Dey, 2012).

After well fermentation of dhool at desired level, it is passed through the dryer for drying. The most important object of drying is to arrest the oxidation and to reduce the moisture content of the dhool to about 3-5% which is suitable for the storage and transportation with a reasonable shelf-life (Sana, 1989; Bhuyan *et al.,* 2012). The conditions experienced during drying need to be carefully regulated in order to ensure the quality of the product and to maximize its keeping ability. The fired tea is a rather heterogeneous mixture of different sizes of leaf fragments together with stalk and fibers. These are sorted into particles of different sizes using a sorting machine. Main objective of sorting is to produce senses of black tea having even sized particles without any visible pale coloured stalk or fibers.

Proper maintenance of all machinery related to tea processing is very important to get better quality of tea. Machinery should be kept in running condition so that each aspect of processing such as withering, CTC, fermentation, drying, sorting and packing would follow a sequential pathway without any interruption during the season especially in peak period.

This paper will help better understanding of different stages of black tea manufacturing and proper maintenance of tea machinery. It also addresses some important points of tea manufacturing and machinery management which play a vital role in the improvement of made tea quality.

Specification for Black Tea- ISO Standard 3720

ISO defines black tea as "Tea derived solely and exclusively and produced by acceptable process, notably fermentation and drying from the leaves, buds and tender stems of varieties of the species *Camellia sinensis"*. The tea shall be clean and reasonable free from extraneous matters that it should comply with the requirements specified in the Table 1. Tea exporting countries also have their own standard specification for tea which in most cases conforms to ISO standard.

Table 1. Chemical requirements for black tea

Characteristic	**ISO**	**Bangladesh**
Water extract, % (m/m) minimum	32	32
Total ash (m/m)- Maximum - minimum	8 4	8 4
Water soluble ash, as percentage of total ash minimum	45.0	45.0
Alkalinity of water soluble ash (as KOH), % (m/m) Maximum Minimum	 1.0 3.0	 1.0 3.0
Acid insoluble ash, % (m/m) maximum	1.0	1.0
Crude fibres, % (m/m) maximum	16.50	16.50

Manufacturing of black tea

Tea manufacturing is a continuous process of removal of the moisture content from freshly plucked tea leaves in different stages where physical and chemical changes take place. Salient features of tea manufacturing are as follows.

Plucking leaf standard

The polyphenolic compounds and the caffeine in the tea shoot decrease in quantity from the bud to the stalk. As these compounds are responsible for quality tea, a good standard of plucking, therefore improve the quality of the tea manufactured. Plucking round should be restricted to 7 days on peak period. It may be extended to 10 days at the end of the season. Leaf quality should be checked regularly by leaf count by numbers or Bolometer count. Recommended standard of plucking at least 70% fine leaf (by Bolometer count).

Effect of coarse plucking
Uneven withering
Uneven cutting
Uneven fermenting
Over handling during sorting- loss of bloom.
Flakey, Open, Mixed leaf appearance.

Leaf Handling

Leaves may be damaged in two ways such as- (1) Physical damage (2) Chemical Damage. Physical damage of the leaf should be avoided, as fermentation sets in as soon as the leaf is bruised.

The flowing are the main reasons of leaf getting damaged –

When the large quantity of leaf is tightly held up in the puckers hand.
Pressed to the baskets.
Compressed walking or sitting on the top of the leaf.
Bulked in large quantity or shaken during transportation.
Exposed to sun.
Damage during transportation.
Damage by heat.
Damage by rain.
During weighing.
Delay in unloading in the factory.
Insufficient or unregulated weighing.

Analysis of green leaf

Quality of made tea depends on plucking standard. So analysis of green leaves is necessary. Analysis of green leaves is done in two ways as leaf count and Ballometer count.

Table 2. Analysis of green leaf by counting

Leaf	% by weight
one leaf and a bud	10%
two leaf and a bud	65%
three leaf and a bud	5%
Soft single bhanji	15%
Soft double bhanji	5%
	= 100%
Bolometer count- Soft leaf 70%	hard leaf 30%

Withering

On an average 78% of green leaf comprises moisture. Through withering this moisture is reduced as per the requirement of deferent type of manufacture. Withering achieves the following-

It imparts style or twist of the leaf so as to avoid flakiness of made tea.
It minimizes water logging during oxidation. Since the excessive moisture interferes with the free supply of oxygen which interferes with the oxidation itself.
It concentrates the cell sap.
It minimizes the loss of essential solid matter from the green leaf with the excess water at the time of rolling.

It minimizes bacterial contamination since under withered leaf is liable to contamination.
It minimizes the fuel cost
Moisture content of withered leaf is important in case of physical wither. Physical wither therefore varies with the moisture content of the freshly plucked leaf and also on the type of manufacture.
Benefit of withering:
Increase in amino acids
Increase in caffeine
Increase in certain flavory compounds
Increase in cell wall permeability
Decrease in poly saccharine and protein

Moisture content of the fresh leaf varies during the different parts of the season. To maintain a consistent standard of tea in make and style the moisture content in the withered leaf should be constant. So with varying moisture in green leaf physical wither has to be varied to maintain constant moisture in withered leaf (Faruk and Rashid, 1989). The simple equation given below is useful for obtaining the physical wither of leaf needed with different fresh leaf moisture contain –

$$100 - Pw = \frac{Mf - Mw}{100 - Mw} \times 100$$

Where,

$$Pw = \text{Physical wither in percentage} = \frac{\text{Weight of wither leaf}}{\text{Weight of fresh leaf}} \times 100$$

Mf = Moisture percentage of the fresh leaf.
Mw = Moisture percentage in wither leaf.
Physical wither depends on moisture contain of the fresh leaf. The variation is presented in Table 3.

Table 3. Physical wither of leaf needed with different fresh leaf moisture content

Type of manufacture	Optimum moisture requirement in W.L Mw (%)	Physical wither (Pw) required for leaf with initial moisture content		
		75% (dry)	78% (Average)	83% (Wet)
Rotor vane (CTC)	70	83	73	57
Roll- CTC	68	78	69	53
Orthodox	65	71	63	49

Table 4. Parameter of chemical withering

Chemical wither	Optimum 10 to 12 hours, but may be extended to 20 hrs. without any adverse effect.
Leaf spread	Tat/ Chung- 0.5 kg per square meter (about 1 ld). Trough 22 to 27 kg per square meter.
Trough heating	Maximum temperature of leaf- 32ºC (Hygrometric difference- maximum 3.3ºC.
Volume of air	14 Cubic meter per minute per square meter of area at 1/2˝ (13 mm) water gauge.
Recommended size	23m × 1.82m

CTC

Preconditioning of withered leaf is a necessity for CTC manufacture. Generally, Rotorvane (RV), Barbora Leaf Conditioner (BLC) and Leaf Shredder (LS) are used for this purpose. Among them, RV is the best suited to produce heavy tea with leaf quality more than 50% soft whereas the LS is suitable for making such tea with coarser leaf. Higher percentage of broken grades is obtained when LS is used. More Fannings and Dusts are obtained with RV and BLC respectively. The difference in liquor characteristic, leaf appearance and infusion of tea are insignificant with the three machines (Faruk and Dey, 1995). Proper meshing of rollers is essential for best result. So setting of rollers is very important. Accurate milling and chasing is essential.

Sizes of machine available:

24 inch	30 inch	36 inch	48 inch
610 mm	760 mm	910 mm	1220 mm

Capacity:

Size:	**24 inch**	**30 inch**	**36 inch**	**48 inch**
Kg W.L/HR (at 70%)	800	1000	1200	1600

Power Requirement:

Size:	**24 inch**	**30 inch**	**36 inch**	**48 inch**
1st Cut:	20 HP	25 HP	30 HP	35 HP
Sub. Cut:	15 HP	20 HP	25 HP	30HP

Power requirement

0.8 HP/inch roller for first cut

0.6 HP/inch roller for subsequent cuts

Speed ratio 10:1; Speeds- 700 rpm/ 70 rpm

Capacity- 7 kg per hour per inch of roller length (made tea) (For Rotorvane/ CTC i.e. at 70% wither). Sizes available- 24.30.36 and inches rollers to be sharpened after processing every 1630 kg withered leaf (at 70%) or earlier if required (per inch of roller length). Milling angel for roller diameter 8 1/2″ - 7 3/4″ - 70º and 7 3/4″ - 71/4″ - 65º

Table 5. Requirement of milling and chasing groove depth for standard chasing

Standard chasing	8 TPI × 50 Milled groove depth- 0.080″ Chased groove depth - 0.096 inch 10 TPI × 60 Milled groove depth- 0.068″ Chased groove depth - 0.080 inch Shoulder to slope ratio 1:1 Maximum power requirement 0.8 HP per inch roller for first cut, 0.6 HP per inch roller for subsequent cuts.

Sharpening of CTC rollers

Changing of rollers: As a rough guide the rollers should be resharpened after cutting about 1630Kg ($8^1/_2$" dia roller) and 2400kgs ($13^1/_2$" dia) of withered leaf (70% wither) per inch of roller length. Rollers below diameter of 7 $^1/_2$" should not be used.

For ready reference the table:
CTC Machine sizes of dia $8^1/_2$"

Tea leaf	CTC Roller length			
	24"	30"	36"	48"
Withered leaf processed (Kg.)	39120	49000	59710	78400
Made tea (Kg.)	11736	14700	17920	23520

To maintain a uniform final cut the set of rollers on the last CTC machine should be most recently sharpened one.

Sharpening procedure: Before using the CTC roller sharpening machine, it should be checked that the square thread lead screw is not worn out and the tool post is rigidly held. There should not be any vibration on the milling cutter; proper cooling fluid should be used. The sharpening process is in two steps- (1) Chasing and (2) Milling. It should always be remembered that the chasing is done fast. A final cleaning round may again be given after the milling. Resharpening of chasing tool and milling cutter should always be done by the proper grinding machine and never by hand. The grinding should be done after cutting of each roller (Faruk and Rashid, 1988).

After a roller has been sharpened the following checks should be made:

Check the chased grove in the correct depth.
The chasing and milling cut should be smooth and there should be no serration or chatter marks.
The diameter should be uniform throughout the length of the roller.
After each pair of rollers have been sharpened cheek if they match with each other on an inspection bench.

Fermentation

This is the stage of enzymic oxidation when color, strength and briskness are developed. The conditions of different types fermentation is presented in Table 6.

Table 6. Conditions for different type of fermentation

Floor Fermentation	:	Room temperature 26ºC to 28ºC Hygrometric difference maximum 1.7ºC Thickness of spread CTC- 1.25 cm, 8-9 kg per square meter. Orthodox- 2.50 cm, 5-6 kg per square meter.
Tray Fermentation	:	Similar to floor fermentation. Aluminum trays placed one over the other forming racks. Spread slightly thinner. Advantageous as less space required.
Trough Fermentation	:	8 to 12 kg per bowl (W.L.) Average pressure of air- 1˝ W.g Air leakages should be prevented by rubber seals.
Machine Fermentation	:	Tray types run by dryer chain. Humid air passed through at intervals. Time may be adjusted. Rubber belt types- open. Jumbo fermented.

Drying

Evaporative capacity of a dryer –

The amount of water a dryer can drive off in a unit time (say per HR).

The Evaporative capacity of a dryer should be worked out for proper feeding.

The feeding of W.L is controlled by the Evaporative capacity of the dryer.

Table 7. Drying condition of different dryer

Conventional dryer	:	Quality. Two stages. Continuous tray, empire temperatures. Single firing- Inlet: 95-99ºC, Exhaust: 49-50ºC Double firing- Inlet: 95-99ºC, Exhaust: 54ºC Passing time dryer: 25 minutes (single), 18 and 15 minutes (double) Made tea output depends on evaporative capacity of dryer. Moisture content of tea: 1st firing 6-7%, single / 2nd – 2-3%. 50% of the moisture in the cut leaf should be evaporated during the first 5 minutes.
Fuel consumption	:	Furnace oil- 0.3 to 0.4 litre per kg M.T. Coal- 1.0 to 1.5 kg per kg M.T. Fire wood- 1.6 kg per kg M.T. (at 30% moisture). Natural gas- 18.0 to 20.0 SCF per kg M.T.
Fluid Bed Dryers	:	Fluidization of the fermented leaf affected by hot air. Contact of leaf with trays avoided. Less moving parts. Temperature- Inlet: 116- 127%, Exhaust: 54- 60ºC. Fuel consumption: 8.0 to 10.0 SCF per kg M.T. (Natural gass) Proper withering should be done for fluidization. Recent ones- Vibratory fluid bed dryers.

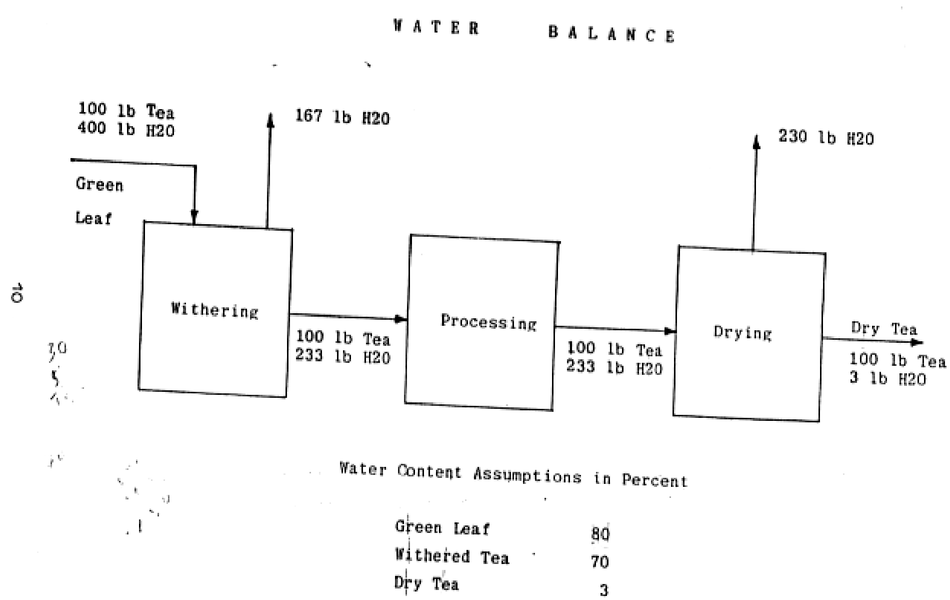

Fig. 2(a): moisture percentage of green leaf, withered leaf and made tea during tea processing

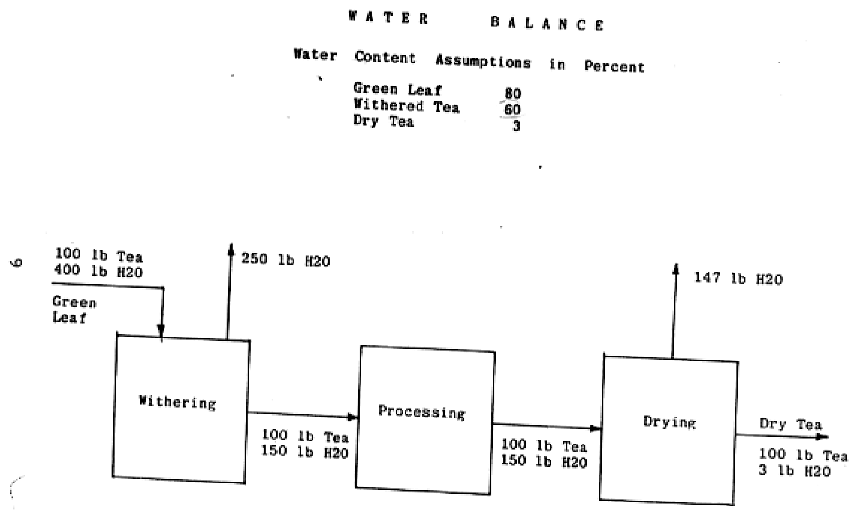

Fig. 2(b): moisture percentage of green leaf, withered leaf and made tea during tea processing

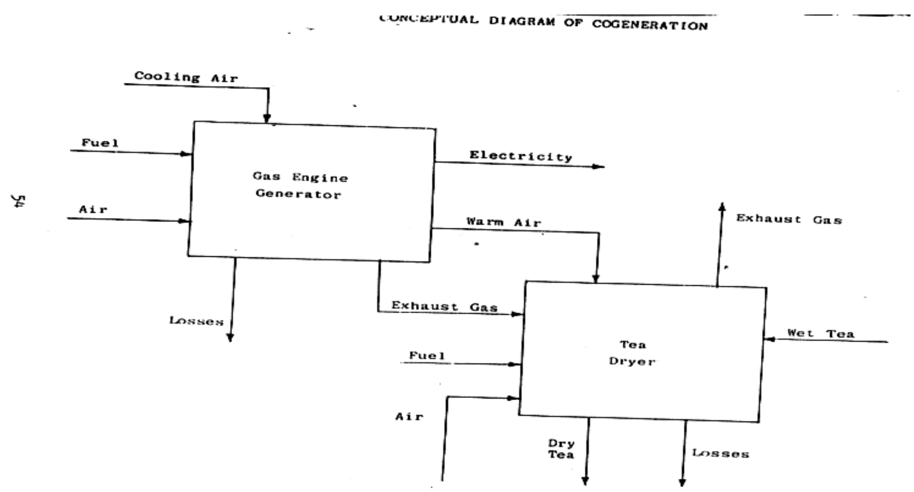

Fig. 3: Energy saving during withering and drying

Sorting

Moisture content of graded tea should be within 2 to 3%. All grades must be of uniform size throughout the year. Over handling of the tea should be avoided. Sorting machinery should be adequate so that there is no backlog.

Table 8. Different sorting machine

Machinery used	:	Middleton Speed: 205 rpm McIntosh: 250 to 260 rpm Fiber Extractor Vibroscreen

Standard Grades

Orthodox	CTC
FOP	FP
OP	FBOP
FBOP	BOP
BOP	OF
OF	FOF
FOF	PD
PD	RD
D	D/ CD

Tea Waste: Normally above 1%.

Packing:

Quality should be assessed before packing.
Moisture content should not exceed 3% on packing.
Temperature of final firing if required: 70-72ºC.
Packet marking must be clear and according to standard practice.

Conclusion

Tea processing is very important operation to maintain the quality of made tea. If proper care would have been taken in every stage of tea processing, appearance of leaves, liquor colour, strength, briskness etc. of made tea will be improved. Production cost will be reduced and market price of made tea will also be increased. Thus tea industry will be benefited.

Acknowledgements

The Author is very much grateful to Dr. Mainuddin Ahmed, Director, BTRI for his inspiration, critical and valuable suggestion during the preparation of this manuscript. The Author is also thankful to Mr. Shovon Kumar Paul, Scientific Officer, BTRI for his help during writing the article.

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OPEN DISCUSSION

Question: You have discussed about the clonal resistance/susceptibility to tea mosquito bug and termites in your paper. My question what is about clonal susceptibility on red spider mite and nematode both of which are the major pests of tea?

Answer: Thanks for your realistic question. Both Red spider mite and nematode are the major pests of tea in Bangladesh. Two experiments on Clonal susceptibility of red spider mite and nematodes have been set up in BTRI. Data are being collected regularly. The experiment is in progress. When the aforesaid experiments will be in a position to answer your query on the basis of research findings.

Question: There is no doubt that the use of plant extracts is eco-friendly and cost effective method but their usage would be feasible or effective in case of severe infestation field?

Answer: Use of botanicals is one of the important components of IPM. Only when the pest infestation is minimum, then the plant extracts could be used to minimize the infestation. However, biopesticides are being considered as environmentally safe, selective, biodegradable, economical and renewable alternatives for use in IPM programmes in tea. Biopesticides are natural plant products and may be grown by the planters with minimum cost and extracted by indigenous methods. But in case of severe infestation, synthetic chemicals should be used for the quick control of pests. The plant extract can therefore be incorporated in the strategy of integrated pest management (IPM) to reduce the chemical load in tea.

Question: Why withering time should be maintained at 10 to 12 hours?

Answer: In withering process, some biochemical changes occur within plucked leaves. Minimum 8 hours are needed to complete the biochemical reactions which take place during withering. That's why, withering time requires at least 10 to 12 hours.

Question: What is the relation between fermenting time and temperature?

Answer: Fermenting time depends on temperature. Generally, fermenting time require 60 minutes at 28°C. If 1°C temperature increases, the fermenting time should be decreased for 5 minutes. If 1°C temperature decreases, the fermenting time should be increased for 5 minutes. Fermenting time should not be below 40 minutes.

Question: What can we do for better thickness if wood thickness is poor for LP (light pruning)?

Answer: LP can be deferred for one year for better thickness of sticks of bushes of the section. The tea bushes of the section should be Skiffed hard and tipped by leaving two full leaves during tipping period. 10% additional fertilizers can be applied at the end of rainy season and plucking should be stopped at least 3 – 4weeks for getting root reserve before commencing LP.

Question: How many generations can we get if we follow standard plucking?

Answer: Number of generations depends on genetic factor, tipping time and standard of plucking practiced. In Bangladesh condition, generally we can get 5 -6 generations.

Question: What is Mycorrhiza?

Answer: The symbiotic association between fungus and the roots of higher plants is called Mycorrhiza. The fungus can produce vesicles and arbuscles in the root cells, so it is also called vesicular arbuscular mycorrhizal (VAM) fungi. It belongs to the order Glomales of class Zygomycetes. It colonizes the cortical tissues of roots during the period of active plant growth. The fungi are known to associate with all families of plants. In this association, the fungus and the roots of the host plants live together in a balanced relationship and it is usually considered a mutualistic symbiosis.

Question: What is the beneficial role of Mycorrhiza?

Answer: The mycorrhizal fungi are known to benefit plant growth by enhancing nutrient uptake from the soil by increasing the absorptive surface of the root system especially P and other poorly mobile micronutrients particularly Zn and Cu. It can mediate inter-plant nutrient transfer. It is known to reduce the severity of root diseases. It plays an important role for soil conservation in the field and increase drought resistance. The fungi can improve the root formation in the nursery and improve the growth of seedlings after transplantation to the field. The fungi increase plant productivity by increasing the rate of photosynthesis. It can alter the chemical and physical properties of soil by providing protection against toxic-metals.

WORKSHOP ON TEA PRODUCTION TECHNOLOGY UPDATED

Chief Guest : **Major General Md. Enayet Ullah,** ***ndu, psc***, Chairman, Bangladesh Tea Board
Special Guest : **Mr. M. Haroon-or-Rashid Sarker**, Director, PDU
Special Guest : **Mr. G. M. Shiblee,** Branch Chairman, Sylhet Branch, BTA
Chair : **Dr. Mainuddin Ahmed,** Director, Bangladesh Tea Research Institute (BTRI)

Organized by: Bangladesh Tea Research Institute (BTRI)
Sponsored by: Krishi Gobeshona Foundation (KGF)
Date: 24 December 2014

Published in December 2014

Price: 250 Taka

Print & Design: Fojlu Computers and Offset Printers