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EDITORIAL

CONTROL OF PLANT PARASITIC NEMATODES OF TEA SOIL USING DIFFERENT SPECIES OF GREEN CROPS IN BANGLADESH

An effort has been made by Mr. M.S.A. Mamun *et al.* to study the effect of different species of green crops on plant parasitic nematodes of tea soil. They found that the nematode population in Guatemala and Citronella plots were below the critical level (7.00/10g soil) while the population in the *Mimosa* and Calapogonium plots were beyond the critical level. It is evident from the findings that Guatemala and Citronella can be used as soil rehabilitation crops to suppress nematode population in field condition to get safe soil with less nematodes (<7.00) for a successful tea nursery.

PERFORMANCE OF SH/D/11/313, A/8/8, A/17/7 AND A/22/39 AS TEST CLONES ON YIELD AND QUALITY OF TEA IN BANGLADESH

Mr. M.I. Hossain *et al.* studied on yield and quality performances of four vegetatively propagated test clones of tea namely Sh/D/11/313, A/8/8, A/17/7 and A/22/39. They found that test clones A/22/39 and A/17/7 gave the highest significant yield compared with control TV1. The overall cup quality of the test clones was assessed by conventional organoleptic taste in respect of liquoring characteristics. The cup quality of Sh/D/11/313, A/8/8, A/17/7 and A/22/39 was found to be above average (AA) while the cup quality of TV1 (control) was excellent. Considering the performances, in respect of yield and quality potentials, the test clones Sh/D/11/313 and A/22/39 were released as BT16 and BT18 respectively for commercial cultivation in the tea estates, while the test clones A/17/7 and A/8/8 appeared superior for release as standard clone.

RECENT CONCEPTS AND STRATEGIES FOR TEA PEST MANAGEMENT IN BANGLADESH

In this paper, Dr. Mainuddin Ahmed and Mr. A.F.M. Aslam described the recent concept and strategies of pest management in tea in Bangladesh. It is the most important factors of tea husbandry. In view of tea ecosystem and diversity of pest complex, a multiple approach of pest management is essential for tea. For easy understanding of the problem, status of major pests, their specificity, biology and environment, their population build up and control measures, cultural as well as chemical control measures with their efficacy and use of insecticides are highlighted. In this perspective, status of pesticide residue survey in relation to human consumption in our tea is projected briefly.

BIODIVERSITY OF ARBUSCULAR MYCORRHIZAL (AM) FUNGI IN TEA CLONES

Dr. Mohammad Ali and Dr. M.A.U Mridha studied biodiversity of arbuscular mycorrhizal (AM) fungal colonization and spore population in the rhizosphere soils of tea clones. They found that the maximum root colonization and spore population was found with BT6 and minimum colonization and spore population was recorded with BT9. Out of six genera of AM fungi, four genera viz. Glomus, Acaulospora, Gigaspora, and Scutellospora were identified in the soil of tea plantations. Biodiversity of AM colonization and spore population in the tea clones indicated that tea plants are mycotrophic in nature and mycorrhizal technologies can be adopted in tea management.

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CONTROL OF PLANT PARASITIC NEMATODES OF TEA SOIL USING DIFFERENT SPECIES OF GREEN CROPS IN BANGLADESH

M.S.A. Mamun[1*], M. Ahmed[2] and S.K. Paul[3]

Abstract

An experiment was carried out to observe the effect of different species of green crops on plant parasitic nematodes of tea soil at Bangladesh Tea Research Institute (BTRI) main farm during January 2007 to December 2010. Four different species of green crops i.e. Guatemala, Citronella, *Mimosa invisa* and Calapogonium were considered as treatments. The experimental plot was laid out in randomized complete block design (RCBD) with 4 replications. Lopping was done thrice at 4 months interval per year for Guatemala and Citronella only to return the biomass to the same plots. Others i.e. *Mimosa* and Calapogonium no lopping and allowed to grow and stay *in situ*. Pre-treatment observation for nematode population was done in each plot before planting of green crops. Soil samples were regularly collected at monthly interval and samples were analyzed for nematode count at Entomology Laboratory through Baermann funnel method. Result revealed that the nematode population in the treatment T1 (Guatemala) and T2 (Citronella) were 2.98 and 4.56 respectively which were below the critical level (7.00/10g soil). In treatments T3 (*Mimosa)* and T4 (Calapogonium), the values were 8.46 and 9.72 respectively which were beyond the critical level. It is evident from the findings that Guatemala and Citronella can be used as soil rehabilitation crops to suppress nematode population in field condition to get safe soil with less nematodes (<7.00) for a successful tea nursery.

Key words: Plant parasitic nematodes, Green crops, Tea soil, Bangladesh

Introduction

Tea is an important cash crop as well as a long established plantation crop of enormous economic importance to Bangladesh meeting the entire domestic demand of this cheapest health beverage. Bangladesh tea being a century old agro industry represents a tiny speck in the magnificent Tea Horizon. Now it is one of the largest agro-based industries in the country. Bangladesh tea is grown in the two divergent ecological zones-namely, i) *Surma valley* in greater Sylhet and ii) *Halda valley* in Chittagong zone. Recently tea area is opened in *Korotoa valley* in Panchagarh district (North-West of Bangladesh). There are 163 tea estates having about 54,000 hectare of standing tea plantation producing about 60 million kg of finished tea per annum (BTB, 2010).

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Materials and Methods

An experiment was conducted at Bangladesh Tea Research Institute (BTRI) main farm to observe the effect of different species of green crops on nematode population during January 2007 to December 2010. The experiment was set up in a Randomized Completely Block Design (RCBD) with 4 replications. Four different species of green crops were planted in a plot size of 4.7 x 3.5 m^2 each. Five treatments were considered such as T1= Guatemala, T2= Citronella, T3= *Mimosa invisa,* T4=Calapogonium and T5=Control (no green crops). Cuttings or suckers of Guatemala and Citronella, seeds of *Mimosa indica* and Calapogonium were planted or sown with a spacing of 1m x 0.75m, 0.90m x 0.60m, 1.2m (R-R) and 1.2m (R-R) respectively (Fig. 1). Other agronomic practices i.e. manuring and fertilizer application, weeding and cleaning etc. were also done as when required. 500g Cowdung, 30g TSP and 15g MOP per pit for Guatemala, Citronella and 1kg Cowdung, 100g TSP and 100g MOP fertilizer for Mimosa, Calapogonium were applied as per BTRI approved dose (Kibria *et al.*, 1994). The pre-treatment observations were taken before planting of green crops. Lopping was done thrice at 4 months interval per annum for Guatemala and Citronella only to return the biomass to the same plots. Others i.e. *Mimosa* and Calapogonium no lopping and allowed to grow and stay *in situ.* The first lopping was done at a height of around 45 cm and subsequent lopping around 60 cm above ground. Pre-treatment observation for nematode population was done in each plot before planting of green crops.

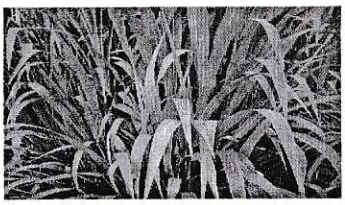

Plate 1. Guatemala

Plate 2. Citronella

Plate 3. Mimosa

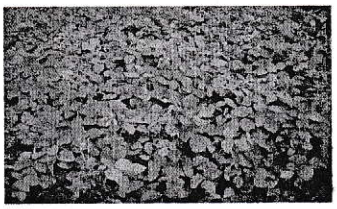

Plate 4. Calopogonium

Fig. 1. Different species of green crops used in the experiment at BTRI main farm

Soil samples are regularly collected randomly by inserting soil sampling auger in to the soil up to 0-9″ (23cm) from the respective plot at monthly interval. Each sample was composite of 20 soil cores from each plot. Soil sample was analyzed in the Entomology Laboratory by Baermann Funnel Method with slight modification (Mian, 1998). Ten grams of soil sample were taken into 50 ml beaker and covered with muslin cloth and kept in the glass funnel (20 cm diameter) in reverse for over night and nematodes were decanting and sieving

into a slide. A rubber tube of 15 cm long was fitted with each stem of each funnel. The rubber tube was closed with a pinch clamp. Tap water was poured in to the funnel until the level is 2.5 cm below the funnel rim. The active nematodes moved through muslin cloth leaving the soil. They were concentrated at the bottom of the rubber tube. Nematodes were collected in a glass slide by releasing the pinch clamp along with small quantity of water. Then nematodes were counted through Stereoscopic microscope.

The experimental data were statistically analyzed by Randomized Complete Block Design (RCBD) using MSTAT statistical software in a microcomputer. The mean values were adjusted by Duncan's Multiple Range Test (DMRT) (Duncan, 1951).

Results and Discussion

Plant parasitic nematodes or eelworms are associated with rhizosphere soils of tea plantation. The average number of nematode population due to four different green crops planted in the soil over four years i.e. from 2007 to 2010 is presented in Table 1. Results revealed that nematode population in the treatment T1 (Guatemala) and T2 (Citronella) were 2.98 and 4.56 respectively which are below the critical level (7.00) whereas nematode population in the treatment T3 (*Mimosa indica*) and T4 (Calapogonium) were 8.46 and 9.72 respectively which are beyond the critical level (Fig. 2).

Table 1. Month wise nematode population using different species of green crops during 2007 to 2010

Month	Average no. of Nematodes (4 years average)				
	T1 Guatemala	T2 Citronella	T3 Mimosa	T4 Calapogonium	T5 Control
January	3.48	6.56	10.38	12.39	26.82
February	3.22	5.24	9.42	11.27	22.38
March	3.26	4.78	9.02	11.6	26.94
April	3.46	4.56	9.52	10.26	28.32
May	3.84	4.48	8.26	9.88	18.96
June	2.24	4.36	9.11	9.67	19.24
July	2.53	4.04	8.86	9.42	20.66
August	3.52	4.12	8.12	9.12	20.58
September	3.41	4.26	8.42	8.42	22.62
October	2.12	4.28	7.36	8.56	20.63
November	2.38	4.08	6.82	8.04	18.84
December	2.32	3.93	6.28	7.97	28.38
Overall mean	2.98	4.56	8.46	9.72	22.86

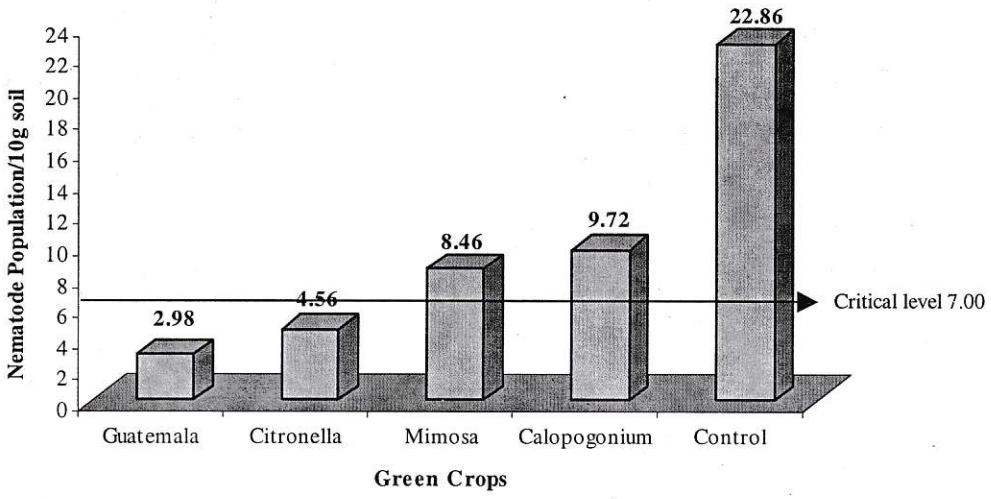

Fig. 2. Nematode population using different species of green crops

Performance of the green crops in suppressing nematode population

The performance of various treatments on the nematode population of tea soil is presented in Table 2. Performance of the green crops in suppressing nematode population was calculated by using Schneider Orelli formula.

(1-ta/ca x tb/cb) x 100

where, ta = data after treatment

ca = data after treatment (Control)

tb = data before treatment

cb = data before treatment (Control)

All the treatments significantly reduced the nematode population. The results revealed that significantly ($P<0.05$) the highest performance in reducing nematode population (88.52%) was obtained in T1 (Guatemala) followed by T2 (Citronella) (83.69%) (Table 2).

Table 2. Performance of different green crops in suppressing nematode population from January 2007 to December 2010

Treatments	Nematode population per 10g soil		Overall performance (%)
	Pre-treatment (tb)	Post-treatment (ta)	
T1 (Guatemala)	11.68	2.98	88.52 a
T2 (Citronella)	10.84	4.56	83.69 b
T3 (Mimosa)	10.72	8.64	70.08 c
T4 (Calapogonium)	11.54	9.72	63.00 d
T5 (Control)	13.26	22.86	-

Mean of 4 replications. Figures in a column having the different letters are not statistically identical ($p>0.05$).

It is recommended from the findings that Guatemala and Citronella can be used as soil rehabilitation crops to suppress nematode population below critical level in field condition to get safe soil with less nematodes (<7.00) for a successful tea nursery.

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PERFORMANCE OF SH/D/11/313, A/8/8, A/17/7 AND A/22/39 AS TEST CLONES ON YIELD AND QUALITY OF TEA IN BANGLADESH

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Abstract

A long term experiment was carried out to investigate the yield and quality performances of four vegetatively propagated test clones of tea namely Sh/D/11/313, A/8/8, A/17/7 and A/22/39 during 1996-2010. The results revealed that test clones A/22/39 and A/17/7 gave the highest significant yield of 3868 kg^{ha} and 3792 kg^{ha} made tea respectively compared with 3213 kg^{ha} made tea for the control TV1, 3646 kg^{ha} for Sh/D/11/313 and 3613 kg^{ha} for A/8/8 at mature stage (2002-2010). At immature stage (1st year to 5th year after plantation) the yield differences amongst the test clones was insignificant. The overall cup quality of the test clones was assessed by conventional organoleptic taste. The cup quality of Sh/D/11/313, A/8/8, A/17/7 and A/22/39 was found to be above average (AA) while the cup quality of TV1 (control) was excellent. Fourteen years data showed that the test clones of Sh/D/11/313, A/22/39, A/17/7 and A/8/8 were promising in respect of yield and quality. Considering the performances, particularly yield and quality potentials, the test clones Sh/D/11/313 and A/22/39 were released as BT16 and BT18 respectively for commercial planting in the tea estates, while the test clones A/17/7 and A/8/8 appeared superior to be released as standard clone.

Key words: Yield performance, cup quality, test clones, BTRI

Introduction

Tea is one of the most important cash crops in Bangladesh and south Asia. It is also an important food commodity of international trade. The principal types of tea produced and consumed in the world are black and green tea with small amounts of other types. A summary of world tea production is 4,162 million kg in 2010 (ITC, 2011). It is a major cash crop as well as an export item of Bangladesh accounting for about 0.81% of the GDP (BTB, 2002). Our present yield per hectare is quite low compared with other tea growing countries of the world. Because a large portion of our tea area is covered with seedling plants which are over 100 years old and are of unimproved jats of low productivity. Moreover a significant area of this old plantation has low plant population density resulting in low yield and poor quality of tea. The increasing cost of production as well as adverse climatic conditions has led to marginal economic return to the tea industry. In these circumstances, the industry needs to replant and extend new tea areas with improved planting materials of higher yield and good quality.

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Due to the heterogenous nature of tea seedlings, the seed available except biclonal stocks, could not guarantee the production of improved planting material (Njuguna, 1990). Emphasis should be given on selection and planting of vegetatively propagated material i.e. high yielding quality clones for better yield and quality of tea (Dutta and Alam, 2001).

Tea is propagated either by seeds or vegetative parts i.e. nodal leaf cutting. The progenies produced by vegetative propagation using nodal leaf cuttings are known as vegetative clones (Sana, 1989). Clonal selection is the most popular practice in tea for evolving better varieties. Desirable potential plants are isolated from the seedling population that have derived from superior jats or breeding lines. Procedure of clonal selection is more or less same in all the tea growing countries (Tubbs, 1946; Vissar & Kehl, 1958; Wight, 1961; Barua, 1964). As tea plant is an allogamous species, a large variation of characters occurs from bush to bush in existing seedling tea population and cross pollinated progenies. Such variation is exploited through selection programs to develop new tea cultivars with enhanced traits (Ranatunga, *et al.*, 2009)

Cup quality is an inherent character and one of the most important considerations in selecting potential commercial cultivars. According to previous studies, other than the genetic inheritance, various other factors such as climate /seasonal changes (Agarwal, 1989; Owuor and Othieno, 1991; Botheju *et al.*, 2000), agricultural practices (Dutta, 1960; Rahman *et al.*, 1978) and processing properties (Takeo, 1984; Hajra, 2001) are also important factors.

With an objective of evolving planting materials with high yield and quality potential BTRI has put its priorities on clonal selection and hybridization programme since its inception. The clonal selection programme was initiated in 1959 and hybridization programme in 1965 (Rashid and Alam, 1990). As an out come of these works, the institute so far released eighteen vegetative clones in the BT-series to the industry. Few more test clones are in various stages of trial. The present experiment was carried out to study the long term yield and quality performances of four vegetatively propagated test clones of tea selected from Shumshernugger and Amo tea estates.

Materials and Method

The experiment was carried out with four test clones of tea in the experimental field of BTRI main farm, during the period from April 1996 to December 2010. Cuttings were collected from the selected bushes of Shumshernugger and Amo tea estates during 1994, which were raised at BTRI nursery. At the time of

preliminary selection of the bushes chloroform test was done. The use of chloroform test (Sanderson, 1963) in estimating fermentation rates of tea clones showed some influence on made tea quality (Samaraweera and Ranaweera, 1988). This method was also used in early selection of potential quality cultivars in tea breeding programs in Kenia (Seurei *et al.*, 1998) and in Pakistan (Waheed *et al.*, 2001). An association between fermentation rate and the quality character of the 5 cultivars tested in the present study was also revealed using the chloroform test during selection period (Data unpublished). After rooting trial in the nursery the selected test clones, namely Sh/D/11/313, A/8/8, A/17/7 and A/22/39 were put to long term yield and quality trial during 1996 at BTRI Farm. The experiment was laid out in Latin Square Design (LSD) with 5 replications and 105cm x 60cm spacing. There were 25 plants per plot. TV1 was used as a standard (control) for yield and quality comparison. Fertilizer was applied at young and mature tea as per BTRI recommendations (Kibria and Uddin, 1998; Kibria and Rashid, 1994). Young and mature tea pruning were followed as per BTRI recommendations for young tea:-Decentre-Prune-Skiff-Prune-Skiff and for mature tea (Rashid, 1986) Light prune-Deep skiff-Medium skiff-Light skiff. The green leaf was harvested at weekly interval during the plucking season starting from mid March to mid December through out the experimental period. Yield data were recorded and analysed statistically in MSTAT programme in a microcomputer. The mean values were adjusted by DMRT. The yield was expressed as mean yield of green leaf g per plant and is presented separately for immature (1st - 5th year) and mature (6th- 14th year) stage. The made tea kg^{ha} was also calculated on the basis of 23% recovery from green leaf and 15875 plants^{ha} at 105 cm x 60 cm spacing. The quality performances of all the test clones as well as control were assessed after manufactured by CTC (Crush, Tear and Curling) method in the BTRI mini tea factory and were assessed weekly by conventional organoleptic taste and scored numerically. General characteristics of four test clones and TV1 are given in Table 1.

Table 1. General Characteristic of selected test clones and TV1

Clone	Bush characters	Leaf type	Pruning recovery	Nursery rooting	Cup quality	Manu. Pref.
T1-Sh/D/11/313	Light leaved Assam, vigorous, semi-orthotropic, good girth, fairly compact	Large, light green with prominent pointed apex, semi erect	Good	Good	Above average	CTC
T2-A/8/8	Assam hybrid, medium bush,vigorous, orthotropic grower with good spread, quite compact plucking table.	Medium to large, quite dark green, erect, pointed apex.	Good	Good	Above average	CTC
T3-A/17/7	Assam hybrid, big bush, heavy girth, good grower with semi-orthotropic, and profuse branching	Medium, slightly broad, light green, semi erect, prominent leaf apex.	Good	Good	Above average	CTC
T4- A/22/39	Assam hybrid, medium bush, vigorous orthotropic grower with a very good spread forming dense plucking table.	Medium to large, light green, glossy, semi-erect, serrated margin, not so prominent leaf apex.	Good	Good	Above average	CTC
T5-TV1 (Control)	Assam hybrid, orthotropic grower with a very good spread forming dense plucking table.	Medium to large, light green, glossy, erect, serrated margin, prominent leaf apex.	Good	Good	Excellent	CTC

Note: Pruning recovery & Nursery rooting: Excellent, very good, good, fair/moderate
Cup quality: Excellent, Above average, Average, Below average.

The Categories of tea clones as yield, standard and quality clones is shown in Table 2.

Table 2. Category of tea clones

Category of clones	Yield clone	Standard clone	Quality clone
Yield	>4000 kg^{-ha}	3000-4000 kg^{-ha}	2500-3000 kg^{-ha}
Cup Quality	AA or A*	AA*	E*

* Quality score: E = Excellent (34 to >34 out of 50)
AA = above average (32 to <34 out of 50)
A = average (30-32 out of 50)
BA = Below Average (<30 out of 50)

Results and discussion

The mean yield of green leaf (g per plant) over the experimental years for immature stage (1st-5th year) and mature stage (6th-14th year) are presented in Table 3 and in Table 4 respectively. Green leaf yield was converted as made tea (kg per hectare) over the experimental period. The converted mean for immature stage and mature stage are presented in Table 5 and Table 6 respectively. From Table 3 result revealed that at initial stage of growth all the test clones showed similar yield trend as control (TV1). When the data were analysed individual year wise, their yield differences were insignificant except the yield differences of the 2nd year. At immature stage (1st - 5th year) the highest average yield (1341 kg^{-ha}) was obtained from the standard clone TV1, (Fig.1) which was statistically identical with A/17/7, A/22/39, Sh/D/11/313 & A/8/8. At standard productivity level i.e. after maturity, in the year of 6th, 7th, 8th, 10th, 11th, 13th & 14th yield variations were significant except in the year of 9th and 12th. On the average of 9 year production, all the test clones gave significantly (LSD at 0.05) higher yield over control TV1 (Table 4). The test clone Sh/D/11/313, A/8/8, A/17/7 and A/22/39 showed superiority statistically over the control TV1 (Table 4). The test clone A/22/39 gave significantly (LSD at 0.05) higher yield (3868 kg^{-ha}) followed by A/17/7 (3792 kg^{-ha}), Sh/D/11/313 (3646.35 kg^{-ha}) and A/8/8 (3613 kg^{-ha}) over control TV1 (3213 kg^{-ha}) (Fig.-2). Thoroughout the experimental period test clone A/22/39, A/17/7, Sh/D/11/313 and A/8/8 maintained higher trend of yield over control (Table 6).

Table 3. Mean yield of green leaf (g/plant) at immature stage (1st–5th year)

Year / Clone	1st Year Skiff 1997	2nd Year Prune 1998	3rd Year Skiff 1999	4th Year Prune 2000	5th Year Skiff 2001	Average
Sh/D/11/313	74.13	216.14a	316.83	395.33	763.09	353.1a
A/8/8	67.88	189.63ab	283.88	432.73	746.90	344.2a
A/17/7	72.56	192.72ab	289.40	430.09	795.12	355.97a
A/22/39	69.31	208.06a	274.02	442.65	781.26	355.06a
TV1	61.62	174.18b	319.86	465.94	815.13	367.34a
LSD at 0.05	NS	26.26	NS	NS	NS	27.9

Within column values followed by same letter (s) are not significantly different by DMRT ($p \leq 0.05$)

Table 4. Mean yield of green leaf (g/plant) at mature stage (6th – 14th year)

Year / Clone	6th Year LP 2002	7th Year DSK 2003	8th Year MSK 2004	9th Year LSK 2005	10th Year LP 2006	11th Year DSK 2007	12th Year MSK 2008	13th Year LSK 2009	14th Year LP 2010	Average
Sh/D/11/313	731.05 b	925.13 b	1158.79 a	1133.42	596.82 b	949.74 ab	1353.18	1192.21 ab	951.00a b	998.78 b
A/8/8	693.30 b	958.40 b	1164.90 a	1162.20	575.76 b	926.37 ab	1256.98	1215.21 ab	958.00a b	989.80 b
A/17/7	702.31 b	971.57 b	1135.92 a	1170.43	759.56 a	1009.37a	1219.73	1306.14 a	1070.00a	1038.75 ab
A/22/39	846.66 a	1068.26a	1118.11 a	1264.93	752.71 a	977.87 a	1213.16	1310.83 a	987.00a	1059.50 a
TV1	658.48 c	792.43 c	928.29b	1055.11	575.76 c	774.62 b	1170.70	1092.3b	874.00 b	880.18 c
LSD at 0.05	105.22	323.97	169.24	NS	140.82	106.47	NS	133.29	129.5.0	50.78

Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)

Table 5. Estimated made tea (kg/ha) at immature stage (1st – 5th year)

Year / Clone	1st Year Skiff 1997	2nd Year Prune 1998	3rd Year Skiff 1999	4th Year Prune 2000	5th Year Skiff 2001	Average
Sh/D/11/313	270.1	789	1156.7	1443.0	2785.6	1289
A/8/8	248	692	1036	1580	2727	1257
A/17/7	265	704	1057	1570	2903	1300
A/22/39	253	760	1000	1616	2852	1296
TV1	225	636	1168	1701	2976	1341

Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)

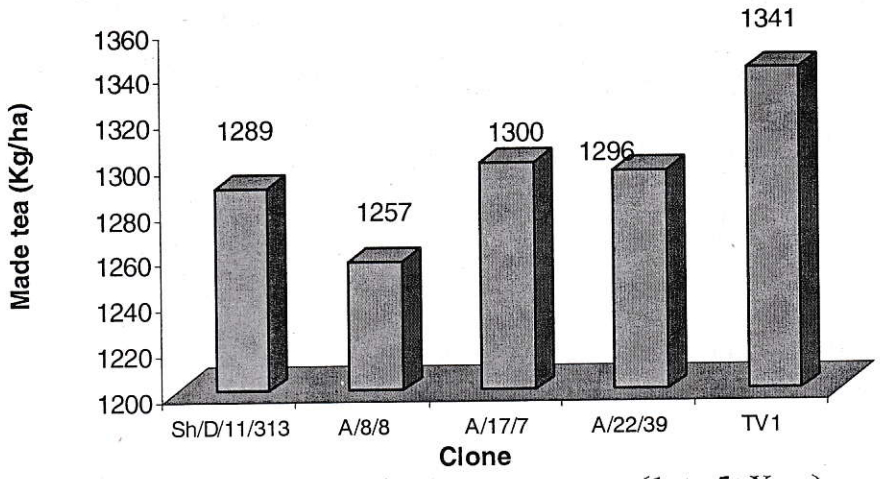

Fig. 1. Estimated yield at immature stage (1st to 5th Year)

Table 6. Estimated Made tea (kg/ha) at mature stage (6th - 14th year)

Year / Clone	6th Year LP 2002	7th Year DSK 2003	8th Year MSK 2004	9th Year LSK 2005	10th Year LP 2006	11th Year DSK 2007	12th Year MSK 2008	13th Year LSK 2009	14th Year LP 2010	Average
Sh/D/11/313	2668.9	3377.5	4230.5	4137.9	2178.9	3467.3	4940.2	4299.8	3471.9	3646.35
A/8/8	2531	3499	4253	4243	2102	3382	4589	4423	3497.5	3613.56
A/17/7	2564	3547	4147	4273	2773	3685	4453	4859.8	3906.4	3792.26
A/22/39	3091	3900	4082	4618	2748	3570	4429	4870.5	3603.3	3868.02
TV1	2404	2893	3389	3852	2102	2828	4274	3987.8	3190.8	3213.36

Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)

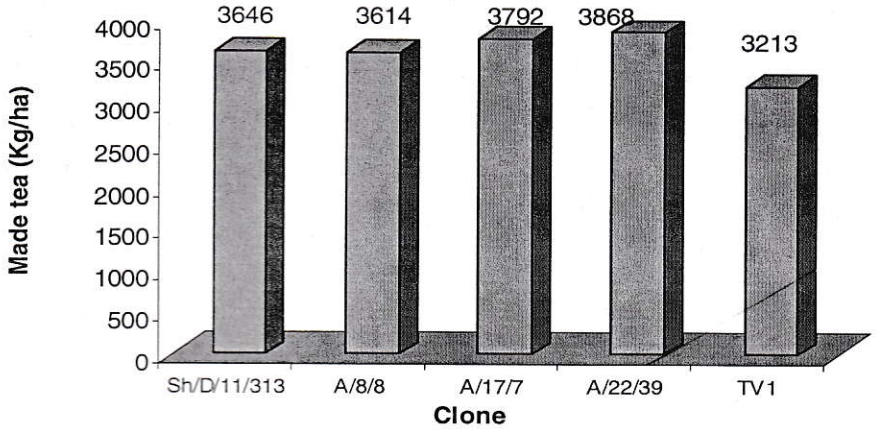

Fig. 2. Estimated yield at mature stage (6th to 14th Year)

Quality performance

The overall quality performances of the test clones and TV1 control assessed by conventional organoleptic test are shown in Table 6. It was observed that the cup characters of all the test clones were categorized as "**Above average**" (having 32 to less than 34 quality score out of 50 is considered as above average quality) while TV1 showed excellent cup quality. The four test clones consistently produced tea of above average quality. They have bright infusion, coloury liquour with useful strength and briskness (Table 7).

Table 7. Cup quality of different test clones (Average score of 10 years, from 2001 to 2010)

Test Clone	Infusion (10)	Liquour colour (10)	Briskness (10)	Strength (10)	Creaming down (10)	Total	Over all Quality
Sh/D/11/313	7.45ab	7.64b	7.43b	7.59b	3.46ab	33.55b	AA
A/8/8	7.48ab	7.53bc	7.31b	7.36b	3.16b	32.81c	AA
A/17/7	7.202b	7.53bc	7.16b	7.42b	3.29b	32.83c	AA
A/22/39	7.37ab	7.47c	7.32b	7.28b	3.17b	32.64c	AA
TV1	7.63a	7.8a	7.69a	7.97a	3.75a	34.82a	E
LSD at 0.05	0.2526	0.1319	0.2974	0.295	0.3117	0.6802	

Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)

Considering the yield performances and quality standard throughout the study period compared with the control TV1, the test clones Sh/D/11/313 and A/22/39 were released as standard clones in BT series for commercial use of the tea industry (Dutta and Alam, 2003; Hossain and Dutta, 2010), while the test clones A/17/7 and A/8/8 appeared superior to be released as standard clone. Later the

test clones Sh/D/11/313 and A/22/39 were renamed as BT16 and BT1 respectively. The other test clone A/8/8 was also found prospective in quali characters and yield and can be used as a standard clone or valuable breedin stock.

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RECENT CONCEPTS AND STRATEGIES FOR TEA PEST MANAGEMENT IN BANGLADESH

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Abstract

Pest management is the most vital component of tea husbandry. In view of tea ecosystem and diversity of pest complex, a multiple approach of pest management is essential for tea. For easy understanding of the problem, status of major pests, their specificity, biology & environment, their populations build up and control measures, cultural as well as chemical control measures and their efficacy and use of insecticides are highlighted. In this context, tea pesticides and recent trend in its consumption and pesticide residue survey in our tea are projected briefly. Tea being an export-oriented commodity also, all the required measures as per international rules and regulations must be taken into consideration to keep the residues well below the Maximum Residue Level (MRL) in the finished product. MRL and its testing for some applied pesticides in tea fields are also discussed. Utilization of the modern pesticide analytical laboratory facilities available at BTRI and the concerted role of our tea producers and traders are emphasized. Integrated pest management (IPM) is also underscored for effective pest control and harness economic advantages in the short run. More studies on IPM and the institutional arrangement for IPM extension are necessary. Finally in the long run, avoidance of problems posed by resistance build up by pests, health hazards due to pesticide use and IPM relationship of beneficial insects to pests are to be mitigated for working out a successful pest control strategy for our tea industry.

Key words: Strategies, Tea Pest Management, Bangladesh

Introduction

A tea plantation is a grown monoculture over large contiguous areas of the common tea plant, an evergreen shrùb *Camellia sinensis* (L). O. Kuntze, integrated with established shade plantation in our environment. Amongst the cultivated practices, Pest management is the most vital component of tea husbandry. Many technological gaps and physical constraints exist in tea cultivation, which hitherto hinder to modulate or compound the known crop protection methodologies and disciplinary interactions. The foremost one is the tea ecosystem, which is comprised of tea, shade trees, green manuring crops, forests, etc. Moreover, the intensive mono-culture of a perennial crop like tea over an extensive and contiguous area in an apparently isolated ecological zone in Sylhet and Chittagong during the last 160 years had virtually formed a stable ecosystem for widely divergent exotic, endemic or introduced pests (Sana, 1983; Ahmed, 2005).

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Besides, the architecture of tea plantation, variability of plant types and systematic interactions of various agro-techniques like sequential pruning cycle, plucking rounds, mulching, permanence of shade trees, etc. impose a significant impact on the subsequent colonization, stabilization and distribution of myriads of pests, diseases and weeds.

Status of Pests

Each tea growing area has its own distinctive pests, though many species have been recorded from more than one geographical area. Every part of tea plant is subjected to the attack of pests and it is estimated that more than 50 species of organisms including insects, mites, and nematodes feed on tea and fungal diseases attack tea as a host plant. Recently rodents are also reported to have invaded tea. Insects, mites, nematodes which attack tea are, therefore, provided with an abundant supply of food in the form of young and mature leaves, stems, barks, roots etc. which encourage their rapid multiplication. Adoption of longer pruning cycle, deforestation, changing agronomic condition, climatic changes, natural imbalance due to indiscriminate use of pesticides, herbicides and fertilizers, use of sub-lethal dose of insecticides with poor spray-efficacy, use of susceptible planting materials and disturbance of normal equilibrium in the pest ecosystem have directly or indirectly increased the pest population and the problems of their control to a great extent (Muraleedharan and Chen, 1997).

Some new insects are often added to the list of tea pests. Because once they happen to be on tea and find it acceptable they continue to thrive on the abundant supply of food available to them. On the contrary, the insects, which cause negligible damage today, may become destructive tomorrow. It is, therefore, essential that every pest, whether it is a minor or a major one, should not be ignored. An outstanding example- a shade tree pest *Brodesia omissa* attacked *Derris robusta* of Phulbari T.E. and Modhupur T.E. recently and feed on the leaf and defoliated completely including soft barks of the shade trees (*Derris*). From the economic point of view, the pests are considered to be major and causing serious damage to tea plantation in respect of both quantity of production and quality of made tea (Sana, 1983, 1989 and Ahmed, 1995). Conservatively at least 15% crop has been lost every year due to this malady (Ahmed, 2005).

It is interesting that some pest like *Helopeltis* is only severe in greater Sylhet Zone while almost absent in Chittagong Zone. It is interesting to note that in the recently opened tea area in Panchagarh (extreme north-west of Bangladesh) there occurs a *Helopeltis* infestation (Ahmed, 2005). This might have the result of close proximity of Indian territorial teas on the other side of the border. Even North Sylhet Valley suffered less than the other valleys of greater Sylhet. It has assumed considerable significance of *Helopeltis* in the last few years due to its widespread occurrence in all the six valleys in Sylhet Zone. The pest has

reappeared in an alarming way even in clear and plain tea fields. Both adults and nymphs of the insect, which are most active during hours daily in the morning and late afternoon, cause the damage. Moreover, the rapid spread and preponderance of *Helopeltis* throughout the tea estates of Sylhet are virtually posing a serious threat to the tea industry.

Specificity, biology, environment and Control measures of major pests

Red Spider Mite (RSM)

Soil pH related to RSM

Tea prefers a soil pH around 5.0. It is better to avoid planting of tea in soils with pH higher than 5.8. Pest outbreak is related to soil pH. An example is such that the bushes grown in sub-optimal pH, soils are generally weak, and are therefore more liable to Red spider mite attack than those grown in soils within the optimum range of pH.

Efficient Red spider mite control

- Prophylactic measure (pre-emptive) is a must (before mite pest attack) with two rounds of Sulphur applications where mite attack occurred every year in the same areas
- Interval period must be 5-6 days in between two applications
- Apply chemical on both surfaces of the leaf
- Avoid planting highly susceptible clonal material
- Irrigation practices suppress mite population
- Copper fungicides can influence the fecundity of mite population
- Knapsack sprayer is more useful than motorized knapsack sprayer
- Target site must be in both surfaces of the leaf and especially fish/janam/goal pata area
- 1% Urea could be used with miticides
- Cattle trespasses and pluckers' unnecessary movement should be restricted

Special attention for Red spider mite

- For control of mite one should first pay special attention to unpruned tea, which harbour these in varying numbers from the beginning of the season.
- Badly drained and temporarily water-logged areas suffer more from red spider mite attack than well-drained areas.
- The areas which are periodically cleaned of weeds and grasses, particularly during the early part of the season, suffer less from red spider mite attack than uncleaned areas.
- Use of synthetic Pyrethroids induces reproductive potentiality which leads to sudden pest outbreak.
- Use of sub-lethal doses of Organophosphate (OP) compounds causes development of resistance in mites.

Helopeltis- Tea Mosquito bug

Occurrence

Tea mosquito bug (*Helopeltis theivora* Waterhouse) is the most serious pest of tea in Bangladesh and India. It is also widely distributed in Sri Lanka, Vietnam, Indonesia, Malaysia and Africa. It is also a phytophagous pest of coffee, cocoa, cashew, etc. *Helopeltis theivora* Waterhouse, popularly known as Tea mosquito bug (not common house mosquito), belongs to the Order- Hemiptera and family Miridae. 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. Every species has a natural tendency to spread as widely as possible but its dispersion is checked by certain limiting factors which make it impossible for the insect to live successfully everywhere.

Crop loss by *Helopeltis*

Crop loss assessment by *Helopeltis* is very difficult because the attack varies seasonally depending upon the climate, shade condition, aspect, altitude and cultural practices. At the same time the damage relationship compared to weight of an uninfested shoot is weak. But later shoot growth or new shoot emergence shows delay as a result final yield is depressed. In Bangladesh context overall crop loss was estimated to be 10-15%.

Seasonal Biology

Maximum fecundity (June - October): 400 - 660 nos.egg
Minimum fecundity (November - May): 40 - 280 nos.egg

Incubation period is one of the important biological phenomena for the population increase/ overlapping generations. Incubation period varies according to weather condition (Table 1). Shorter incubation period in the main cropping season means the vulnerable condition for the crop.

Table 1. Incubation period of *Helopeltis* in different months

Months	Days
November - January	11 - 23 days
February	19 days
March - April	10 - 12 days
May	8 days
June - July	6-7 days
August - September	5 - 6 days
October	7 days

Nuptial behaviour of *Helopeltis*

- Capable of mating just after moulting.
- Copulation lasts for 60 - 210 minutes.
- ♂ finds out a ♀ for mating.
- Repeated mating ensures a sure chance of fertilization and consequently greater build up of population.

Survival potential

The ability to survive under inimical environment is called survival potential. The survival potential of a pest helps to overcome the adversities of life process through some contrivances such as, protective devices, mimicry, food habit, shelter, migration, laggard stages (Table 2).

Table 2. Different factors and response to *Helopeltis*

Factors		*Response*
Temperature	:	Positively thermotropic
Humidity	:	Positively hydrotropic
Light	:	Negatively phototropic
Cloud	:	Positive
Hosts specificity	:	Polyphagous (feeds on various plants)
Protection	:	Embedded eggs in plant tissues
Dispersion	:	Slow flier

Factors influencing the population build up

- Alternate weed species as host.
- Extended pruning cycle.
- Longer pruning cycle.
- Higher or lower dose (reduction of dose will ultimately create resistant strains).
- Same chemicals used in the same fields for longer period.
- Density of shade.
- Typical topography.
- Microclimate.
- Lack of proper understanding and monitoring of the pest.
- Lack of timely control measures.
- Height bound bushes- spraying is often inefficient in such areas.
- Spraying interval
- Resistant or susceptible clone or seed jat.
- Avoid higher dose of MOP (KCl) as a foliar application, which increases resistance to *Helopeltis.*

Susceptibility of tea plants

Different tea clones show varying degrees of susceptibility to *Helopeltis*. However, at present there are no clones 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.

Cultural control options

- Allow sufficient sunlight and better aeration.
- Over shaded plantation should be thinned.
- Avoid damping condition.
- Drainage should be improved.
- Remove alternate hosts.
- Remove jungles as much as possible.
- Keep sections free from weeds.
- Barrier spraying may be used.
- Plucking round should be maintained (6-7 days).
- Late pruning is better for severely infested areas.
- Interval between 2 rounds of spraying is very important.

Selective use of insecticides

Retrospective records or memories of the use of pesticides against these pests over a period of three decades show that Endosulfan (Thiodan 35EC) was the most dominant pesticide used against this malady. Endosulfan is a broad-spectrum non-selective contact and stomach poison. Continuous "Blanket spraying" with this insecticide has helped develop strains of the bug with increased tolerance/resistance. So, it would be wise to switch over the other group of insecticides like Synthetic Pyrethroid, or Organophosphate, at least temporarily for immediate and efficient control.

Application procedure

- Do not use same chemical in the same fields for long time.
- Do not spray when rainfall is apprehended.
- Spraying is preferable on the following day of plucking.
- To enhance the shoots foliar application of Urea (1-2%) may be given along with insecticides.
- 1% MOP could also be applied as a foliar application to enhance the healthy vegetative growth (avoid higher dosage of potassium KCl).
- Prune the badly affected sections during December-January.

Schedule of effective control

For scheduling effective control of Helopeltis, timely application of chemicals, method of spraying and interval between two immediate rounds of spraying are very important. Fungicide Cupravit/Macuprax could be mixed with the insecticide. For effective control of Helopeltis following spraying schedule should be considered as in Table-3.

Table 3. Spraying schedule of *Helopeltis*

March - April	During initial symptom noticed, 2 rounds at 10 days interval
May - June	2 rounds at 6-7 days interval
July - August	2 rounds at 6-7 days interval
September - October	2 rounds at 6-9 days interval

Note: For severe cases - black plucking followed by spraying of skiffing

Weather factors

The influence of weather factors such as temperature, relative humidity, rainfa sunshine hours and cloud coverage (Octa) is very important (Ahmed and Uddi 2001). But these factors are beyond our control in the nature. Heavy rainfa adversely affects the pest's population. Its population growth has a negati relationship operative with lower relative humidity. Cloud coverage (critic value i.e.8.0) is also important for their intensity of infestation.

Why chemical efficacy performs poor?

Following factors are related to the chemical efficacy of a pesticide:

- Endosulfan (Thiodan 35EC) has been in use for last three decades. Th same pesticide used in the same field for long period might ha increased tolerance/resistance capacity of the Mosquito bug.
- Temperature higher than 35°C in the cropping season reduces th efficacy of EC (Emulsifiable Concentrate) formulated pesticides.
- Some typical dense canopy structure of the tea bush itself may resi thorough spraying.
- Cloud coverage influences the intensity of attack.
- Unpredictable rainfall interferes with the pesticide application timing a well as efficacy.
- Erratic rainfall also interferes with its spraying schedule.
- Improper dose or under-calculated quantity of chemical compared to are coverage does not kill the target pest properly.
- Rapid growth potential of the pest.
- Unskilled spray team does not fulfil the goal.

Termites

Termite Phyla

Insects of the order Isoptera are usually known as termites or white ants. Th word 'termites' comes from the Latin word *tarmes,* which is given to a sma worm that makes holes in wood. Their differences from Hymenoptera, such a ants, bees, and wasps, have resulted in them being placed in a separate order, th Isoptera. 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. Soil particles are frequently used for nest construction. They are highly organized, relying on chemical and sensory messages for communication and defence, enabling them to exist in total darkness. Many termite species are responsible for considerable damage to tea bushes and shade trees. Among the termite castes, worker caste is very dangerous to tea.

Termite species of Bangladesh tea

Termites that are responsible for damage to tea bushes may be classified into two groups-

Live wood termites

These attack living tissues of tea bushes and are considered to be primary pests of tea. They excavate galleries within the live wood healthy tea plants. Tea plantation of Bangladesh is primarily invaded by four species of live wood termite, namely *Coptotermes heimi* Wasmann of Rhinotermitidae family; *Microcerotermes championi* Snyder, *Microtermes obesi* Holmgren and *Macrotermes aleemi* Holmgren of Termitidae family.

Scavenging termites

These generally attack dead and dying tissues and are regarded as secondary pests of tea. There are three species of scavenger termites, namely *Odontotermes feae* Wasmann and *Odontotermes horni* Wasmann and *Odontotermes parvidens* Holmgren and Holmgren.

Termite species of Bangladesh tea

Termites that are responsible for damage to tea bushes may be classified into two groups-

A. Reproductive or fertile castes, B. Sterile castes

Why termite is a problem today?

- More attention is generally paid to defoliator pests, which are often responsible for immediate damage to crop but termite go unnoticed for years before.
- Awareness of the planters and scientists were less than today.
- No systemic chemical was in tea against termites.
- Cultural and mechanical controls were not highlighted.
- Persistent chlorinated hydrocarbon group was only effective against scavenging termite.
- Concealed/ subterranean habit.
- Highly reproductive.
- Available alternate host plant.
- Damage process is comparatively slow.
- Intensive cropping, especially mono-cropping reduces the soil fertility and structure of soil more conducive to attack.

Host plant resistance to termite

Use of resistant tea varieties is one of the outstanding components of integrated pest management (IPM) system. Even low level of resistance can contribute to the minimization of other control methods. Emphasis should be given on the resistant varieties to pests. Different agrotypes or clones of tea with varying growth habits differ in their susceptibility, resistance or tolerance to pests. Attempts have been made at the institute to screen some well-known tea agrotypes/clones against termites. Ahmed *et al.* (1994 and 1999) studied twenty three agrotypes including Indian and Bangladeshi clones and analyzed which gave some interesting information. Based on the findings, Munipuri-China hybrid and a few broad leaf Assam hybrid clones were found to have best resistance while some hybrids or Camboid type of small to intermediate leaf size may be in the second preference. In the improvement programme like breeding and selection, Munipuri hybrids (fairly broad and dark leaf hybrid) to general hybrids (small to intermediate leaf size) should be the choice for termite resistance in tea and *Assamica* (big and broad leaf) or China types (small leaf) are not to be preferred for such purpose.

Threshold decision process of termite

A decision profile for termite management was formulated in view of "Eco-management" concept of pest control strategies. A concise control decision profile is construed by comparing the contrasting bio- ecological factors which modulate the dynamics of termite population in plantations (Fig. 1).

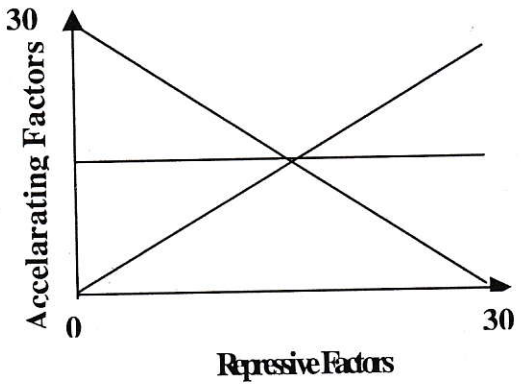

Fig. 1. Threshold decision process of termite management

There are various contrasting factors of "Eco- management" which are critically examined in order to fulfil the following objectives:

- Optimization of climatic factors
- Modulation of agro-techniques
- Selection of judicious chemical control method
- Encouragement of cultural control method
- Conscious application of mechanical control method
- Cultivation of resistant/ tolerant cultivars-agrotypes/clones
- Establishment of pest monitoring/ surveillance system

Destruction of termite colony

There is no denying fact that the devastating attack of termite on tea plant causes huge amount of loss to tea crop in Bangladesh. The fact is that the eradication of termite is impossible, but it may be controlled to a minimum level so that one can get the targeted crop. Experiment at BTRI on integrated control aspect of termite colony show that insecticide like Thiodan 35EC and Calixin 75EC could be used with an injecting rod having 0.95cm diameter and 94cm length directly inside the termite colony having effective results.

Field testing device: Use of food traps to monitor termite population

Termites are soil pests and invade all types of woody materials such as tea plants, shade trees, cover crops, bamboo, grasses and mulches used in tea culture. 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 at BTRI main farm. 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 (Ahmed, 2001).

Jassid

Occurrence

Tea Jassid *Empsaca flavescens* (Fab.), are commonly known as "Green fly". It is a major pest of nursery and young tea. It is more pronounced in unshaded areas than shaded ones.

Seasonal prevalence

Infestation on tea bushes and nurseries is found almost round the year. A mild to severe outbreak is occasionally seen localized in tea estates especially during dry periods such as February- April when plant recovers from light pruning or medium pruning. Prevalence of longer dry period during cropping season is considered to be very conducive to their rapid multiplication and spread. Assam jats of tea are generally more susceptible than the China- hybrid.

Cultural control

- Establishment of optimum shade in plantation and providing overhead shade in nurseries.
- Cleaning the section and keeping the section weed free.
- Improvement of drainage condition.
- Health and vigour of the bushes be maintained with due cultural and nutritional practice.

Mechanical control

- Shortening of plucking rounds during acute infestation.
- Hard plucking may be practiced during severe cases.
- Target point is especially the top shoot and under surface of young leaf.

Flush worm

Etiology

Flushworm is the larvae of the moth *Laspeyresia leucostoma* Meyer. This larva attacks few top leaves tying them together and forms a telescopic appearance. It is commonly known as flushworm.

Seasonal prevalence

In Bangladesh condition, there are several generations in a year. The pest is found sporadically localized in tea estates, especially in the pruned or skiffed tea plantation during March- May. The incidence of the pest, however, declines after August.

Management

It is very difficult to control the pest with insecticide alone.

- Best way to control through collection and destruction of shoots.
- Affected areas are plucked hard to the janam (Scale leaf) for one round so as to reduce the population suddenly and effectively.

Nematode in tea nursery

In tea nurseries, the health of saplings is greatly impaired due to ravages of various nursery pests. Among them, soil nematode (Eelworm) is regarded as the most serious one. It destroys root system of the saplings causing deterioration, poor growth and death of saplings.

Meloidogyne javanica (Treub.) attacks tea plants in nursery (Ahmed, 2005). Severe infestation of nematode in tea nursery in Luskerpore valley circle was observed. Many of the tea estates of Luskerpore valley frequently sent their soil samples to BTRI for nematode analysis. So nematode problems in tea is an important issue now a days. In addition, many tea estates use cherra (stream) or pond water for sprayer media. Such water carries soils contaminated with

eelworms and eggs and when water thus contaminated with eelworm in used for irrigating the nursery plants it will undoubtedly infest the plants.

Favourable conditions

- Rainfall positively influences the parasitic nematodes.
- Highest population is observed in rainy season (April- August).
- Population varies with soil properties.
- Highest population was found in higher pH, organic matter content and silt content.

Recommended practices

The following recommendations should be followed to minimize the infestation of nematodes:

Replanting

- Resistant or tolerant variety should be adopted.
- Useful step to be taken to incorporate nematicides during the time of new planting of tea.
- Granular (G) formulations- Furadan 5G @ 3g/plant, Curatar 3G @ 5g/ plant can be used.

Rehabilitation

Guatemala or Citronella grass is useful to bring down nematode population (for a period of 18 months).

Nursery

- Decomposed cowdung is a threat for tea nursery.
- Infested nursery plants are one of the main sources of spreading.
- Routinely treat/ fumigate nursery soils as a prophylactic measure.
- Pile nursery soils to a height of 45cm, then use 500g Basamid/2.8m^3 mixed with the soil, lightly water and cover with thatch.
- Heavy clayey soils should be avoided.
- Bags are to be staked on nursery beds and 15cm trenches cut around each bed.

Pesticides

Trend of Pesticide consumption in Bangladesh

Pesticides use in Bangladesh had been started from mid 1950s and rapidly increased in late 1960s with the introduction of green revolution. But at that time the use of pesticides was mainly confined to rice, sugarcane, vegetables and fruits.

Total consumption of pesticides in Bangladesh for the last 9 years (1999-2007) was 14,340.55 to 37,712 tons. The overall trend in 2007 was almost 2.5 times higher than that of the year 1999 (Fig. 2).

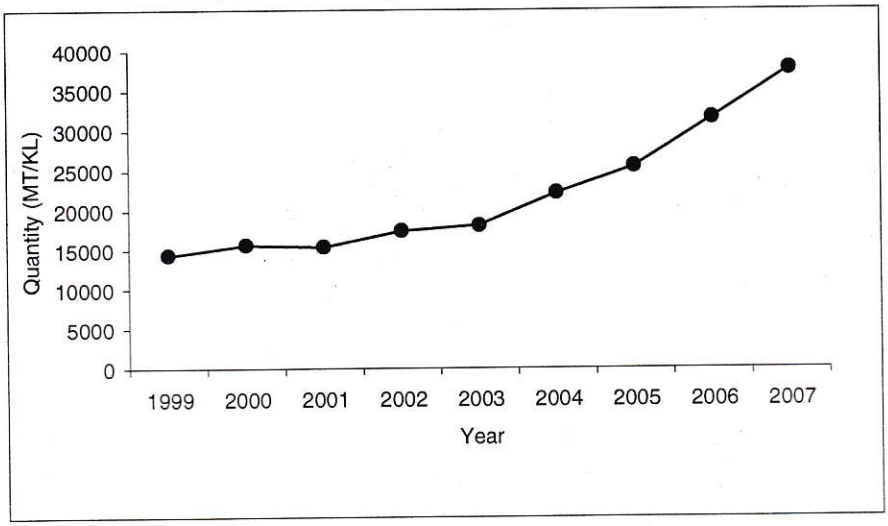

Fig. 2. Increasing trend of use of pesticide in Bangladesh

Use of pesticide by category

Although the pesticide use in the country started with insecticides, which dominates till today, the other classes of pesticides such as fungicide, herbicide, rodenticide and miticides have recently occupied a good position in the market (Rahman, 2000). An analysis of pesticide use by category over a period of last 9 years has been shown in Fig. 3 which indicates that during the whole period under consideration among the pesticides, insecticide upholds highest position in the trend curve, followed by fungicide, herbicide and the lowest being the rodenticide. The consumption of pesticide by category in 2007 as shown in Fig. 4 which indicates the largest share (62.54%) occupied by insecticide followed by fungicides (27.12%) and then followed by herbicide (10.14%).

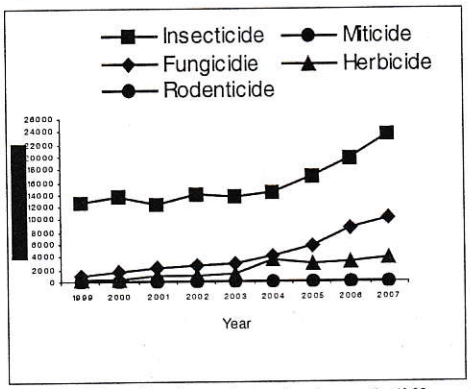

Fig. 3. Trend of market sharing of different categories of pesticides during 1999 to 2007 in Bangladesh

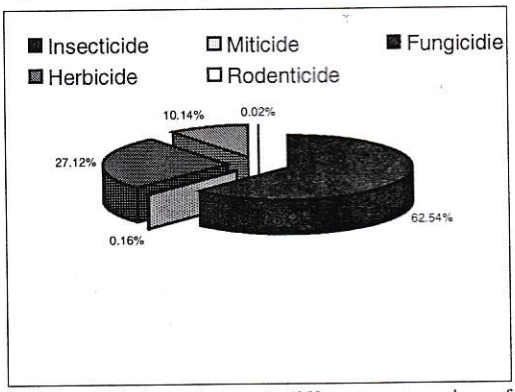

Fig. 4. Market share of different categories of pesticides of formulated product in 2007 in Bangladesh

Trend of pesticide marketing in Bangladesh tea plantation

The use of pesticides in tea was introduced in late 1950s of Bangladesh. The first introduced pesticide in tea was DDT against *Helopeltis* and Termites.

In tea plantation, the use of pesticide is increasing day by day. Different group of pesticides are frequently used in tea industry. It is showed that the use of Ethion (miticide), Ripcord (insecticide) and Furadan (nematicide) was 3.50 MT, 0 MT and 1.40 MT during the year of 1998-99 and consumption reached to 13.50 MT, 1.40MT and 5.50 MT respectively in the year of 2007-2008 (Fig. 5). The trend of pesticides use up to 2007-2008 is 3.85, 1.40 and 3.92 times higher than that of 1998-99.

The trend in the use of three chemicals namely Thiodan (insecticide), Cupravit (fungicide) and 2,4-D Amine (herbicide) in tea plantations over last 5 years is shown in Fig. 6. The use of Thiodan, Cupravit and 2,4-D Amine was 28,750 Lit, 9,640 Kg and 8,760 Kg respectively during 2003 and reached to 31,540 Lit, 5,875 Kg and 4,960 Kg in 2007. The use of Thiodan has increased dramatically whereas Cupravit fell down drastically.

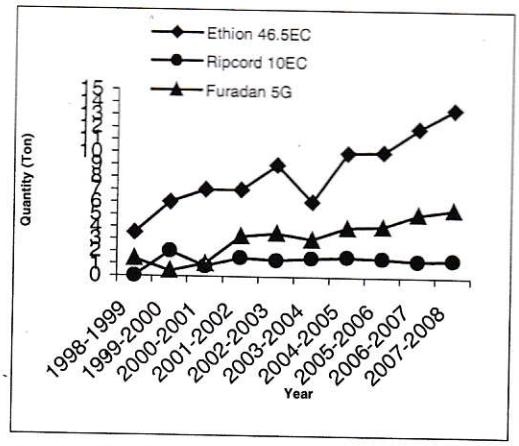

Fig. 5. Trend of Ethion 46.5EC, Ripcord 10EC and Furadan 5G during 1998-99 to 2007-08

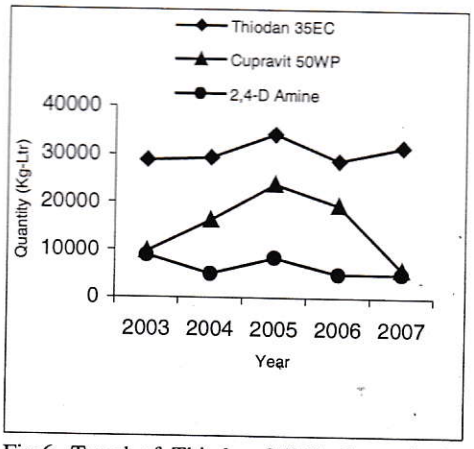

Fig.6. Trend of Thiodan 35EC, Cupravit 50WP and 2,4-D Amine during 2003 to 2007

Omite (Propargite) is one of the important miticides used in tea plantation. The last 5 years consumption data of Omite used in tea is presented in Fig. 7. It shows that the consumption of Omite was 16,650 Lit in 2003 and reached to 24,660 Lit in 2006. The trend of Omite use up to 2006 is almost 1.5 times higher than that of 2003 while it was fell down drastically in 2007.

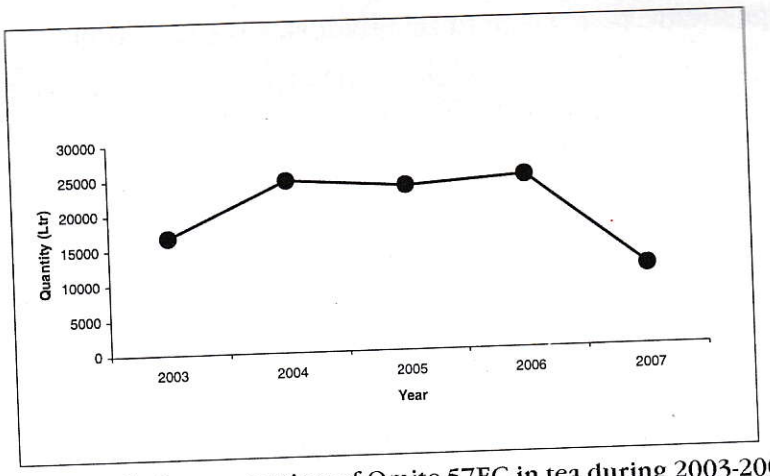

Fig. 7. Trend of consumption of Omite 57EC in tea during 2003-2007

Impact of pesticide use

The most serious concern regarding the pesticide use is its hazardous effect on different components of the environment including fish, birds, useful insects, wildlife and human being. Although the pesticide use in Bangladesh as reported in previous sections is very negligible, their use is highly uneven and indiscriminate. Widespread and longtime use of Endosulfan, Propargite, and Ethion in tea has induced resistance development in *Helopeltis* and Red spider mite. Therefore prudent use of insecticide in tea must be taken seriously.

Pesticide residue in tea

Pesticide residue in tea means what is left over or remains of pesticide in the made tea after the application of a pesticide to tea bushes in the field prior to plucking and subsequent manufacturing.

Analytical facilities available at BTRI

Now Bangladesh Tea Research Institute at Srimangal has established a well-equipped modern pesticide residue analytical laboratory at its own premises and is run by well trained personnel. All sorts of precision analyses of international standard of different pesticides like organochlorine, organophosphate, carbamate, pyrethroid and some unclassified groups are done successfully. It strictly adheres to the standard of Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP) which are accepted internationally. The facilities are now open to tea industry for the purpose. Tea industry has already started deriving benefit out of it. They can take full advantage of it to consolidate their tea product up to the satisfaction of international pesticide MRL regulations.

How the industry and country will be benefited

The modern pesticide residue analysis laboratory established at BTRI will benefit the tea industry by rendering adequate, efficient and economic service at its doorstep. The Institute estimates to analyze about 200 tea samples per annum at different levels eg. field application, made tea at factory, experimental samples, auction point, export point and random samples in the market point. Thus the Institute plans to ensure MRL safe tea to any destination for the consumers home and abroad. As well as the overall improvement of tea industry will be made and production of quality ensured tea will be possible.

Role of Bangladesh tea producers and traders

As tea is a consumable commodity, tea drinkers in advanced countries are quite conscious of health hazards out of pesticides in their food and drinks and tea is no exception. Domestic consumers are elevating their choice for such toxicity free food. Choice for organic food has been getting momentum. BTB should keep abreast of these conscious markets and advice the industry accordingly. The producers and traders also have the responsibility to scrutinize their teas on regular basis at field, factory and trade points without delay. They should contact BTRI and harness the full advantage of the available facilities.

Pesticide residue survey in Bangladesh tea

Tea Estates frequently send the made tea samples for pesticide residue analysis at BTRI. Fortunately so far none of these samples exceeded the MRL fixed by the EPA, Codex Commission and EC/EU (Table 4).

Table 4. Residue level of different group of pesticides received from different tea estate

Name of Tea Estate	Technical /commercial name of pesticide	Pesticide contain (ppm)	Remarks
Lungla T.E.	Omite 57EC	1.598	Below MRL level
Siloah T.E.	Ethion 46.5EC	1.98	,,
Karimpur T.E.	Omite 57EC	0.0	Not detected from peaks
Chatlapore T.E.	Omite 57EC	0.0	,,
Chaklapunji T.E.	Ethion 46.5EC	0.2	Below MRL level
Etah T.E.	Omite 57EC	2.44	,,
Rajkie T.E.	Thiodan 35EC	0.18	,,
Allynugger T.E.	Thiodan 35EC	0.09	,,
Kazi & Kazi T.E.	Thiodan 35EC	0.0	Not detected from peaks
,,	Malathion 57EC	0.0	,,
,,	Ethion 46.5EC	0.0	,,
,,	Fenvalerate 20EC	0.0	,,
,,	Cypermethrin 10EC	0.0	,,
,,	Propergite 57EC	0.0	,,

Testing MRL of some applied pesticides in tea fields

Endosulfan (Thiodan 35EC) residue in made tea (black)

An experiment was conducted on Endosulfan (Thiodan 35EC). It revealed that the residue level of Thiodan in made tea decreased exponentially with the increase of plucking intervals after spraying.

Analysis results presented in table 5 indicated that the residue level of pesticide in made tea initially degraded sharply and then gradually while plucking interval increased. The residues were initially 121.69 mg/kg in normal doses (1.5 litre/ha) (Ahmed and Shahiduzzaman, 2007) which came down to 0.87 mg/kg on the 14th day.

Table 5. Residues of Thiodan 35EC in made tea

PHI (Days)	Residues in made tea (mg/kg)
0 day (4hr)	121.69
1	46.98
3	18.62
5	5.71
7	1.40
10	0.88
14	0.87

*PHI=Pre-Harvest Interval

Cypermethrin 10 EC residue in made tea (black)

It is a synthetic pyrethroid insecticide with predominantly contact action. It is relatively stable to light in field condition. Environmental factors especially temperature and rain is initially responsible for gradual decline of the residue level. Biochemical reaction is also a factor in degrading the absorbed pesticide inside the plant cell. On the other hand, thermal degradation during manufacturing of tea is the main reason in declining the residue level of black tea compared to green leaves of same day. The residue of cypermethrin was initially (0 day) 23.52 mg/kg and came down to 0.05 mg/kg on the 14th day.

Table 6. Residues of Cypermethrin 10EC in made tea

PHI (Days)	Residues in made tea (mg/kg)
0 day (4hr)	23.52
1	18.31
3	7.26
5	1.33
7	0.85
10	0.61
14	0.05

Ethion 46.5EC residue in made tea (black)

The MRLs of Ethion 46.5EC was imposed by the EPA, Codex Commission, and EEC/EU were 10, 5 and 2 ppm respectively. In an experiment at UPASI, India (Anon, 1997), residue level of Ethion 46.5EC declined to 0.78 ppm on the 7th day after application and residue level of Quinalphos was found to decline to 0.09 ppm on the 10th day. In view of these imposed values, an experiment was conducted in the cropping season; none of the samples exceeded the MRL which were fixed by the EPA, Codex Commission and EEC/EU. But it is the safest time to pluck leaves at least 6th days after application.

Studies on IPM

Some IPM studies carried out for tea pests are outlined below:

- Identification of resistant clonal varieties/agrotypes
- Preying mantids are identified as predator of *Helopeltis theivora* W.
- Beetles, *Verania vincta* and *Verania discolor* are identified as a predators of Red spider mites in Bangladesh tea.
- Predation of tea aphid using bio-control agent, Ladybird beetle, *Hippodamia convergens* G.
- Ants, *Lophomyrmex quadrispinosa* Jerdon and *Crematogaster subnuda* Mayr as effective predators of termites.
- Use of bio-pesticides, extracts of Neem, Mehogoni, Lantana, etc against major foliar pests of tea.
- Control of plant parasitic nematodes using four different species of green crops namely-*Mimisa indica, Calapogonium sp.* Guatemala grass and Citronella.

Institutional arrangement for IPM extension

In addition to the means and methods in vogue in tea pest management, some highly sophisticated techniques could be of use in future pest control strategies.

- Use of pheromones, bacterial pathogens, repellents and chaemosterilants.
- Shall have to check tea soil for endemic species or strains of entomopathogenic nematodes.

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BIODIVERSITY OF ARBUSCULAR MYCORRHIZAL (AM) FUNGI IN TEA CLONES

Mohammad Ali[1]* and M.A.U. Mridha[2]

Abstract

Biodiversity of arbuscular mycorrhizal (AM) fungal colonization and spore population in the rhizosphere soils of tea clones was studied. The percent colonization varied from clone to clone of tea. The range of AM colonization and spore population was recorded 20-55% and 60-120 respectively. The maximum root colonization (55%) and spore population (120) was found with BT6 and minimum colonization (20%) and spore population (60) was recorded with BT9. Positive correlation was observed between root colonization and spore populations of tea clones (r = 0.80). Out of six genera of AM fungi, four genera viz. *Glomus, Acaulospora, Gigaspora,* and *Scutellospora* were identified in the soil of tea plantations. The highest Simpson's diversity index (Ds) of AM spores was recorded with clone BT9 (0.798) and BT11 (0.798). The highest Shannon's diversity index (Hs) was recorded with BT11 (0.687). Biodiversity of AM colonization and spore population in the tea clones indicated that tea plants are mycotrophic in nature and mycorrhizal technologies can be adopted in tea management.

Key words: Biodiversity, Mycorrhiza, Colonization, Fungi, Tea Clones

Introduction

Tea plant (*Camellia sinensis* (L) O. kuntze) population raised from a single source plant or mother plant by vegetative part like stem is called a clone (Sana, 1989). Due to the out breeding nature of tea, the seedling populations exhibit considerable variation in their growth, yield and quality potentials. These heterogeneous seedling populations provide the basic genetic materials for selecting clones by vegetative propagation. For quality potentials and better yield, Bangladesh Tea Research Institute (BTRI) developed different tea clones. Under normal cultural practice on average the yield is between 3000 to 5000 kg/ha although national yield of Bangladesh tea is about 1247 kg per hectare (Islam and Latifi, 2004), which is quite low. The reasons for low productivity of tea are mainly low pH and low fertility of soils, shortage of soil-organic matters, erratic rainfall and drought in summer (Sana, 1989). The mycorrhizal fungi are recognized to assist plant development by enhancing nutrients uptake (Gnekow and Marschner, 1989), mediating inter-plant nutrients transfer (McNeil and Wood, 1990), falling the harshness of root diseases (Jalali and Jalali, 1991), defensive soil erosion (Bethlenfalvay and Schuepp, 1994) and rising drought confrontation (Levy and Kirkun, 1980).

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In tea roots first the incidence of mycorrhiza was recorded by Tunstall (1930) in North-East India. Thereafter, many authors (Mejistrik, 1974; Sieverding and Toro, 1987; Balasuriya *et al.*, 1991; Kumaran and Santhanakrishnan, 1995) reported AM colonization and the application of AM fungi in the development of tea plants. In Bangladesh, few works were done on the AM colonization and the biodiversity of mycorrhiza in tea plants and soils (Begum, 1995; Barshed, 1997; Mridha *et al.*, 1995). However, no detail research work regarding the influence of different clones on the biodiversity of AM colonization in tea plants were accomplished. The present program has been scheduled to observe biodiversity of AM colonization in tea roots and spore population in the tea soils regarding different clones.

Materials and Methods

Sample collection

Roots and rhizosphere soils of tea clones were collected for the assessment of biodiversity of AM colonization and spore population. Fifteen tea clones namely BT1, BT2, BT3, BT4, BT5, BT6, BT7, BT8, BT9, BT10, BT11, BT12, BT13, BT14 and BT15 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 spore population

The collected soil samples were mixed thoroughly and sieved through 2mm mesh to remove the gravels and other particles. From each sample, 100g of soils were taken in a bucket of 10-liter capacity and the bucket was filled three quarters with tap water. The soils were mixed well with water and a soil-water suspension was made. The suspension was left for few minutes for settling down of insoluble and heavy particles. Then the suspension was passed through the ASTM-60 (250µm), ASTM-100 (150µm), ASTM-240 (65µm) and ASTM-400 (37µm) sieves gradually to extract the spores following the wet sieving and decanting method (Gerdemann and Nicolson, 1963). The residues of the sieves were taken separately in watch glass and observed under stereo-binocular microscope at 10×2.5 magnification. From the residues of the sieves of ASTM 60 and ASTM 100, larger spores and sporocarps were separated by soft forceps. The residues of ASTM 240 and ASTM 400 sieves were taken in watch glass and spread on the filter paper. Using stereo-binocular microscope small spores were taken into watch glass by soft forceps. Isolated spores with water spread on the filter paper, on which squares of intersected gridlines were drawn earlier for easy counting of spores. Spore population was counted on the basis of 100g 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:

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

Simpson's diversity index (Ds) and Shannon-Wiener diversity index (Hs) of AM fungi spores were calculated by the following formulas:

$$\text{Simpson's Index (Ds)} = 1 - (\sum n_i^2 - N) / N (N-1)$$

$$\text{Shannon's Index (Hs)} = \frac{1}{N} (N \log_{10} N - \sum n_i \log_{10} n_i)$$

Where "n_i" is the total number of individuals of a genus and "N" is the total number of individuals of all genus (Lloyd *et al.*, 1968; Simpson, 1949).

Assessment of AM fungal colonization

Preserved roots were washed thoroughly with tap water to remove the formalin and then cut into approximately 1.0cm long segments 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°C temperature. Then the root segments 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°C for 30 minutes. Subsequently the roots were destained in acidic glycerol. A total of 50 segments were examined from each sample. Root segments were studied with the 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:

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

The intensity of structural colonization was measured as poor (less then 10% area colonized), moderate (10% to 20% area colonized) and abundant (more then 20% area colonized) with each of the individual structure according to Dhar and Mridha (2003). Statistical analysis was done using SPSS and MS Excel software.

Results and Discussion

The results of total AM root colonizations in fifteen different tea clones are presented in the Table 1. Structural colonization of AM fungi in the roots of

different tea clones collected from BTRI farm varied widely. The range of mycelial root colonization was observed as 20 - 55% in different tea clones. 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 root colonization from 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 tea clones. In case of intensity of colonization in different tea clones, it was clear that the mycelial intensity was recorded as poor (20-50%) and as moderate (5%). Abundant intensity of mycelial colonization was not observed. From the data of the arbuscular intensity in different clones, it was recorded as poor (10-20%). Neither moderate nor abundant intensity of arbuscular colonization was observed (Table 1).

Table 1. Structural colonization (mycelium, arbuscule and 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	Arbuscules	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

Table 2 showed the results of the biodiversity and the distribution of AM fungi in rhizosphere soils of different tea clones. The range of spore population was recorded from 60 to 120 in the rhizosphere soils of different tea clones. 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. The rate of the population of *Gigaspora* was recorded as 25% to 45%. The maximum *Gigaspora* was recorded in the soils of BT2 (45%) which was followed by BT1 (40%), BT4 (40%) and BT6 (40%). BT8 and BT11 showed the minimum as recorded 25%. Spore population of *Scutellospora* ranged between 15% to 30% while BT3 and BT8 produced the maximum *Scutellospora* of 30%.

Table 2. 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 soils of each of the clones of BT5, BT10, BT11, BT12, BT14 and BT15 produced the same population at the rate of 25%. The minimum rate of 15% was recorded in the soils of BT6. *Glomus* was recorded as 10-25%. Maximum spore population of *Glomus* was recorded in BT7 and BT8 at the rate of 25%. Other clones viz. BT6, BT9, BT11, BT12, BT13 and BT15 resulted the rate of 20%. The minimum was recorded in the rhizosphere soils of BT2 (10%). The range of population of *Acaulospora* was recorded as 10-15%. The maximum *Acaulospora* i.e.15% was recorded in each of the clones of BT1, BT4, BT5, BT7, BT9, BT10,

BT12, BT13 and BT14. Results came out as minimum rate of 10% population in each of BT2, BT3, BT6, BT8, BT11 and BT15. A few spores remained unidentified. Out of 15 clones, the range of "Ds" and "Hs" were calculated 0.719-0.798 and 0.617- 0.687 respectively. The highest "Ds" (0.798) was calculated with BT9 and BT11, which was followed by BT13 with 0.794, BT12 with 0.785 and BT7 with 0.782. The highest "Hs" (0.687) was calculated with BT11 and it was followed by BT13, BT12 and BT7 with 0.684, 0.668 and (0.667 respectively. BT2 gave the lowest "Ds" and "Hs" as 0.719 and 0.617 (Fig. 1). There was a positive correlation (r= 0.796) between total colonization and spore population of different tea clones (Fig. 2).

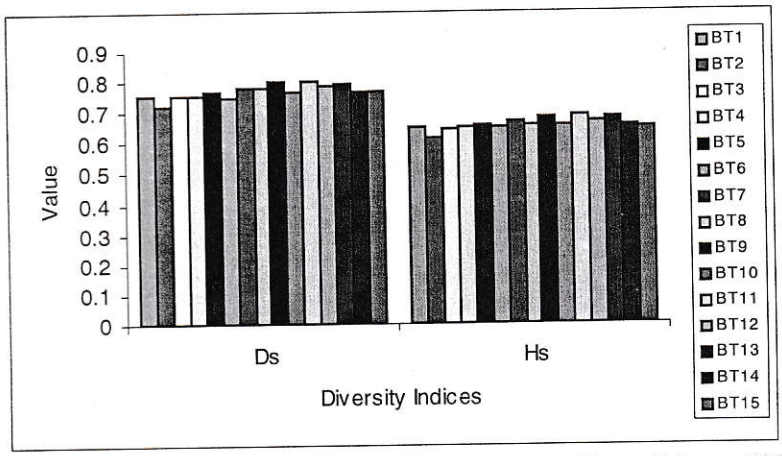

Fig. 1. Diversity indices in different tea clones collected from BTRI farm

Biodiversity of root colonization and spore population of AM fungi in tea plants indicated that tea plants are mycotrophic in nature. Under natural condition of 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% but the intensity of colonization was poor as was found by Balasuriya *et al.* (1991). It was clear that the percentage colonization of AM fungi was variable within tea clones. These results are in consistent with the reports of Balasuriya *et al.* (1991), Barshed (1997), Begum (1995) and Mridha *et al.* (1995). The range of root colonization of AM fungi was recorded from 30 - 65% with Bangladesh tea (Barshed, 1997, Begum, 1995, Mridha *et al.*, 1995) and from 6 to 45% in Indian tea (Balasuriya *et al.*, 1991). The variation of root colonization might be the results of the interaction of different edaphic factors like moisture, organic matter and nutrient status (Abbott and Robson, 1991). Presence of wide range of AM fungal genera in the tea soils might also contribute this variation in the percent colonization. The number spores increased significantly with age of the plant, which corroborates with report of Tiwari *et al.* (1995). The status of AM fungi may vary greatly in different plant species grown in different types of soils (Jakobsen and Nielsen, 1983) as was observed by Mejistrik (1974) and Mridha *et al.* (1995) with tea plants. Vesicular colonization was not observed in all tea

plants screened. But in the results of the biodiversity of AM fungi in the tea soils, *Glomus* sp was present. As the soils samples were collected from the tea plantations where tea plants are growing along with the different biome crops like weeds and different leguminous ancillary crops, the biome crops may contribute part of the population in the rhizosphere soils of tea plants.

Only four genera named *Glomus, Acaulospora, Gigaspora* and *Scutellospora* were identified in the soil of tea plantations Out of six genera of AM fungi. Among them *Gigaspora* was highest in abundance and *Glomus* and *Acaulospora* were lowest. But according to Kumaran and Santhanakrishnan (1995) *Glomus* sp. dominates in tea soils, which contradict with the present study. However, species of *Glomus, Acaulospora, Gigaspora and Sclerocystis* have been recorded in tea soil by Barua, (1998) and Mridha *et al.*, 1995).

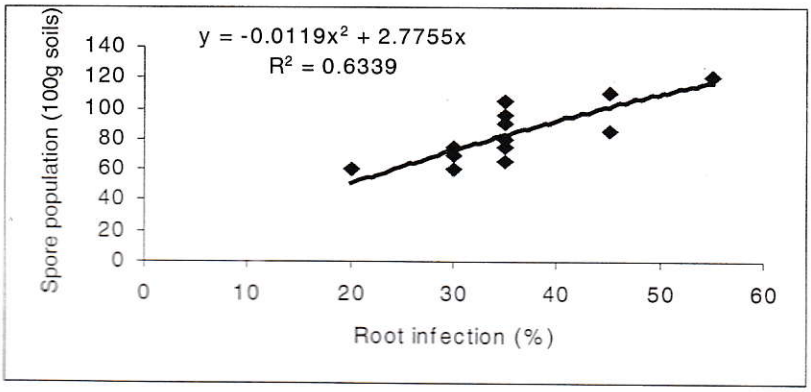

Fig. 2. Relationship between root colonization (%) and spore population (no./100g soil) in different tea clones

The variation of Simpson's diversity index (Ds) and Shannon's diversity index (Hs) of spore population in the rhizosphere soils of different tea clones was similar as it was found by Chaurasia *et al.* (2005) in case of Himalayan Rhododendron for *Ipomoea batatus* studied by Harikumar and Potty (1999). According to Abbott and Robson, (1991) and Allen *et al.* (1995) the diversity indices of AM fungi depends on the size of area sampled and yearly changes in the precipitation and temperature. Giovannetti and Nicolson, (1983) also reported that it might have a certain degree of ecological specificity. Wide range of environmental requirements and the capacity of genetic differentiation at the intra-specific level were found Abbott and Robson, (1991) in some of the species of *Glomus, Acaulospora, Entrophospora* and *Scutellospora.*

It may be concluded that tea clones are associated with AM fungi and the biodiversity of AM fungi in tea soils is as broad as tropical forest soils. 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.

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