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Evaluation of Tea (*Camellia sinensis* L.) Germplasm for Host-plant Resistance to Shot-hole borer, *Xyleborus fornicatus* Eichh. (Coleoptera: Scolytidae)

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ABSTRACT

Shot-hole borer (SHB), *Xyleborus fornicatus* Eichh. is a major pest in tea plantations in many south asian countries including Sri Lanka and India. Presence of high degree of resistance to this pest is an important consideration in developing new tea cultivars for tea growing regions where the pest is a major threat for crop productivity. However, high degree of resistance is not found in cultivated tea. Evaluation of germplasm helps identification of sources of resistance and promotes effective and greater utilization of the germplasm in breeding and crop improvement. The present study investigate the extent of variations in host plant resistance to SHB in tea germplasm, in order to search for high levels of resistance enabling identification of candidate parents for breeding SHB resistant tea cultivars. A representative sample of germplasm collection consisting of 74 accessions covering cultivated and unadapted tea genotypes conserved in the *ex situ* field gene bank was evaluated in the field under natural infestation to study the profile of tea genotypes for SHB infestation. More than 81% of the accessions showed high level of susceptibility to SHB. Only 3% of the accessions were found to have higher levels of resistance than TRI 2023, which is currently considered as the highly resistant tea cultivar among the adapted gene pool. Accessions, DG 7, DG 39 and DG 66 were shown to have higher resistant levels than all the other accessions evaluated. The present study provides information on new and additional sources of SHB resistant genotypes present in the existing germplasm collection which could be used in the breeding program to incorporate high levels of SHB resistance.

INTRODUCTION

Tea (*Camellia sinensis* L.) is an important plantation crop in Sri Lanka, which contributed 1.2% of the share of agriculture to the GDP (Anon, 2005). It is imperative to increase the productivity of tea plantations to enhance the contribution by the tea sector to the national economy. Productivity and sustainability of tea plantations depend on many factors and among them availability of improved tea cultivars possessing desirable traits is the main factor. Furthermore, genetic resistance against insect pests has become a decisive factor determining the productive value of a cultivar.

Shot Hole Borer (SHB) is a major pest in tea, particularly in plantations situated in the elevation range of about 200 – 1400m *amsl* (Walgama and Pallemulla, 2005). Control of the damage due to shot-hole borer results in a yield increase of about 25% over the cycle on average and the percent increase is the highest in the second year of the pruning cycle (Cranham, 1963; Cranham *et al.*, 1966; Judenko *et al.*, 1962). Around 40% of yield increase could be achieved by controlling severe SHB infestations.

Host-plant resistance has been viewed as the most environmentally friendly and economically feasible method of control of many pests (Waage, 1996), including SHB (Danthanarayana, 2003). Cultivars possessing genetic resistance to pests are promising components in an integrated pest management system and have the potential to reduce pesticide use and production cost while increasing on-farm yields. Tea breeders face formidable challenges in developing high yielding cultivars incorporated with genetic resistance to pests and diseases owing to inaccessibility for sources with adequate levels of resistance to pests and diseases. In order to search for sources of resistance to be utilized in resistant-breeding program, evaluation of available tea genetic resources for biotic stress resistance is an essential component (Gunasekare, 2007). Despite the potential use of unadapted sources for breeding purposes, the germplasm of tea in Sri Lanka has not been sufficiently evaluated or utilized effectively in resistant breeding programs (Gunasekera and Kumara, 2005). As the pool of resistant germplasm for tea breeding is small, additional genotypes must be identified with the increased levels of resistant to the SHB than the existing cultivars.

The objective of this study therefore, was to identify tea germplasm (both cultivated and unadapted), having higher levels of resistance to SHB than what is currently available in the cultivated gene pool.

MATERIALS AND METHODS

Seventy-four germplasm accessions conserved in the *ex situ* gene bank at Uva Extension Centre of Tea Research Institute at Passara (Agro Ecological Region - IU3, Lat: 6^0 56N, Long: 81^0 07E, Elevation 1120m *amsl*) were evaluated to identify sources of resistance to SHB. Details of the accessions evaluated are given in Table 1. Selection of regional gene bank site for this study was based on the pest pressure at the site (elevation 1120m *amsl*) to ensure effective field screening to assess the sensitivity of the accessions to SHB attack. These accessions were planted as a germplasm backup collection and have been therefore nearly 60 years demonstrating their adaptability to the environment in the particular site.

Twenty randomly selected plants per accession from a plot containing 30 plants per each accession were evaluated for pest attack just before the plants were pruned. All the normal cultural practices were followed with the exception that no chemical treatment was used to control SHB in the gene bank block. From each plant a 30cm long stem piece, that originated from the previous prune cut was removed (Vitarana, 2003). Those stems were then split open longitudinally and number of galleries was recorded.

The infestation levels, in terms of the average number of galleries per accession, were computed as (total number of galleries/ number of stems in the sample) and sensitivity to SHB was evaluated for all accessions using the following descriptor state (scale):

1 Highly resistant where average gallery numbers are in the range of 0 – 1.0
2 Resistant where average gallery numbers are in the range of 1.1 – 2.0
3 Moderately susceptible where average gallery numbers are in the range of 2.1– 3.0
4 Susceptible where average gallery numbers are in the range of 3.1 – 4.0
5 Highly susceptible where average gallery numbers are > 4.0

RESULTS AND DISCUSSION

Screening of the germplasm collection conserved at the Uva Extension Centre of Tea Research Institute showed that the shot-hole borer infestation levels varied in a wide range. The lowest infestation level was 0.9 and the highest infestation level recorded was 6.5 galleries per stem (Figure 1). The high values of infestation indicate the existence of extreme pest pressure at the gene bank site and extreme vulnerability of some tea accessions to SHB infestation. The distribution of SHB sensitivity of the genotypes was continuous and skewed towards high severity levels (Figure 1). Of the 74 accessions evaluated, 81% of the accessions showed infestation levels of more than 3 (Figure 2), which is considered as a high infestation level. Among the tea cultivars recommended, TRI 2023 and TRI 2025 have been confirmed as tolerant and susceptible respectively, to SHB with several years of observations and through screening procedures (Thirugnanasundaran and Calnaido, 1968, 1969). Compared to the highly resistant, TRI 2023, which is currently considered as "resistant" to SHB, three accessions namely DG 7, DG 39 and DG 66 that belong to estates selection category showed higher levels of resistance to SHB and infestation was recorded as less than 2.0 (Figure 1). All three accessions were the selections made from old seedling tea population on the same tea estate (Balangoda Estate) in the agro-ecological region WM3. In the past, when mass selection from seedling populations were adopted, one of the criteria for selecting promising seedling bushes were the resistance to major pests and diseases (Visser and Kehl, 1958). Furthermore, SHB incidents in that location where the particular accessions have been originally selected were reported to be high (Walgama and Pallemulla, 2005).

Table 1. Accession identity, origin and its agro-ecology, and type of material of the tea accessions evaluated for SHB sensitivity

Accession	Origin/ Parentage/ location of selection	Agro-ecological region	Type of the Accession
TRI 18	St Coombs	WU 2	Unadapted
TRI 23	St Coombs	WU 2	Unadapted
TRI 25	St Coombs	WU 2	Unadapted
TRI 740	St Coombs	WU 2	Unadapted
TRI 1076	St Coombs	WU 2	Unadapted
TRI 2012	St Coombs	WU 2	Unadapted
TRI 2016	St Coombs	WU 2	Cultivated
TRI 2020	ASM 4/10 O.P.	WU 2	Cultivated
TRI 2023	ASM 4/10 O.P.	WU 2	Cultivated
TRI 2024	ASM 4/10 O.P.	WU 2	Cultivated
TRI 2025	ASM 4/10 O.P.	WU 2	Cultivated
TRI 2026	ASM 4/10 O.P.	WU 2	Cultivated
TRI 2027	ASM 4/10 O.P.	WU 2	Cultivated
TRI 2043	Indo-China Introduction	WU2	Cultivated
TRI 2086	St Coombs	WU 2	Unadapted
AMA 5/60	Ampittikanda	IU 3	Unadapted
AMAH 3/12	Ampittikanda	IU 3	Unadapted
B 35	Gartmor	WU 1	Unadapted
C 21	Chapelton	WU 1	Unadapted
CH 13	Craighead	WM 2	Advanced breeding line
CY 9	Thangakelle	WU 1	Cultivated
D	Dayagama	WU 2	Unadapted
DG 3	Balangoda	WM 3	Advanced breeding line
DG 7	Balangoda	WM 3	Advanced breeding line
DG 32	Balangoda	WM 3	Unadapted
DG 39	Balangoda	WM 3	Advanced breeding line
DG 52	Balangoda	WM 3	Unadapted
DG 66	Balangoda	WM 3	Unadapted
DW 3	Downside	IU 3	Unadapted
DW 5	Downside	IU 3	Unadapted
DW 12	Downside	IU 3	Unadapted
DW 16	Downside	IU 3	Unadapted
DW 19	Downside	IU 3	Unadapted
DW 26	Downside	IU 3	Unadapted
DW 29	Downside	IU 3	Unadapted
DW 32	Downside	IU 3	Unadapted
EELD 163	Kirkoswald	WU 1	Unadapted
GMT 9	Gonamottawa	IU 3	Unadapted

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Accession	Origin/ Parentage/ location of selection	Agro-ecological region	Type of the Accession
K 145	Kirkoswald	WU 1	Cultivated
K 150	Kirkoswald	WU 1	Unadapted
KEN 15/2	Kenilworth	WM 1	Unadapted
KEN 16/3	Kenilworth	WM 1	Cultivated
KEW 14/1	Kew	WU 1	Unadapted
MG 3/31	Cannavarella	IU 3	Unadapted
MT 18	Balangoda	WM 3	Cultivated
MT 20	Balangoda	WM 3	Unadapted
MT 35	Balangoda	WM 3	Unadapted
MTBG	Balangoda	WM 3	Advanced breeding line
NK3B1	Cannavarella	IU 3	Unadapted
NL 3/1	Neluwa	IU 3	Unadapted
NL 8/3	Neluwa	IU 3	Unadapted
OK 4	Ouvakelle	WU 1	Unadapted
PD 14	Gonakelle	IU 3	Unadapted
PGG 2	Poonagala	IU 3	Unadapted
PLLG 1	Poonagala	IU 3	Unadapted
PLLG 2	Poonagala	IU 3	Unadapted
PUH 1	Poonagala	IU 3	Unadapted
QT 1/3	Queenstown	IU 3	Unadapted
QT 4/4	Queenstown	IU 3	Unadapted
QT 7/1	Queenstown	IU 3	Unadapted
SS/P	Passara	IU 3	Unadapted
T 5/2	Thotalagala	IU 3	Unadapted
T 5/3	Thotalagala	IU 3	Unadapted
TK 42	Thalankanda	WU 1	Unadapted
UH 3/4	Uva Highlands	IU 3	Unadapted
UH 9/3	Uva Highlands	IU 3	Advanced breeding line
UR 12	Uda Radella	WU 2	Unadapted
VK 9	Ouvakelle	WU 1	Unadapted
W/W1/1	Welimada	IU 3	Unadapted
W/W3/10	Welimada	IU 3	Unadapted
W/W5/1	Welimada	IU 3	Unadapted
W/W6/1	Welimada	IU 3	Unadapted
W/W7/1	Welimada	IU 3	Unadapted
Y 2/3	Yapame	WU 1	Unadapted

O.P. : Open Pollinated
WU : Wet zone -Up country
IU : Intermediate zone - Up country
WM : Wet zone - Mid country

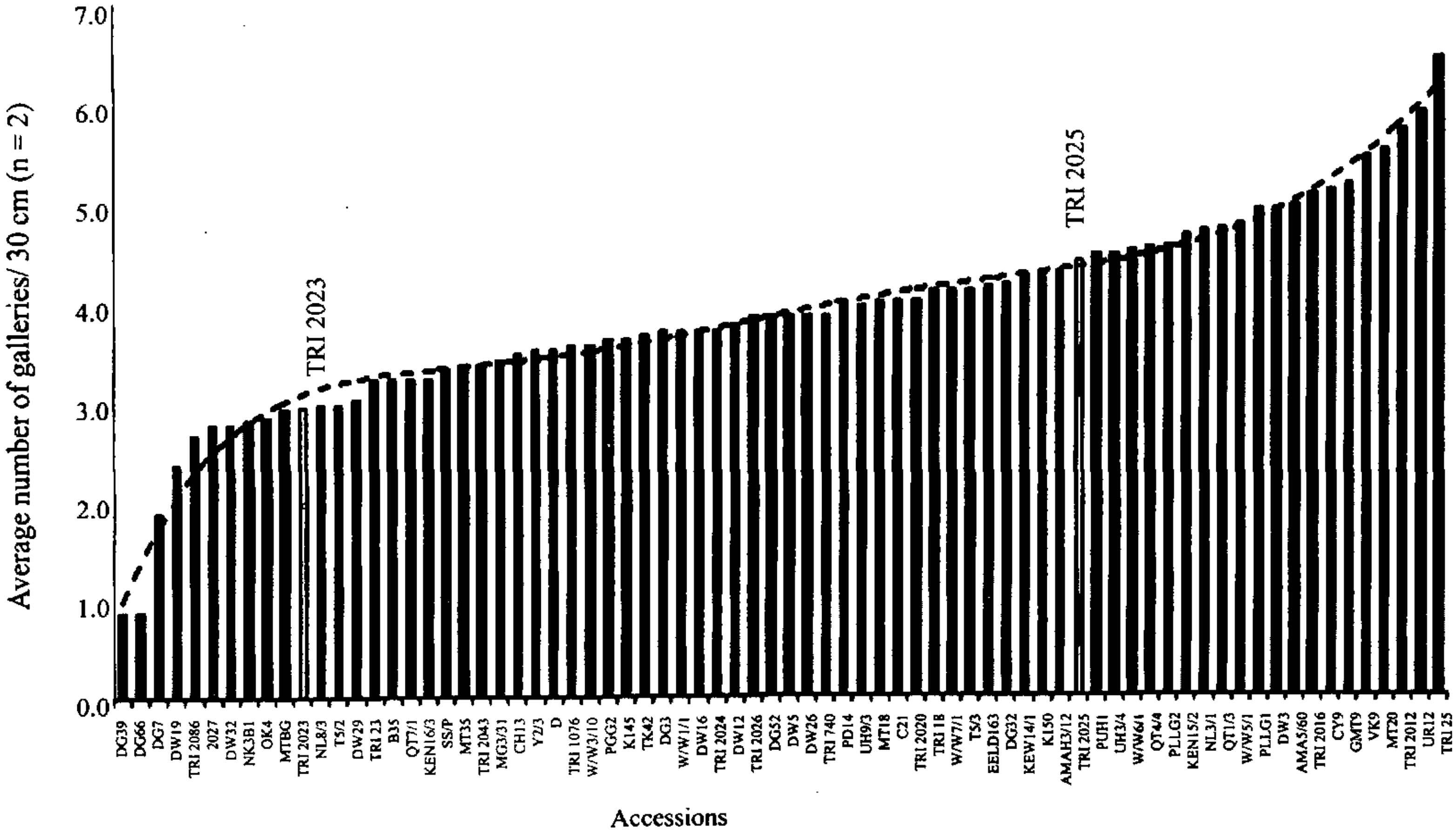

Figure 1. Infestation levels of the accesions of the germplasm in Mid country dry zone as expressed in terms of the average number of galleries/ 30 cm stem of tea

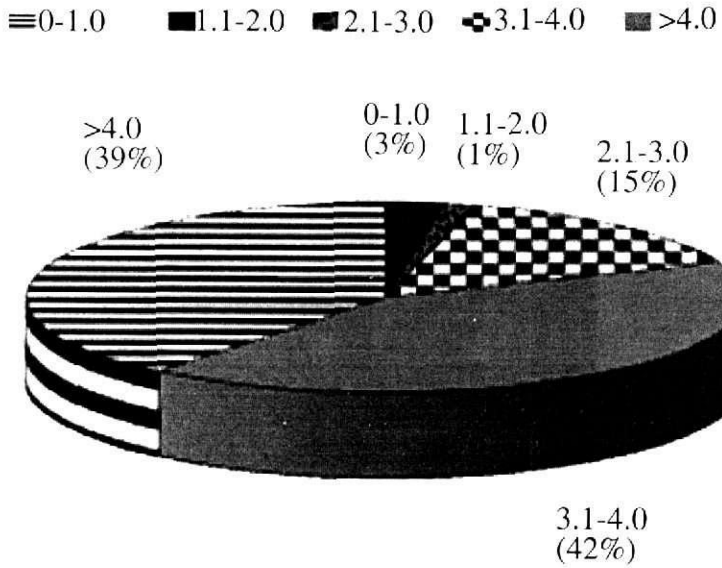

Figure 2. Percentage of accessions in different infestation categories

Thus, it could be assumed that those accessions which were adapted to the said location show SHB resistance.

Among those three accessions, highest level of resistance were found in DG 39 and DG 66 for which only less than 1.0 gallery percentage was recorded (Figure 1). Only few resistant tea cultivars to SHB have been reported in the past (Vitarana, 2003), but that was not as high as the resistant levels captured in the present study. Results of the present study also revealed that a high level of resistance is found only in a limited number of accessions and that is accounted for 3% of the total accessions evaluated. Even in rice, resistance to insects was reported to present only in 0.01 to 2% of rice germplasm accessions (Heinriche, 1986). Successful identification of candidate parents with resistant traits depends primarily on the availability of adequate levels of resistance and the present study reveals that those two particular accessions posses higher levels of resistance. As the pool of resistant germplasm for breeding for SHB resistance in tea is small, only TRI 2023 have been used recurrently in the breeding program to incorporate SHB resistance to the new progenies. Therefore, high levels of resistance captured from the present local germplasm collection are highly useful as a source for future breeding program aiming at incorporating SHB resistance to proven cultivars. This is the first study conducted on evaluation of a wide range of germplasm on comparative basis for SHB at a site where high SHB pressure exists.

Although there are ample evidence that introgression breeding could play a vital role in transferring resistant genes from wild relatives or related species (Ocampo *et al.*, 2000;

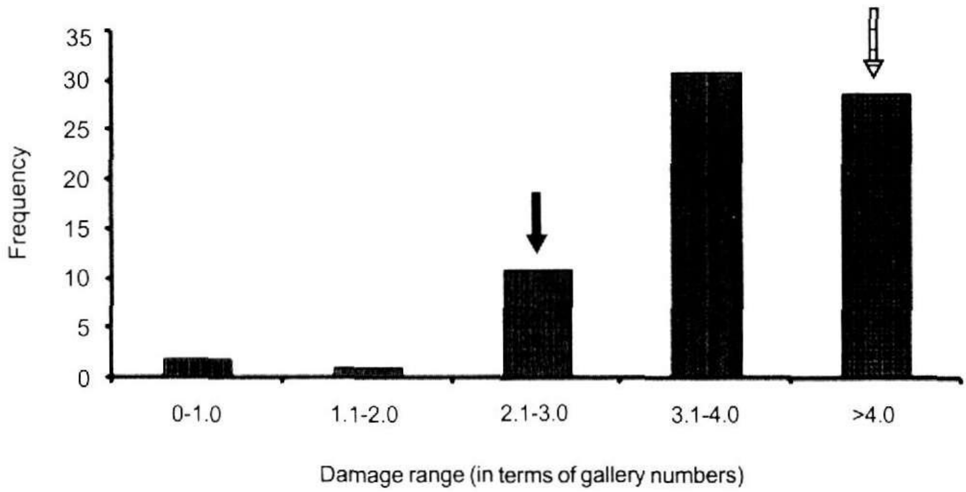

Figure 3. Frequency distribution of tea accessions based on SHB sensitivity (Solid arrow indicates the position of resistant cultivar [TRI 2023] while the hatched arrow indicates the position of susceptible cultivar [TRI 2025]

Saxena and Kumar, 2003; Clement, 2002; Russell, 1981), problems exist when attempts were made to cross such candidate parents, mainly due to incompatibilities (Marta *et al.*, 2004; Cohen *et al.*, 1984) and linkage drag of undesirable or agronomically inferior traits with the target gene (Russell, 1981). As a general rule, the best sources of resistance are likely to be those in locally adapted germplasm because they can easily and quickly be exploited in a breeding program (Russell, 1981). Hence, it is economically feasible and technically-sound if the sources of resistance for the trait could be found among the cultivated gene pool or advanced breeding lines. From a breeding perspective, it may be easier to transfer resistant genes from cultivated or existing old varieties than from the wild relatives or related species/genera owing to the issues discussed above. As two of the accessions, DG 7 and DG 39, do not belong to wild types or unadapted germplasm lines, those could be readily used in the breeding program without negative impacts on linkage drag of undesirable traits into the resulting progeny. Thus, transfer of SHB resistance captured in the present study into high yielding cultivars or to a more adapted genetic background with other desirable traits will be considered in the tea-breeding program.

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