Improved Tea Seeds as a Source of Planting Material: A Strategy for Adaptation to Climate Change

J H N Piyasundara[1], M A B Ranatunga[1], M T K Gunasekare[2], P D Upali[1], R Paskaradevan[1], J D Kottawa Arachchi[1], K K Ranaweera[1], T M Sarathchandra[1] and A K Mudalige[1]

([1]*Plant Breeding Division, Tea Research Institute of Sri Lanka, Talawakelle, Sri Lanka*
[2]*Council for Agriculture Research Policy, 114/9, Wijerama Mawatha, Colombo 7, Sri Lanka*)

ABSTRACT

Seeds obtained from bi- and poly-clonal seed gardens with different parental combinations of known VP cultivars were used to establish seedling plantations and their performances were evaluated in comparison to standard VP cultivars in on-station trials representing four regions for over two pruning cycles. Yield and tolerance to biotic and abiotic stresses were assessed to identify promising seed materials. Seed materials collected from Reucastle, St. Coombs, Anhettigama, Salawa, Halpe, Karadupona and Sapumalkanda seed gardens recorded yields comparable to standard cultivars, depending on the regions where testing was carried out. About 70% of the individual seedlings in the above seed sources showed tolerance to shot hole borer in the trial carried out in Uva. Majority of the seed sources were found to be tolerant/moderately tolerant to canker (*Macrophoma*) in the Low country regional trial while majority of seed sources showed their high levels of tolerance to moisture stress conditions in the field assessment carried out in 2007 and 2009 during dry weather conditions. Seven seed sources were having comparable made tea quality with TRI 2025 but none of them were superior in quality to of DT 1. With respect to commercial scale seed plantations seed sources of St. Coombs, Salawa, Halpe, Sapumalkanda and Karadupona were identified as high productive. The potential of using improved seeds to achieve appreciable productivity gain in commercial scale in low productive areas was evident and thus, would be one of the appropriate adaptation measures to tackle perceived consequences of climate change.

Key words: Adaptation, climate change, improved seeds, seed sources, variation

INTRODUCTION

Tea (*Camellia sinensis* L.) is grown in Sri Lanka under wildly varying soil and climatic conditions, which cause profound effects on productivity (Pethiyagoda, 1968). Furthermore with the expansion of the tea industry tea cultivation has been extended to moderately suitable or even unsuitable lands; especially drought prone or low potential lands (marginal lands) that limit productivity potential of vegetatively propagated (VP) cultivars. Moreover, the productivity of tea lands is greatly influenced by the environmental factors (Wijeratne *et al.,* 2007). Therefore, a rain-fed crop such as tea may have to face anticipated consequences of climate change, such as shift in agro-climatic zones, productive lands becoming unproductive, drought, heat stress, and unforeseen pest and disease out breaks due to changes in ecological spread of pests and pathogen populations. Use of few popular VP cultivars in large extents could lead to crop vulnerability to climate changes and pest/ disease outbreaks specially, in marginal lands. In contrast seedling tea populations show wide adaptability to a range of soil and climatic conditions owing to the presence of heterogeneity in terms of variation in growth, vigour, and resistance to pests and diseases (Piyasundara *et al.,* 2003).

Presence of tap root in seedling tea as compared to VP tea could be capitalized in such a situation provided that seedlings have the potential of producing acceptable yields at least that are comparable to VP cultivars. If improved seed materials could be developed by using natural hybridization among known improved VP cultivars with known performances, those seeds could be used to have seedling populations with higher yields and more uniformity than that of the old seedling teas of which the parent`s performances are unknown.

These facts necessitate the task of evolving improved seeds as alternative source of planting materials particularly for marginal lands to be used in blend with improved VP cultivars. With a realization of the importance of such hybrid seeds, number of commercial tea seed gardens have been established with known VP cultivars having certain superior characteristics. These gardens were established as bi-clonal (with only two known cultivars, inter-planted in alternate rows) and poly-clonal (with more than two known cultivars, planted according to a design) seed gardens by the Tea Research Institute of Sri Lanka (TRI), in collaboration with respective estate managements, in various agro-ecological regions (Gunasekare, 2008). The objective of the present study therefore, was to evaluate seeds derived from bi and poly clonal seed gardens to identify seed materials that can result in seedling populations with equal or better performances when compared to the VP cultivars, especially in drought prone or low productive tea lands that limit productivity potential of VP cultivars.

MATERIALS AND METHODS

Evaluation for yield and tolerance to biotic and abiotic stresses

In the initial phase, seedlings raised from seeds collected from 10 seed sources (gardens) namely Reucastle, Sapumalkanda, Salawa, Anhettigama, St. Coombs, Halpe, Karadupona, Aislaby, Eltab and Poonagala (irrespective of parental cultivars) were evaluated in medium scale replicated experimental trials on regional stations using RCBD design (40 plants each in two replicates). Standard commercial cultivars (TRI cultivars and estate cultivars widely grown in particular regions) were included for comparison to identify promising seed sources. Made tea yields were recorded and yield data were statistically analyzed using ANOVA. Mean separation was performed using DMRT tests (Anon, 2009).

The evaluations were continued for over two pruning cycles. Visual observation on performances under dry weather conditions in different locations were reported. Furthermore seed sources were evaluated for made tea quality by the Technology Division. Sensory evaluation was made by two professional tea tasters on the basis of infused leaf colour, liquor colour, strength and liquor quality and final quality was judged compared to the known high quality cultivar DT 1. Seed sources were evaluated for their tolerance/susceptibility to shot hole borer and canker (*Macrophoma*) by the Entomology and Plant Pathology Divisions respectively following standard pest and disease screening protocols. Ability of seed germination of seed stocks collected from different female parents (cultivars) was evaluated to enhance the practical feasibility of using seed stocks for commercial planting.

Evaluation for seed production

Visual observation on seed production of the promising seed source (gardens) as a whole as well as seed bearers of different cultivars were conducted for about one year to select the most productive seed gardens and potential cultivars of each garden. Following ratings were allotted to the levels of seed production as per visual observations.

High: 3, Moderate: 2, Low: 1, Very low or no seed production at all: 0

Adaptive trials

In the second phase, adaptive trials (non replicated large blocks of about 100-200 plants) were established with the partnership of the growers at Passara, Galaha, Endane, Warapitiya, Verellapathana and Medamahanuwara to evaluate the potential of seed stocks under commercial conditions. Adaptive trials were established in low productive lands and seeds were collected from different female parents of seed garden to increase the uniformity of seed stocks. Trials are under 1st pruning cycle yield evaluation and evaluation for other traits such as performances under dry weather conditions, tolerance/susceptibility to shot hole borer and canker (Macrophoma) are also been continued.

RESULTS AND DISCUSSION

Evaluations based on yield, tolerance to biotic and abiotic stresses

Yield

Promising seed sources based on yield assessment on cycle yield averages showed comparable yield at least with one standard cultivar (Table 1). Results indicated that yield of 5 seed sources in Up country trial showed comparable performances with all 4 standard cultivars used and while the other 3 sources showed comparable yields with at least one standard cultivar.

In the Low country trial, Salawa exhibited comparable yields with both the standards while the other nine sources showed comparable yields with at least one standard. In Mid country, St. Coombs seed source showed the highest yield and 5 seed sources including St. Coombs exhibited comparable yields with both standards.

Four seed sources tested in Uva trial recorded comparable yields with both the standards whereas Anhettigama showed the highest yield, while the other 3 sources showed comparable yield with at least one standard. When all 4 trials were considered, 7 sources could be identified as promising yielders and they are; Reucastle, Sapumalkanda, Salawa, Anhettigama, St. Coombs, Halpe and Karadupona.

Tolerance to abiotic and biotic stresses

Tolerance to moisture stress

Majority of seed stocks including all seven promising yielders; Reucastle, Sapumalkanda, Salawa, Anhettigama, St.Coombs, Halpe and Karadupona, showed high levels of tolerance to moisture stress conditions according to the visual observations carried out in 3 locations during the dry weather conditions; 2007 in Low country; 2009 in Up country and Uva.

Tolerance to shot hole borer

Based on the screening carried out for evaluating seed sources for shot hole borer in Uva (Table 2) by Entomology Division, more than 70% of the individuals in the seed sources of Reucastle, Sapumalkanda, Salawa, St. Coombs, Halpe and

Table 1. Yield comparison of seed stocks with standard cultivars in the 4 regional trials (Standard cultivars are in bold letters)

Up country		Low country		Mid country		Uva	
Seed stock/ Cultivar	Yield MT kg ha^{-1} yr^{-1}	Seed stock/ Cultivar	Yield MT kg ha^{-1} yr^{-1}	Seed stock/ Cultivar	Yield MT kg ha^{-1} yr^{-1}	Seed stock/ Cultivar	Yield MT kg ha^{-1} yr^{-1}
TRI 2025	**3869**a	**TRI 2023**	**4347a**	St. Coombs	2704a	Anhetti.	3285a
TRI 3020	**3634**ab	Salawa	4123ab	**TRI 2025**	**2520ab**	**DN**	**3088ab**
Rucastle	3591ab	Halpe	3683bc	Anhetti.	2480ab	Halpe	2940abc
TRI 4006	**3532**ab	Sapumal.	3477bcd	Halpe	2228bc	**TRI 2023**	**2927abc**
Salawa	3340abc	**TRI 4046**	**3454cd**	**DG 7**	**2178bcd**	Aislaby	2680abc
Sapumal.	3266abc	St. Coombs	3386cd	Salawa	1956cd	Karandu.	2546abcd
Anhetti.	3184abc	Reucastle	3105cde	Sapumal.	1764d	Salawa	2275cd
St. Coombs	3152abc	Karandu.	3041cde			Sapumal.	2161cd
DT 1	**3135**abc	Anhetti.	2940def			Rucastle	2150cd
Aislaby	3062bc	Eltab	2620efg				
Karandu.	2930bc	Aislaby	2539efg				
Eltab	2740c	**DG 39**	**2387fg**				
		Poonagala	2139g				
CV	11.36961	CV	12.16408	CV	7.73924	CV	13.90042
LSD	781.16	LSD	646.6	LSD	428.25	LSD	797.47

Sapumal= Sapumalkanda ; Anhetti = Anhettigama ; Karandu = Karandupona ;
kg ha^{-1} yr^{-1} = Made Tea in Kilo Grams per Hectare per year
Means with the same letters are not significantly different

Karadupona and more than 65% of Anhettigama, reported as resistant to shot hole borer. On the other hand 100% of the standard TRI 2025 was infected (susceptible) with SHB.

Table 2. Resistance/susceptibility of seed sources for shot hole borer (SHB) in Uva (Standard cultivars are in bold letters)

Seed source / cultivar	Resistance/susceptibility to SHB (% out of the total population)
Halpe	84 % resistant / moderately resistant
St. Coombs	84 % resistant / moderately resistant
Reucastle	77 % resistant / moderately resistant
Sapumalkanda	73 % resistant / moderately resistant
Salawa	71 % resistant / moderately resistant
Karadupona	71 % resistant / moderately resistant
Anhettigama	66 % resistant / moderately resistant
TRI 2025	**100 % susceptible**

Tolerance to canker *(Macrophoma)*

According to the results of the screening for Canker *(Macrophoma)* in Low country (Table 3) by Pathology Division, seedlings from seed source Reucastle found resistant whereas seedlings of all the other sources, Sapumalkanda, Salawa, Anhettigama, St. Coombs, Halpe, Karadupona, Aislaby and Eltab found moderately resistant. The standard cultivars TRI 2023 and TRI 4046 found to be moderately susceptible and susceptible respectively.

Made tea quality

Made tea quality of the above promising seed sources were compared with known high quality cultivar, DT 1 and moderate quality cultivar, TRI 2025. Organoleptic analysis done by professional tea tasters confirmed that none of the seed sources were superior to quality of DT 1 or having comparable quality with DT1. However, all seven seed sources; Salawa, Halpe, Karadupona, Sapumalkanda, Anhettigama, St. Coombs and Reucastle were comparable with the quality of TRI 2025.

Table 3. Resistance/susceptibility of seed sources for canker *(Macrophoma)* in Low country (Standard cultivars are in bold letters)

Seed source/ cultivar	Resistance/ susceptibility
Reucastle	Resistant
Sapumalkanda	Moderately resistant
Salawa	Moderately resistant
Anhettigama	Moderately resistant
St. Coombs	Moderately resistant
Halpe	Moderately resistant
Karadupona	Moderately resistant
Aislaby	Moderately resistant
Eltab	Moderately resistant
DG 39	**Moderately resistant**
TRI 2023	**Moderately susceptible**
TRI 4046	**Susceptible**

Table 4. Made tea quality of seed sources (Standard cultivars are in bold letters)

Seed source/ cultivar	Made tea quality
DT 1	**High quality**
Karadupona	Moderate quality
Salawa	Moderate quality
Sapumalkanda	Moderate quality
TRI 2025	**Moderate quality**
Anhettigama	Moderate quality
Halpe	Moderate quality
St. Coombs	Moderate quality
Reucastle	Moderate quality

Considering the yield and screening for tolerance to biotic and abiotic stresses 7 sources; Salawa, Halpe, Karadupona, Sapumalkanda, Anhettigama, St. Coombs and Reucastle were found promising and selected of next phase of evaluation.

Seed germination ability

The germination percentage of seed stocks of different cultivars of the 7 promising sources (gardens) varied from 30-70%. But in contrast seed stocks of TRI 2016 exhibited highest germination percentage (about 90%) irrespective of the seed source (garden). The cultivars, which having germination percentage of at least 40% or above were selected to be included in the adaptive trials.

Seed production

Based on the visual observations carried out on flowering and fruit set the 7 promising sources (gardens) were broadly categorized into three groups depending on the overall seed productivity levels as follows:

Seed productivity level (Rating)	Seed source/s (Gardens)
High (3)	St. Coombs
Moderate (2)	Salawa, Halpe, Sapumalkanda and Karadupona
Low (1)	Reucastle and Anhettigama

The information on seed productivity levels of seed gardens is useful in commercial scale seed production and dissemination among tea growers. In addition to the above seed sources, two high productive seed sources Rambukkanda and Kiriporuwa were found and included in subsequent evaluations. Seed productivity levels of individual cultivars planted in nine seed gardens were monitored and they could be categorized into 4 groups based on their level of seed production: ratings allotted are given in the parenthesis.

1. **High (3)** : TRI 2016, TRI 2022, TRI 2043, KEN 16/3, S 106
2. **Moderate (2)** : TRI 2021, TRI 2023, TRI 2025, TRI 2026, TRI 2027, TRI 3055, TRI 62/6, DN, KP 204
3. **Low (1)** : TRI 3014 and TRI 3063
4. **Very low or No (0)** : TRI 3047 and H 1/58

The information on overall seed productivity levels of individual seed bearers could be useful in selecting appropriate cultivar combinations for establishment of seed gardens in the future.

Adaptive trials

The adaptive trials in all locations just completed one pruning cycle and second cycle evaluations are being carried out. The outcome of the preliminary observations/ evaluation can be summarized as follows:

At Galaha, seedling population derived from Anhettigama TRI 62/9 seed bearers has exhibited higher yield than all 3 standards. Except seed stock of Rambukkanda TRI 2025 seed bearer all the seed stocks have exhibited at least 75% of yield of highest yielding standard (TRI 4046). Out of the 14 stocks 11 have yielded better than standard DG 7 up to now. At Passara adaptive trial, seedling populations derived from seed bearers of Rambukkanda KEN 16/3, Halpe TRI 2016, Reucastle S 106, Salawa TRI 2016, Salawa KEN 16/3 and Kiriporuwa TRI 2016 have exhibited better yield than standard TRI 4042 but none of them recorded higher yield than that of TRI 2025.

Visual observations on performances under dry weather condition conducted at the Galaha trial during the dry spell in 2009 revealed that all the seedling populations derived from seed bearers of Sapumalkanda garden (TRI 2025, TRI 2043, TRI 3055, S 106), seedling population derived from TRI 2043, seed bearer of Anhettigama garden, seedlings raised from seed bearers of TRI 2025 and TRI 3055 of Rambukkanda garden withstand the drought better than the standard VP cultivars (TRI 4042 and TRI 4046) confirming their potential to withstand unfavorable weather conditions.

The preliminary observations on tolerance/susceptibility to shot hole borer carried out at Passara revealed that about 70-90% of the individuals in seed stocks of Rambukkanda KEN 16/3, Salawa TRI 2016 and Kiriporuwa TRI 2016 showed resistant to moderately resistant to SHB and performances are more predictive.

In general the preliminary observations/evaluations suggest that there is an increased uniformity, similar to VP cultivar, when using seed stocks of individual cultivars separately other than using bulk of seeds from all the cultivars of a single source.

A comprehensive study on flowering and fruiting phenology together with study of floral/ fruit/ seed morphology of promising stocks together with mating system analysis using molecular makers has been planned to carry out. The steps have already been taken to improve the material availability by intensifying the maintenance activities of the respective seed gardens with the support of stakeholders. Initial arrangements have been made to establish a few new seed gardens to fulfill the future demand.

Grower empowerment initiatives have been taken in adopting new improved seed materials with the aspiration to learn the technology and to practice and test new materials in their own estates. The potential of using these improved seeds while achieving appreciable productivity gain in commercial scale in low productive areas was evident and thus, would be one of the appropriate adaptation measures to tackle perceived consequences of climate change.

CONCLUSION

Promising seed stocks of tea based on seed productivity, comparable yields with known VP cultivars, tolerance to shot hole borer and canker and moderate made tea quality have been identified. With the completion of the evaluation by the adaptive trials these promising seed stocks may be recommend for commercial plantation particularly in the low productive areas as one of the appropriate adaptation measures to tackle perceived consequences of climate change.

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