Tea Research Institute of Sri Lanka

244TH EXPERIMENTS AND EXTENSION FORUM

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TRI AUDITORIUM, TALAWAKELLE

New Generation of Tea Cultivars: A Strategic Intervention for Environmental Challenges and Emerging Market Opportunities

JHN PIYASUNDARA, MAB RANATUNGA, JD KOTTAWA-ARACHCHI, KK RANAWEERA, AK MUDALIGE, JMK UDALANGANI,GDNN DAYARATHNA, HWMMM JAYARATHNA, MMN DAMAYANTHI, NM VITHANAGE, K RAVEENDRAN, L JAYASINGHE, PD SENANAYAKA, BMGK GODAVITA, DGNP KARUNAJEEVA, M NIRANJAN, RKA AMALI, KGJP MAHINDAPALA, TGN MAHINDA, ROHITHA LIYANAGE, KRWB KAHADAWA, PD DE ALWIS, CE MUNASINGHE, HIROMI NISHANTHI, CJ LIYANAARCHCHI, HB THARANGIKA, JKAD KALHARI, SRW PATHIRANAGE,RBL HEMAKUMARA, MA CHAMINDRA AND KACL KODDITHUWAKKU

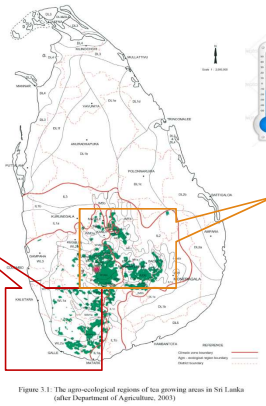
Why Different Tea Cultivars???



0-300 m amsl



30-35 ^{O} C





10-20 ^{O} C

2000 m amsl



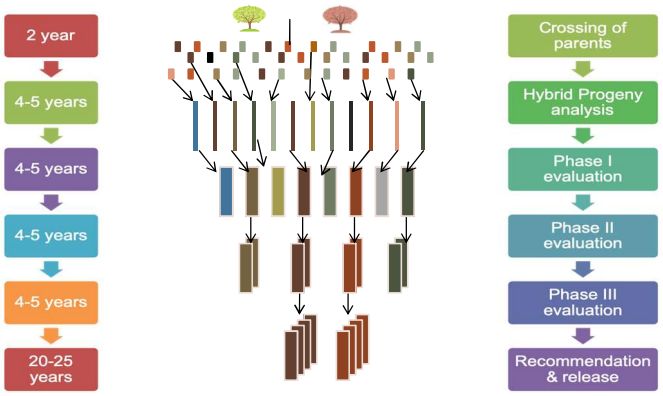
Soil type???
Pest & diseases??

Breeding Strategy

- **Create new progenies – Selection & Hybridization**
- **Comparative evaluation of the individuals of new generation to test the**
  - ✓ superiority, in comparison to existing standard cultivar
  - ✓ stability and adaptability

  through series of field/laboratory evaluation and screening

Identify NEW CULTIVAR/S
“superior to existing commercial cultivars”



Tea Cultivar Development Programme

Trends in Tea Breeding

After 1990
- High Yield
- High Quality Made Tea
- Tolerance to Pests and Diseases
- Tolerance to Drought and Climate Change Effects
- Amenability for Mechanization (Specially Mechanical Harvesting)
- Market Opportunities

Between 1980- 90
- High Yield
- High Quantity Made Tea
- Tolerance to Pests and Diseases

Before 1980
- High Yield

Basket of Cultivars for each Region

is recommended to:

- Minimize threats from major pests and diseases
- Maintain genetic diversity (tea is grown as a mono-crop)
- Achieve yield stability by minimizing crop losses due to P&D

The overall combined characteristics of the cultivar mixture should meet the typical desired need of a particular Region / Estate

Major Challenges in Present Day

- **Impact of global climate change** - **Increasing temperatures / extreme weather events (prolonged droughts, sudden downpours)** - cause severe soil degradation and reduce soil fertility (Wijeratne, 2018 ; Ranathunga, 2019)
- **Increase of the incidences of pests, diseases and weeds** due to climate change (Lal 2005).
- **The demand for a pure beverage among tea consumers** - the challenge of developing new tea cultivars with multiple resistances to pest and diseases without compromising quality. (Wijeratne 2018) – MRL and related issues
- **Scarcity of skilled work force** – need tea cultivars amenable to mechanization
- **Increasing demand for tea as functional food / health promoting food**
- **Versatility of the market** – demand for specialty teas

Main Objectives of the Experimentation

- Development of a new generation of tea cultivars (TRI 5000 series) suitable for different agro-ecological regions in Sri Lanka, with high yield, Tolerance to biotic and abiotic stresses to face the emerging environmental and market challenges
- To evaluate the new cultivars as well as the existing cultivars for their potential for specialty tea production to suit with the Emerging Market Opportunities

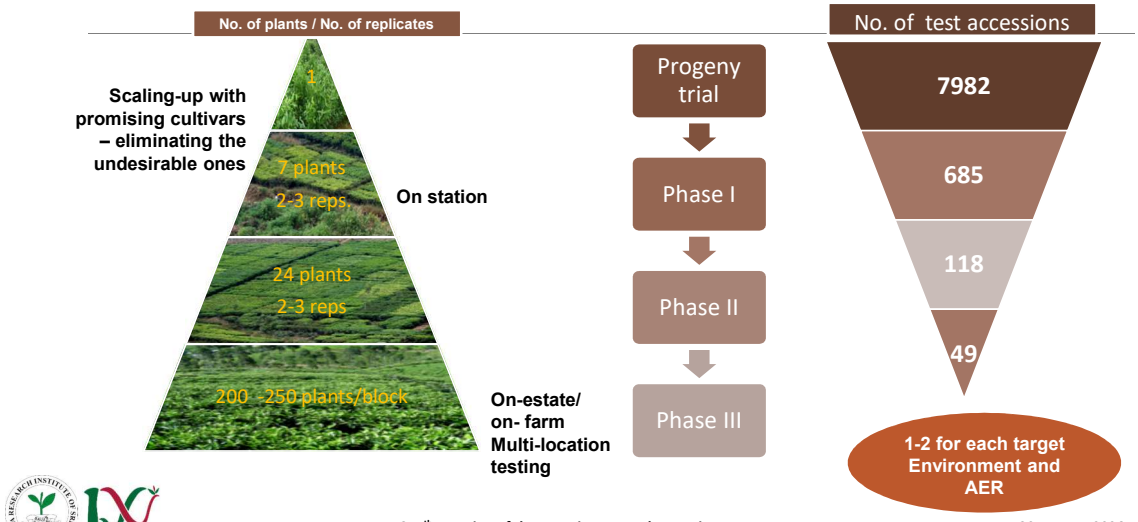
Multi- Disciplinary approach to address Multi-Stakeholder needs

The Materials – TRI 5000 Series

Parentage	No. of Accessions			
	Progeny (12 Progenies)	Phase I	Phase II 03 Trials	Phase III RPC & SH Lands
TRI 777 OP	1006	177	22	07
DT 1 OP	37	13	04	02
TRI 2025 OP	253	97	14	10
TRI 2043 OP	59	25	03	00
Ais. 2025 x 2023 OP	694	12	05	05
Ais. 2025 x 2024 OP	1131	108	36	12
Hug. 2025 x 2024 OP	1302	70	05	01
Vy. 2026 X DN OP	1500	15	08	03
K 2016 OP	500	96	11	04
K S106 OP	500	39	05	02
K 2023 OP	500	19	03	01
U 2016 OP	500	14	02	02
Total	7982	685	118	49

OP = Open pollinated / Vy. = Vykumubura / Ais. = Aislabey/ U = Urumewella / K = Kardupona

Approach and Design



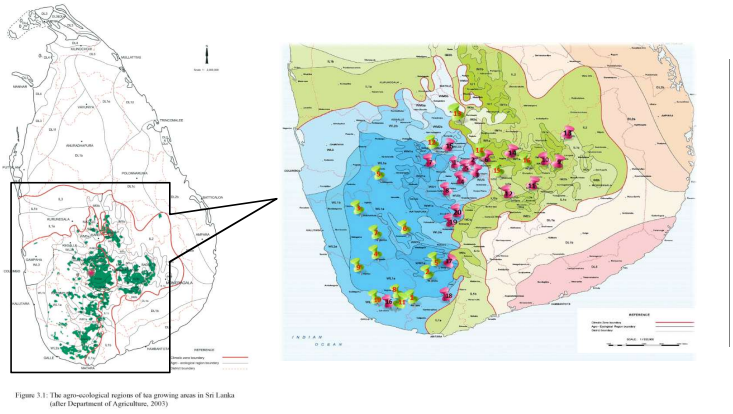


Figure 3.1: The agro-ecological regions of tea growing areas in Sri Lanka (after Department of Agriculture, 2003)

Locations : TRI 5000 Series Adaptive Trials / Observation Plots

TRI 5000 Series - Adaptive Trial / Observation Plots - Locations

Up Country	Uva	Low Country
• Mattakelle Estate, Talawakelle • Somerset Estate, Nanuoya • Dayagama –West Estate, Dayagama • Glasgow Estate, Agarapathana • Hapugastenna Estate, Maskelliya • Pedro Estate, Nuwara Eliya • Waltrim Estate, Lindula • Carolina Estate, Watawala • Small Holding, Kothmale	• TRI, Passara • Glen Alpine Estate, Badulla • Craig Estate, Bandarawella • Haputale Estate, Haputale • Verellapatane Estate, Madolsima • Shall Holding, Haliela	• Cecilton Estate, Balangoda • TRI, Kottawa • Deniyaya Estate, Deniyaya • Indola Estate, Mawarala • Kriwanganga Estate, Deniyaya • St. Joachim Estate, Ratnapura • TRI, Deniyaya • 13 Small Holdings

Methodology

Yield and Yield Component Evaluations

YIELD

- Weekly yield recording for 1 pruning cycle
- Yield is expressed as made tea kg/hectare/year



YIELD COMPONENTS





Screening for Drought Tolerance

- **Drought Susceptibility Index (DSI)**

$$DSI = [1 - Y / Yp] / [1 - X / Xp]$$

Where,

Y = Yield under stress / Yp = Yield under no stress

X = Average yield over all genotypes under stressed conditions;

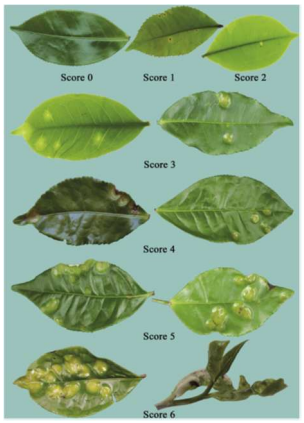
Xp = Average yield over all genotypes under non-stressed conditions (Torrie, 1981)

  - DSI proposed by Fischer and Maurer (1978) - calculated using photosynthesis rate and Relative Water Content (RWC) as a reference parameters (Nainanayake, 2004).
  - Used for screening tea cultivars (Damayanthi *et. al*.,2017)
- **Long term field observations also conducted**

Screening for Disease Tolerance

BLISTER BLIGHT

- **Field infestation**
  - Assessment key developed using infested leaf areas (Sinnaiah *et al.,* 2016)
  - Different locations and time



CANKER

- **Field Screening**
- **Inoculation Studies**





Screening for Pest Tolerance

- **Shot hole borer**
  - Field infestation - Gallery count (Walgama *et al*., 2008).
  - Validated with bioassay
- **Low Country Live Wood Termites**
  - Field screening
- **Nematodes**
  - Artificial inoculation - Nursery plants
  - Combination of parameters
  - Nematode Susceptibility Index (NSI)























Biochemical Analysis of Green Leaves and Organoleptic Analysis of Made Tea

Green leaf parameters

Total Polyphenols (Spectrophotometric) ISO 14502-2 (2005)

Total Catechins & fractions (HPLC method) ISO 14502-2 (2005)



Total amino acids (Yemm and Cocking 1955)

Made tea quality



Organoleptic parameters

- **Infused leaf colour**
- **Made tea appearance**
- **Liquor characteristics**

TF/TR - Roberts and Smith (1963)

Methodology : **Amenability for mechanical harvesting**

- Field trials
- Yield & Shoot growth (Pathiranage *et al*., 2019)



Methodology : **Response of new accessions to different Nitrogen rates**

- Field trials
- Yield & yield components
- Leaf Nitrogen Content
- Agronomic Nitrogen Use Efficiency (AgNUE)





In Addition .....

- **Frequent assessments on growth parameters :** Tipping weights, Pruning weights *etc.,*
- **Visual Assessments under dry weather conditions**
- **Bush survival – including revisits to Phase I & II trials**
- **Perception assessments**
  - Only the **accessions with significantly higher or comparable yields with standard cultivars in the Phase I & II (replicated trials)** advanced into to Phase III / adaptive trials:
  - Except for the **accessions with outstanding tolerance levels for biotic / abiotic stresses over long period of time**

Methodology: **Data analysis**

- Analysis of Variance (ANOVA)
- Correlation analysis
  - Using Statistical Analysis System (SAS) software



Results and Discussion

Summary of Results : TRI 5000 Series Cultivars Recommended for Up Country

Cultivar	Percentage	Yield MT (Kg/ha/Yr)		Made Tea Quality	Tolerance biotic Stresses		Remarks
		Phase II (VP 80)	Phase III (Average)		Blister Blight	Nematodes	
TRI 5001	TRI 777 OP	2393*	2815	High	High	Moderate	
TRI 5002	TRI 777 OP	1956*	3268	High	Hight	Moderate	Specific adaptable cultivar
TRI 5003	TRI 2043 OP	2714*	3674	Moderate	High	High	General adaptable cultivar. High response to applied nutrients
TRI 5004	TRI 2043 OP	2337*	3443	Moderate	High	Moderate	General adaptable cultivar
TRI 2025	ASM4/10 OP	2013*	2140	Low	Low	Moderate	

Summary of Results : TRI 5000 series Cultivars Recommended for Uva

Accession	Parentage	Yield MT*		Made Tea Quality	Tolerance to abiotic / biotic stresses			Remarks
		Phase II	Phase III (Average)		Drought	Blister Blight	Nematodes	
TRI 5002	TRI 777 OP	5043[a]	4102	High	High	High	Moderate	
TRI 5005	TRI 2025 OP	4406[a]	4917	Moderate	High	Low	Moderate	
TRI 5006	TRI 2025 OP	3568[a]	3718	Low	Low	High	Moderate	Potential to produce Specility teas
TRI 2025	ASM 4/10	3959[a]	3806	Low	High	Low	Moderate	

Summary of Results : TRI 5000 Series Cultivars Recommended for Low Country

Cultivar		Yield MT*			Tolerance / Resistance to abiotic / biotic stresses					Remarks
		Phase II		Phase III (Average)	Drought	Canker	LCLWT	Nematodes	SHB	
		LV 74	LVP 75							
TRI 5007	TRI 2026 X DN		4916[cdefg]	3377	High	Moderate		Moderate		Moderately amenable for mechanical harvesting
TRI 5008	TRI 2026 X DN		4050[efghi]	3804	High			Moderate	Moderate	Highest TPP %
TRI 5009	Hug. TRI 2025 x TRI 2024 OP	2901[d]		3645	High	High	High		Moderate	
TRI 5010	Ais. TRI 2025 x TRI 2024 OP	3094[cd]		3638	High	High			Moderate	
TRI 2026	ASM 4/10 OP	4576[abc]	5213[bcde]	3661	Moderate					

Screening for Potential Cultivars for Specialty Teas

- 17 tea cultivars/accessions
- Selected based on metabolite profile, popularity, high quality and to represent estate selections, TRI developed cultivars and introduction from other countries
- Field gene bank (Germplasm) at TRI, Talawakelle

Concentration of Major Biochemical Compounds in Fresh Leaves of 17 Cultivars [values were expressed as mg g^{-1}]

Cultivars	Type	CF	EGC	EC	EGCg	ECg	TC
CY9	Cambod	37.40	49.26	20.48	61.04	20.29	151.07
DN	Cambod	44.48	37.49	14.20	97.23	28.60	177.52
DT 1	Cambod	39.87	40.47	19.80	77.08	33.47	170.82
PBGT 100	China	27.84	40.22	19.08	84.85	33.68	177.83
PBGT 115	China	18.85	29.89	10.46	94.40	14.74	149.49
PBGT 41	China	20.45	38.24	16.67	64.78	20.56	140.26
PBGT 48	China	13.91	35.24	11.87	55.85	11.36	114.31
PBGT 55	China	19.24	30.14	12.65	71.09	17.94	131.83
PBGT 60	China	20.36	41.90	11.21	70.41	12.13	135.64
PBGT 61	China	20.94	50.51	13.43	60.83	11.00	135.77
PBGT 73	China	16.02	45.10	15.48	58.93	13.74	133.25
PK 2	Cambod	37.53	54.17	19.09	84.64	27.85	185.75
TRI 3073	Cambod	33.06	26.46	18.82	83.28	39.83	168.39
TRI 4067	Cambod	29.39	54.38	15.65	83.15	20.42	173.59
TRI 4078	Cambod	35.66	39.72	13.24	94.29	27.38	174.63
TRI 4079	Cambod	30.97	31.29	13.46	100.29	32.42	177.46
TRI 5006	Cambod	34.90	25.50	13.80	56.90	22.00	118.20

EC:(-)-epicatechin,
ECg:(-)-epicatechin gallate,
EGC:(-)-epigallocatechin,
EGCg:(-)epigallocatechin gallate,
CF: caffeine,
TC: Total catechins,

Highest
Lowest

Total Polyphenol Content of Green Tea Samples

Cultivars	TPP mg g^{-1}
CY 9	222.7
DN	223.9
DT 1	283.5
PBGT 100	292.2
PBGT 115	228.2
PBGT 61	231.2
PBGT 73	168.3
PBGT41	210.3
PBGT48	141.4
PBGT55	195.6
PBGT60	217.2
PK 2	226.7
TRI 4067	239.4
TRI 4078	256.2
TRI 3073	270.9
TRI 4079	276.4
TRI 5006	338.5

- The highest TPP - TRI 5006
- The lowest TPP - PBGT 48
- Contribute to astringency and bitterness in green tea
- High TPP leads to a decrease in economic value
- Antioxidant, anti-mutagenic, anti-carcinogenic and free radical scavenging ability
- **Green tea with a lower polyphenol-to-amino acid ratio (TPP/AA) is considered to have a good quality with a fresh and crisp taste**

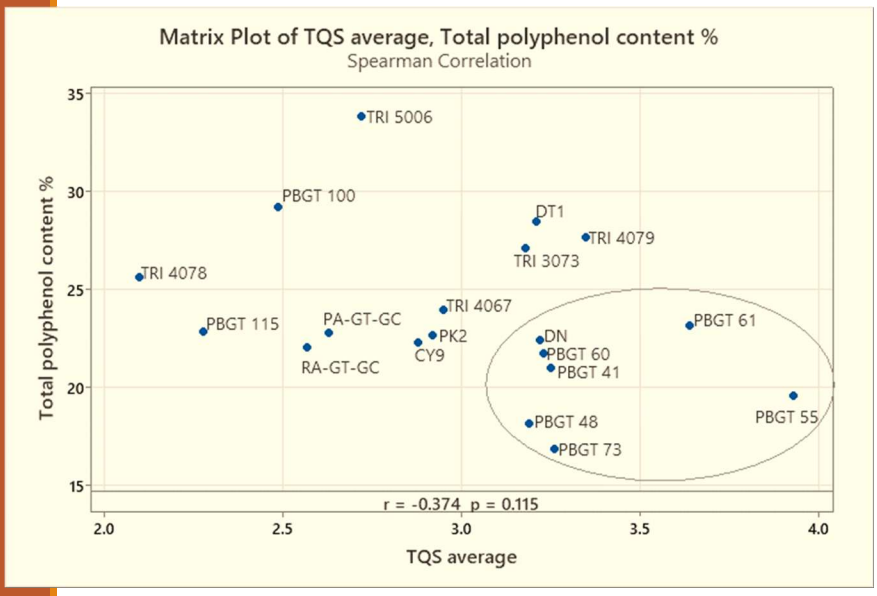
Correlation Plot between Total Polyphenol (TPP) % and Total Quality Scores (TQS) of Green Tea Samples

- **Better cultivars for green tea production.**

  PBGT 41, PBGT 48, PBGT 55,

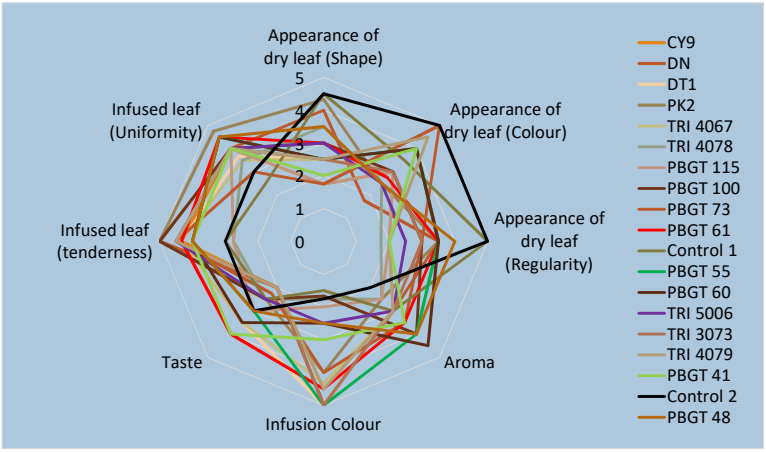
  PBGT 60, PBGT 61 and PBGT 73

- **Characters:**
  - Low caffeine
  - Low polyphenol content
  - High TQS



Radar Plot of Green Tea Organoleptic Parameters

- **Clear, bright green liquor color and aroma :** TRI 4067, CY 9, DT 1, PBGT 55, PBGT 60, PBGT 61, PBGT 73
- **Pleasant and mellow taste :** PBGT 41, PBGT 55, PBGT 60, PBGT 61, PBGT 73
- **Bitter and astringent:** CY 9 and DN
- **Purple liquor color :** TRI 5006
- **Overall best:** PBGT 55, PBGT 61 and PBGT 73



Conclusions

Ten (10) new TRI 5000 Series Cultivars with higher / compatible yields and better resilience to biotic & abiotic stresses have been recommended and released to the tea industry

One of the cultivars (TRI 5006) with the potential of producing white teas (Silver tips) & Purple / Pink teas

Three (03) Cultivars; PBGT 55, PBGT 61 and PBGT 73 identified with the potential of producing high quality green tea

The findings pave the way to enhance the productivity, profitability and long term sustainability of the tea cultivation in Sri Lanka

In Progress

Mechanism to Disseminate of quality planting materials among the growers

- Mother bush programmes – already in progress – 30 ha established from 2017 up to now

Research on potential of specialty tea production of TRI 5000 Series

Mother bush Sites of New Cultivars

Up Country	Uva	Low Country
• St. Coombs Estate, Talawakelle • Maddekcombra Estate, Watagoda • TSHDA, Thispene	• TRI, Passara • TSHDA, Haliela • TSHDA, Bandarawela	• Vogan Estate, Mathugama • Kriwanganga Estate, Deniyaya • St. Joachim Estate, Ratnapura • TRI, Deniyaya • TRI, Kottawa • RRI, Niwithigalakella • Morawakorala Co-op Society • 09 TSHDA Sites



Acknowledgements

- Past Tea Breeders
- TRB and Management
- SAC Reviewers
- All Collaborating Research Divisions
- Advisory and Extension Division
- Staff of TRI Regional Stations
- All Staff of TRI (Administration, Finance, *etc*.)
- Staff of St. Joachim and St. Coombs Estates
- Staff of RPC Estates – Adaptive trials
- Tea Small Holders – Adaptive trials
- THSDA Staff
- E & E Organizing committee



Thank You !
For Listening to this Presentation …



Dr. JHN Piyasundara

+94 714431557

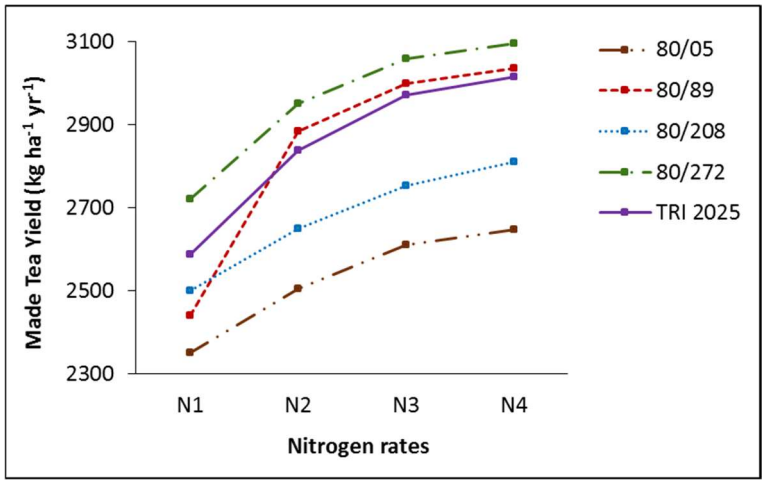
noelpiyasundara@gmail.com

www.tri.lk

Plant Breeding Division
Tea Research Institute of Sri Lanka,
Talawakelle

Biochemical Parameters and Taster's Scores of Made Tea Samples of TRI 5000 Series Accessions for Up Country

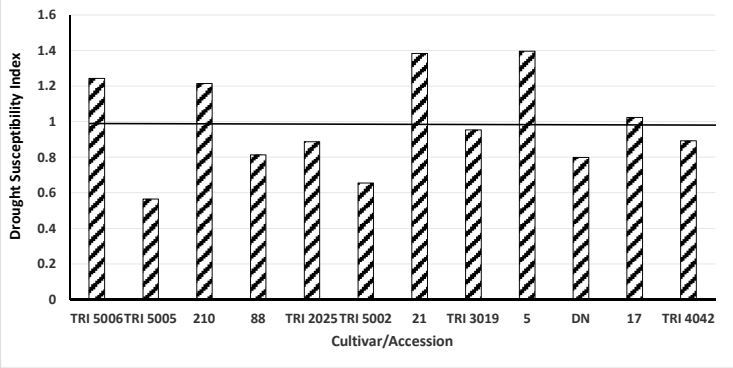
Accession / cultivar	Biochemical parameters					Taster scores			
	TF (%)	TR (%)	Total Colour	Brightness	TR/TF	Infusion colour	Liquor colour	Strength	Liquor quality
TRI 5001	1.1	15.6	5.1	22.0	13.9	4.5	4.2	4.0	6.0
TRI 5002	1.1	16.8	6.0	18.4	15.1	3.8	5.2	3.8	4.7
101	1.0	15.3	4.2	23.1	14.8	4.2	3.5	3.8	4.3
208	1.3	17.5	5.4	23.3	13.6	4.3	4.0	3.5	4.8
210	0.9	14.8	4.0	19.6	16.3	2.3	4.5	3.5	2.3
TRI 5003	1.0	19.6	5.8	17.3	18.7	5.8	3.3	4.3	4.5
497	1.0	17.2	4.8	20.0	16.8	4.0	3.2	3.7	4.2
TRI 5004	0.9	16.8	4.7	18.3	18.4	4.0	3.8	3.8	4.3
DT1	1.2	18.4	5.6	21.1	15.0	4.9	4.5	4.6	5.9



- The response of TRI 5003 (272) and TRI 5002 (89) to applied nitrogen are comparatively high
- In low fertilization conditions, TRI 5003 (272) is better for producing higher crop yields

80/05 , 80/89 = TRI 5002, 80/ 272 = TRI 5003
N1 = 0, N2 = 120, N3 = 240, N4 = 360 kg N/ha/yea

Drought Susceptibility Index (DSI) - Uva



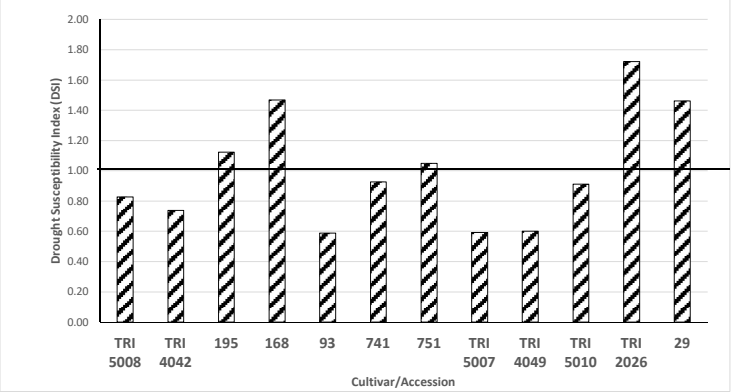
TRI 5005 exhibiting lowest DSI

- **DSI : <1 - Drought tolerant (5005, 88. 2025, 5002, 3019, DN, 4042)**
- **DSI : >1 - Drought susceptible (5006, 210, 21, 5, 17)**

Comparison of White Tea (Silver tips) by the Professional Tasters – TRI 2043 Vs TRI 5006

	TRI 2043	TRI 5006
		
Appearance	**Bright silvery color comparing**	**Not Silvery enough, tending dark ash color**
Infusion	**Bright**	**Tending pink**
Liquor	**Mellow flavor liquor**	**Not pungent and flavor enough**
Value Rs. per Kg	**Rs. 27000/= to 29000/=**	**Rs. 20000/=**

Drought Susceptibility Index (DSI) Low Country



TRI 5007 & 93 exhibiting lowest DSI

- **DSI : <1 - Drought tolerant (5007, 5008, 4042. 93, 741, 5010)**
- **DSI : >1 - Drought susceptible (195, 168, 751, 2026, 29)**

Amenability for mechanical harvesting (MH)

Accession	Parentage	Amenability for MH
174	Ais. TRI 2025 x TRI 2024 OP	Moderate
TRI 5007	TRI 2026 X DN OP	Moderate
TRI 5008	TRI 2026 X DN OP	Not Amenable

Biochemical Analysis – Green leaf – Low Country

Accession / Standard	TPP (%)	Caffeine (%)	Catechin (%)	EGC (%)	EC (%)	EGCG (%)	ECG (%)	Total Catechin (%)
TRI 5007	21.33^{ed}	3.59^{d}	0.168^{d}	2.363^{d}	1.45^{e}	6.46^{f}	1.76^{h}	12.19^{f}
TRI 5008	27.64^{a}	4.13^{b}	0.15^{e}	3.08^{b}	1.66^{d}	10.04^{a}	3.14^{b}	18.07^{b}
TRI 5009	25.42^{bac}	2.74^{f}	0.175^{d}	1.54^{f}	1.61^{d}	4.13^{h}	2.24^{g}	9.69^{g}
TRI 5010	18.76^{e}	3.53^{d}	0.236^{cb}	3.68^{ba}	3.31^{a}	6.07^{g}	3.25^{a}	16.74^{c}
174	25.09^{bac}	4.2^{b}	0.314^{a}	3.12^{c}	1.96^{c}	7.04^{e}	2.99^{cd}	15.41^{d}
TRI 2026	23.68^{dc}	3.77^{c}	0.225^{c}	3.58^{b}	1.90^{c}	9.45^{b}	3.07^{cb}	18.22^{b}
TRI 4042	26.57^{ba}	4.09^{b}	0.241^{cb}	2.85^{c}	2.19^{b}	6.98^{e}	2.67^{e}	15.87^{d}
TRI 4049	24.27^{bc}	5.60^{a}	0.124^{f}	3.61^{b}	1.95^{c}	10.22^{a}	2.91^{d}	18.81^{a}

TRI 5008- Highest TPP % : **174** – Highest Catechin % : **TRI 5010 -** Highest EGC %