Agronomy of Irrigated Tea in Low Elevation Growing Areas of Sri Lanka

Shyamantha Nelum Bandara

Thesis submitted for the Degree of Doctor of Philosophy

School of Agriculture, Food & Wine

The University of Adelaide

2011 November

Declaration

NAME:…………………………………………………………………............PROGRAM:…………………………

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue, the Australasian Digital Theses Program (ADTP) and also through web search engines, unless permission has been granted by the university to restrict access for a period of time.

SIGNATURE:……………………………………..........................DATE:…………………………....

Abstract

The low elevation tea growing region of Sri Lanka produces 60% of the national production and the most limiting factor affecting productivity in this region is the short but intense inter-monsoonal dry period. Irrigation, along with other methods like cultivar selection, is likely to be the best way to mitigate the impact of drought and generally improve productivity. However the dearth of knowledge of the response, and financial feasibility, of low elevation tea to irrigation retards its adoption. Therefore the Tea Research Institute of Sri Lanka (TRISL) funded a series of trials from 2006 to 2009 with the aim to understand the agronomic and physiological characteristics of low-grown tea in response to irrigation, and the financial practicality of introducing irrigation in the region. This aim was achieved through the following objectives to evaluate: (1) the changes in physiology and yield as affected by the drought and recovery by irrigation; (2) the environmental parameters that govern the water use of tea in low elevation growing areas; (Li, Yang et al.) the physiological and yield responses to different micro-irrigation methods; (4) the effect of soil moisture limitation on young tea plant growth and physiology; and (5) the practical financial feasibility of irrigating tea in the region.

Field trials were conducted at the TRISL‘s low-country research station at Ratnapura, Sri Lanka using mainly drip, and to a lesser extent sprinkler, irrigation to evaluate the response using different tea cultivars. Irrigation was only applied during the inter-monsoonal dry period of the January to March. Glasshouse experiments with different water stress levels were conducted specially for evaluating the short term drought effect on the post-nursery growth stages, which is critical for long term productivity.

The key results to the research objectives were as follows:

1] Key physiological process underpinning yield (P_n, E_l, g_s, Ψ) were depressed even under drip irrigation. Nevertheless, the drip-irrigated crop had an annual yield increase of 21% ($p<0.001$) over the rain-fed control. Higher yields were observed even during non-irrigated periods as tea plants irrigated from establishment had better root and canopy structure. Strong cultivar differences were observed. The benchmark high-yielding, but drought-susceptible, cultivar TRI 2023 yielded 16% more under drip irrigation than the benchmark drought-tolerant cultivar TRI 3025. Evaluation of more recently developed cultivars revealed that irrigation will be a more effective drought mitigation strategy than selection of drought-tolerant cultivars. Among a group of 5 leading new cultivars only TRI 4049 showed physiological characters preferred for irrigation.

2] The environmental parameters measured were rainfall, ambient temperature, solar radiation, vapour pressure deficit and potential evapotranspiration. Temperature is the dominant parameter driving transpiration in the wet season (r^2=0.62, P=<0.0001) and suppressing all the other physiological processes in the dry season. Average daily transpiration was 2.3(±0.3) and 1.3(±0.2) mm in wet and dry seasons respectively for rain-fed plants. Irrigated plants showed >100% increase in transpiration than rain-fed plants in dry season.

3] During a very wet year (2008) sprinkler irrigation resulted in 15% higher assimilation rates and produced 6% higher yield increase than drip irrigation on TRI 2023. This was due to the maintenance of 2-4^{0}C lower leaf temperature in midday hours than under drip irrigation. Between 6 to 8% higher water use efficiency was achieved under sprinkler than drip irrigation.

4] Glasshouse and field experiments emphasised the importance of irrigation for the establishment of young (<1 year) tea plants. Decreasing the irrigation frequency from daily irrigation to a 4 day interval reduced stem growth by 20% and root growth by 46%. Deficit irrigation of 50% for 20 days, reduced the stem and root growth by 34% and 45% respectively. In the field, short dry spells (<3 weeks), reduced LAI and root growth. Establishing plants on mounds, as opposed to conventional flat ground preparation, enhanced the effect of irrigation to facilitate the growth of more root (12 and 8% increase in fine and coarse root) and leaf (60% increase in leaf area).

5] The on-farm feasibility of irrigating tea in low elevation areas was evaluated using Net Present Value (NPV) analysis. The analysis was based on 10 years (1999-2009) of yield data of TRI 2023 and TRI 3025 under drip irrigation. Long term yield data was not available for sprinkler irrigation. Sensitivity analysis was applied using variables of wage rate, green leaf price and discount rate (2007 as base year). Under these assumptions it is highly feasible to establish TRI 2023 under drip irrigation but not TRI 3025 (NPVs Rs 391779 and Rs -57898 respectively. The threshold levels for feasibility of TRI 2023 are a discount rate of 15%, or a green leaf price below Rs48. Irrigating TRI 3025 is economically viable only if green leaf price reaches Rs 65. Cultivar selection is a key factor in the financial success of tea irrigation. The higher water demand of a sprinkler system may limit its practical application.

The study confirms that irrigation can be used as viable option to improve productivity and to mitigate short term drought effects in low elevation tea growing areas. It is crucial to irrigate from establishment of young plants as early growth determines later yield potential. Cultivars suitable for irrigation are those that are inherently faster growing and less drought tolerant.

Further studies are encouraged comparing sprinkler and drip irrigation, soil moisture based irrigation scheduling and different water application rates under drip irrigation.

Table of Contents

List of Tables

List of Figures

List of Acronyms

Ψ	Leaf water potential (MPa)
Φ	Quantum efficiency (μmol $(PAR)^{-1}$)
ADB	Asian Development Bank
D_r	root zone water depletion (mm)
E	Transpiration (mm/day)
E_l	Instantaneous leaf transpiration (mmol H_2O $m^{-2}s^{-1}$)
ET_0	Potential evapotranspiration (mm/day)
g_s	Stomatal conductance (mol H_2O $m^{-2}s^{-1}$)
I	Incident light intensity (μmol$m^{-2}s^{-1}$)
IRR	Internal Rate of Return (%)
IRR_i	Irrigation water applied (mm)
IWUE	Irrigation water use efficiency (kg/ha/mm)
K_c	Crop coefficient
K_s	Water stress coefficient
LCLWT	Low country live wood termite (*Glyptotermes dilatatus*)
MARR	Minimum Attractive Rate of Return (%)
N	Sunshine hours
NPV	Net Present Value
PAR	Photosynthetically active radiation (Wm^{-2})
P_n	Photosynthesis (μmol CO_2 $m^{-2}s^{-1}$)
R_d	Dark respiration
RF	Rainfall (mm)
Rn	Solar radiation (MJm^{-2})
SHB	Shot hole borer (*Xyleborus fornicatus)*
SLTB	Sri Lanka Tea Board
T_{avg}	Average air temperature (^0C)
T_{max}	Maximum air temperature (^0C)
T_{min}	Minimum air temperature (^0C)
TAW	Total available water in root zone (mm)
TE	Transpiration efficiency (g/mm)
TRISL	Tea Research Institute of Sri Lanka
TSHDA	Tea Small Holder Development Authority
W_i	Instantaneous water use efficiency
VPD	Vapor pressure deficit (kPa)

Acknowledgement

I would like to thank the Government of the Republic of Sri Lanka for supporting this research. In particular I would like to thank the Hon. Anura Yapa, Former Minister of Plantation Industries and Dr. Sunil Jayasekara, former Chairman TRISL who activated the scholarship. I wish to thank Dr. S.S.B.D.G. Jayawardana, Chairman and Research Board for continuing the scholarship, and Dr. I.S.B. Abeysighe, Director and Dr. K.G. Premathilka, Head/Agronomy Division, for their logistic and administrative support.

It is the great effort of my team of supervisors who ultimately delivered the product. Dr. Ian Nuberg with his vast knowledge ranging from highlands of Sri Lanka to the perfect tea cup, guided me well, and with great patience, particularly through the irrationalities and subtleties of the English language. I also thank Prof. Janendra de Costa who was always at my rescue during long field works in Sri Lanka; Dr. A. Ananthacumarasmamy, former scientist at TRISL helped me with his resources and expertise during field work; and Assoc Prof. Glenn McDonald for guiding me through critical points. I especially appreciate the moral support of Dr. Annie McNeill. She, together with Murray, was once offered fee accommodation for my rescue. I appreciate kind advices of Assoc Prof. Gurjeet Gill as well. A very special thank should be delivered to Ms Jane Copeland, University of Adelaide, for advising effectively how to recover from disastrous situations. Dr. John Golding, of the Gosford Horticultural Institute NSW, is also acknowledged for assistance with quality analysis of tea in a parallel experiment.

Without the kind patronage of Mr. Somapala Jayasinghe and Mr.Sunil Fernando of Hettipola, Mr.Shiyabdeen of Asanakotuwa the scholarship would simply not have materialized. Great thanks are also due to Mr.Palitha Jayasinghe (*Dudley ayya*)Ja of Chilaw High Court who voluntarily assisted in processing the bond agreement for the scholarship. Mr.K.G.Piyasena and Ms.Rohini Dissanayake, TRISL at Talawakalle were very helpful in administration and financial matters.

Dr. M.A.Wijeratna and Staff-TRILCS and Manager and Staff-St. Joachim Estate, Ratnapura, were always helpful during the hard field work time. Specially, DWV, Padmini, Noel, Shantha, Jaliya, Samanthi, Mahinda and all others who were at my call. Nevil B, Wasantha M and Randika gave much needed technical solutions. I am indebted specially to the field staff at Ratnapura: Suresh, Sanju, Anura, Siva, ChandraKumar, Devaraj and all who greatly assisted me in field even during mid night.

During my stay at Adelaide, my friends at Roseworthy Campus in South Australia – Ben, Mick, Chris, Hugh and Malinee assisted me in employing in their own research projects. In Adelaide, my friends Laxman, Lakshitha, Dr. Senaka, Nilmini, Pryantha, Rasika, gave much needed encouragement.

Finally, but most importantly, my two kids, Pasindu and Sandani and loving Manju, endured great suffering during my involvement in the research work. Manju and kids endured two long years isolation when I was in Australia. In such instances, I highly appreciate the assistance provided by both my parents and Manju‘s parents.