

EVALUATION OF ELITE BREEDING LINES OF FLUE-CURED TOBACCO FOR  
FIELD AND MARKET PERFORMANCE

OFFICE LOCARNO PIOUS MULEKANO

EVALUATION OF ELITE BREEDING LINES OF FLUE-CURED TOBACCO FOR  
FIELD AND MARKET PERFORMANCE

EVALUATION OF ELITE BREEDING LINES OF FLUE-CURED TOBACCO FOR  
FIELD AND MARKET PERFORMANCE

OFFICE LOCARNO PIOUS MULEKANO

A DISSERTATION SUBMITTED TO  
THE FACULTY OF BIOLOGICAL AND AGRICULTURAL SCIENCES  
DEPARTMENT OF GENETICS  
UNIVERSITY OF PRETORIA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF  
MAGISTER INSTITUTIONIS AGRARIAE  
M.INST.AGRAR.  
(SUSTAINABLE PLANT GENETIC RESOURCES MANAGEMENT)

PROMOTER: PROFESSOR CARL Z. ROUX  
CO-PROMOTER: DR. TOM B. VORSTER

October 12, 1999.

To the late my father

You sustained severe sunburns in those cotton fields in pains-taking effort of setting me on this narrow path to the destination you foresaw!

Kwa malemu bambo wanga

Munazunzika ndi dzuwa lowamba koopsya m'minda ija ya thonje mkuyesetsa kolimba kundilozera kanjira aka ka masomphenya anu!

## Acknowledgements

The author wishes to record his gratitude to the Agricultural Research and Extension Trust (ARET) in Malawi, who funded this work. The kind gesture of the Tobacco and Cotton Research Institute (TCRI) of the Agricultural Research Council (ARC) of South Africa in allowing access to tobacco research facilities is highly appreciated.

Professor Carl Z. Roux and Dr. Tom B. Vorster are most sincerely thanked for their enthusiastic and untiring advice and criticism. Professor Carl Z. Roux's fatherly guidance had a profound influence on the success of this work. Dr. Tom B. Vorster was a promoter not only in scientific research, but also in the search for 'life'.

A word of thanks goes to the administration of the ARC-TCRI, who, with the help of Simon Molohe, the Liaison officer, ably incorporated the author into the ARC-TCRI community so that he could pursue his studies effectively. The author is greatly indebted to the department of plant breeding of the ARC-TCRI for kindly allowing the use of data from trials at Groblersdal, Potgietersrus and Vaalwater for combined and AMMI analyses. The ARC headquarters in Pretoria is sincerely thanked for conducting the AMMI analysis with urgency when the need arose.

Dr. M.C. Dippenaar, Dr. G.C. Prinsloo, Dr. Martie Greeff-Botha, Annette Bennett, and Luanda Van Staden are thanked for their various worthwhile and enriching contributions in their various disciplines. The advice on soil fertility by Hennie Boshoff and his work on soil sample analyses are recorded in appreciation. Special mention is made of Marietjie Van der Merwe's help in chlorophyll *a* fluorescence measurements. The untiring instructions by Elise Eulitz and Reine Steyn on the use of the computer are highly appreciated. The author is indebted to Nettie Steyn for helping with the statistical analyses of data, and to Grietha Breet for providing information on tobacco plant genetic resources. Mario Gouws,

Jody Terblanche, Jeannie Van Biljon and other members of the plant pathology and nematology laboratories are thanked for introducing the author to the techniques for isolating and pure-culturing disease-causal agents. The technical support offered by Hannes Blignaut and Ishmael Magodiello, was quite indispensable. Michael Kabotho, Jepta Molekoa, Johannes Sethole, Alpheos Molekwa, Daniel Majoko, Seaboy Malatsi and Sox Moeng are sincerely thanked for the field and post-harvest management of the experimental crop. It is a pleasure to record the help of Alfreda Pohl and Antoon Cornelissen who read parts of the text in draft and made constructive suggestions.

The acknowledgements would be incomplete without the mention of the spiritual support of the Rustenburg Assembly of God. The encouragement from the author's wife, children, mother and relatives was valuable. The general ARC-TCRI community offered moral support to the author throughout the study period. It is worth mentioning the interesting time spent with the members of the Molapo village on the grounds of ARC-TCRI despite the language barrier. The author looks back on the ARC-TCRI community with melancholy!

## Declaration

The work contained herein is original of the author. A part thereof or its entirety has not been submitted elsewhere for any course. The institutions, authorities, colleagues, friends and relatives acknowledged or quoted may not be held responsible for any clarifications that may be sought.

# EVALUATION OF ELITE BREEDING LINES OF FLUE-CURED TOBACCO FOR FIELD AND MARKET PERFORMANCE

Office Locarno Pious Mulekano

Promoter: Professor Carl Z. Roux (University of Pretoria, Department of  
Genetics)

Co-promoter: Dr. Tom B. Vorster (Agricultural Research Council-Tobacco and  
Cotton Research Institute).

Magister Institutionis Agrariae  
(M.Inst.Agrar.)

Sustainable Plant Genetic Resources Management.

## Abstract

Eleven elite breeding lines of flue-cured tobacco, OD1, OD2, ODT1, ODT8, ODT19, ODT82, ODT92, ODT100, OD313, OD490 and OD486B were evaluated for their field and market performance at the Tobacco and Cotton Research Institute in the 1998/99 growing season. The currently accepted cultivar, TL33, was used as a control.

Crop growth duration, photosynthetic competence, plant height at topping, number of leaves per plant, leaf area, and yield were investigated as parameters of field performance. Leaf quality, nicotine and reducing sugar concentrations and monetary returns per hectare were investigated as parameters of market performance.

The correlation analyses of the parameters of field performance showed that plant height at topping and whole-plant leaf area might be the most important

yield components of these elite breeding lines. Non-significant differences existed between any one of the elite breeding lines and TL33, in terms of cured leaf yields, concentrations of nicotine and reducing sugars in the leaves, cured leaf quality and market income. The Non-significant differences could be attributed to either the restricted genetic advance that is due to the common ancestry and the limited genetic base of *Nicotiana tabacum* or the inherent inaccuracy of one trial at a single locality.

A combined analysis of data from the trial at Rustenburg and other similar trials at Groblersdal, Potgietersrus and Vaalwater was conducted so that accurate information could be arrived at for meaningful conclusions.

The combined analysis showed significant differences among the localities and among the entries. ODT92, ODT82, OD2 and OD1 produced significantly higher yields than TL33 across the four localities. However, the four elite breeding lines were not significantly different from each other. ODT82, ODT92 and OD2 gave significantly higher market income per hectare than TL33, but the three elite breeding lines did not differ significantly. The interaction between the localities and the entries were non-significant.

The Additive Main effects and Multiplicative Interaction (AMMI) analysis showed that the first Interaction Principal Component Analysis (IPCA1) was non-significant. However, the AMMI analysis predicted that ODT82 and ODT92 would be the best-adapted genotypes at Groblersdal, Potgietersrus and Rustenburg while ODT92 and OD2 would be the best-adapted genotypes at Vaalwater in productivity and economic viability.

ODT82 and ODT92 were recommended for on-farm trials at Groblersdal, Potgietersrus and Rustenburg. ODT92 and OD2 were recommended for on-farm trials at Vaalwater. The three elite breeding lines would undergo the on-farm trials pending their release as commercial cultivars at their respective localities.

A holistic approach to crop improvement in multiple locality experiments with designs that maximise genetic effects might be a panacea to experimental irregularities and low producer income levels that prohibit investment.

Research programmes may need to have linkages with the concerned industry, have clear research objectives and adhere to the acceptable procedures of recommendation development.

## Table of contents

Dedication	i
Acknowledgements	ii
Declaration	iv
Abstract	v
Table of contents	viii
List of abbreviations	xiv
CHAPTER 1 Introduction	1
CHAPTER 2 Literature review	5
CHAPTER 3 The conventional method of tobacco cultivar development	10
3.1 Desirable characters that need improvement in flue-cured tobacco	11
3.2 Problems encountered in flue-cured tobacco breeding	13
3.3 Crucial issues in tobacco cultivar development	14
3.4 Hybridization	14
3.5 Hybrid-breeding and cytoplasmic male sterility	17
3.6 Modern tobacco plant breeding and future prospects	19
3.7 Release of new tobacco cultivars	19
3.8 Maintenance of tobacco breeder-seed	20
3.9 Production and marketing of commercial tobacco seed	20
CHAPTER 4 Materials and methods	21
4.1 Background work	21
4.2 Current work	21
4.3 Tobacco nursery management	22
4.4 Land preparation	24
4.5 Transplanting	29
4.6 Field management	30
4.7 Field data collection	31

4.8	The visual evaluation of the elite breeding lines by the representatives of the tobacco industry	32
4.9	Harvesting of the tobacco leaf	32
4.10	Post-harvest management of the tobacco leaf	33
4.11	Statistical analyses of data	35
CHAPTER 5 Results and discussion		38
5.1	The field performance of the elite breeding lines in the Rustenburg trial	38
5.2	The market performance of the elite breeding lines in the Rustenburg trial	42
5.3	Genotype-locality interaction	44
5.3.1	Combined analysis of data from the four localities using the AGROBASE program	44
5.3.2	The AMMI analysis	45
CHAPTER 6 Conclusions and recommendations		51
Summary		54
Tables of results		57
Literature cited		72
Appendices		78
Illustrations		
AMMI Table 1	Table of the AMMI genotype selections for adaptability to particular localities in terms of yield according to Figure 5.1	47
AMMI Table 2	Table of the AMMI genotype selections for adaptability in particular localities in terms of income according to Figure 5.2	49
Appendix 1	Computer tabulated raw data on the field performance of the elite breeding lines and the control, TL33, at the ARC-TCRI in the 1998/1999 season	79

Appendix 2	Analysis of variance of the parameters of field performance of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	80
Appendix 3	An evaluation card used by the representatives of the tobacco industry in the field evaluation of the elite breeding lines at the ARC-TCRI	81
Appendix 4	Computer tabulated raw data of yields (kg/ha), quality components (leaf colours) and income (Rands/ha) of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	82
Appendix 5	Analysis of variance of the yields (kg/ha), quality components (leaf colours), grade indices (average prices in cents/kg) and income (Rands/ha) of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	83
Appendix 6	Computer tabulated raw data of the concentration of nicotine and reducing sugars of the leaves of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	84
Appendix 7	Analysis of variance of the concentration of nicotine and reducing sugars in the leaves of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	85
Appendix 8	Pictorial characteristic features of the ripe leaves of TL33 and the breeding lines; ODT82, ODT92 and OD2 as observed at the ARC-TCRI in the 1998/1999 season	86
Figure 1.1	Tobacco producing areas in South Africa	2
Figure 1.2	Contributions of different economic sectors to total GDP at current prices for the first three-quarters of 1998	3
Figure 4.1	Experimental field plan-Randomised design	28
Figure 4.2	Weather pattern at the ARC-TCRI during the 1998/1999 season	29
Figure 5.1	Plot of IPCA scores versus yield means for genotype and locality	47

Figure 5.2	Plot of IPCA scores versus income means (in tens) for genotype and locality	49
Schedule 4.1	Fertilizer application and disease and insect pest control programme used in the seed tray nursery	23
Schedule 4.2	Fertilizer application regime	31
Schedule 4.3	A guide to the curing procedure of flue-cured tobacco	34
Table 1.1	The decline in the local consumption of tobacco in South Africa from 1991 to 1992	4
Table 3.1	Some of the catastrophic tobacco diseases in South Africa and plant genetic resources for resistance	11
Table 3.2	Acceptable ranges of chemical concentrations in flue-cured tobacco leaf	13
Table 3.3	A typical conventional tobacco cultivar development programme in flue-cured tobacco	17
Table 4.1	The elite breeding lines and their pedigrees	22
Table 4.2	Results of soil chemistry analysis	25
Table 4.3	Average mineral removals (kg/ha) from the soil by a flue-cured tobacco crop	27
Table 4.4	Contribution of applied fertilizers to N, P and K levels (kg/ha) in the soil according to Schedule 4.2	27
Table 4.5	The treatment (T) numbers and the corresponding genotypes (G)	28
Table 5.1	Days to physiological maturity, Chlorophyll <i>a</i> fluorescence, plant height at topping and number of leaves per plant of the elite breeding lines	57
Table 5.2	Lengths, widths and areas of the second-bottom leaves of the elite breeding lines at the ARC-TCRI in 1998/1999 season	58
Table 5.3	Lengths, widths and areas of the tenth leaves of the elite breeding lines at the ARC-TCRI in 1998/1999 season	59

Table 5.4	Lengths, widths and areas of the eighteenth leaves of the elite breeding lines at the ARC-TCRI in 1998/1999 season	60
Table 5.5	Single-leaf areas and whole-plant leaf areas of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	61
Table 5.6	Total yield (kg/ha), dip or throwaway mass (percentage of total yield) and marketable yield (kg/ha) of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	62
Table 5.7	The correlation of the parameters of field performance of the elite breeding lines and the control, TL33, at the ARC-TCRI in the 1998/1999 season	63
Table 5.8	The visual evaluation of the elite breeding lines by the representatives of the tobacco industry in the referred 1997/1998 replicated trial at the ARC-TCRI	64
Table 5.9	The cured leaf quality components (expressed as percentages) of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	65
Table 5.10	The cured leaf quality components (nicotine and reducing-sugar concentrations of the leaf expressed as percentages) of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	66
Table 5.11	The grade indices (cents/kg), total income (Rands/ha) and market income (Rands/ha) of the elite breeding lines at the ARC-TCRI in the 1998/1999 season	67
Table 5.12	The mean yield (kg/ha), quality (cents/kg) and income (Rands/ha) of the elite breeding lines at all the four localities in the 1998/1999 season	68
Table 5.13	The mean marketable yield (kg/ha), quality (cents/kg) and market income (Rands/ha) from the AGROBASE combined analysis of variance for the data from the four localities in the 1998/1999 season	69



Table 5.14	The combined analysis of variance for marketable yield (kg/ha) data from the four localities in the 1998/1999 season -AMMI model	70
Table 5.15	The combined analysis of variance for market income (Rands/ha) data from the four localities in the 1998/1999 season - AMMI model	71



## List of abbreviations

AMMI	Additive Main effects and Multiplicative Interaction
ARC	Agricultural Research Council
CV	Coefficient of variation
DT	Dry bulb thermometer reading
DTES	District Trial Evaluation System
DTPM	Days to physiological maturity
FLES	Fixed Location Evaluation System
GM	General mean
Ha	Hectare
HR	Hours
IPCA	Interaction Principal Component Analysis
IPCA1	First Interaction Principal Component Analysis
IPCA1 <sub>G</sub>	Genotype First Interaction Principal Component Analysis
IPCA1 <sub>L</sub>	Locality First Interaction Principal Component Analysis
Kg	Kilograms
LA	Leaf area
LAN	Limestone ammonium nitrate
LL	Leaf length
LSD	Least significant difference
LW <sub>m</sub>	Maximum leaf width
M <sub>g</sub>	Genotypic means
MKTV	Magaliesburg Tobacco Growers' Cooperative
M <sub>l</sub>	Locality means
NLP	Number of leaves per plant
NS	Not significant
PHT	Plant height at topping
PTK	Potgietersrus Tobacco Growers' Cooperative
R	Rand (South African monetary unit)
Rep	Replication
RH	Relative humidity
SLA	Single leaf area
TCRI	Tobacco and Cotton Research Institute
TMV	Tobacco mosaic virus
WPLA	Whole plant leaf area
WT	Wet bulb thermometer reading
Y	Genotypic performance