GENETIC INVESTIGATION IN TWO F_2 POPULATIONS OF FLUE-CURED VIRGINIA (FCV) TOBACCO (*Nicotiana tabacum* L.)

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MA1TAD076

DEPARTMENT OF GENETICS AND PLANT BREEDING
COLLEGE OF AGRICULTURE, NAVILE
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SHIVAMOGGA - 577 225

2016

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Thesis submitted to the

UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA

In partial fulfillment of the requirements

for the award of the Degree of

Master of Science (Agriculture)

in

GENETICS AND PLANT BREEDING

SHIVAMOGGA JULY, 2016

DEPARTMENT OF GENETICS AND PLANT BREEDING
COLLEGE OF AGRICULTURE, NAVILE
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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC INVESTIGATION IN TWO F_2 POPULATIONS OF FLUE-CURED VIRGINIA (FCV) TOBACCO (*Nicotiana tabacum* L.)"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (Agriculture) in GENETICS AND PLANT BREEDING** to the University of Agricultural and Horticultural Sciences, Shivamogga, is a bonafide record of research work carried out by **Ms. SAMPURNA. D.**, during the period of study in this University under my guidance and supervision and this thesis has not previously formed the basis of the award of any other degree, diploma, associate ship, fellowship or any other similar titles.

Shivamogga
Date: JULY, 2016

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Affectionately dedicated to

My Beloved parents

Mr. Srinivas rao

Smt. Krishnaveni

My Sister

Annapurna

AND

My Brother

Shanth kumar

&

Chairperson

Dr. H. D. Mohan Kumar

ACKNOWLEDGEMENT

A journey is effortless when we travel together. Interdependence is definitely more valuable than independence. This thesis is the result of two years of work whereby I have been accompanied, supported and guided by many people. I would thus like to thank everyone who, knowingly or otherwise, has provided support, encouragement and assistance along the way.

I like to express my profound sense of gratitude to ***Dr. H.D. Mohan Kumar,*** *Chief Scientist, AINRPT, Shivamogga, esteemed chairman of my advisory committee. His didactic advice was instrumental in bringing out the present thesis. The most important was his much precious instruction at every step during my thesis work. I thank him for his creative guidance, creative criticism and constant encouragement throughout the period of study.*

I am grateful to the members of my advisory committee*,* ***Dr. B. M. Dushyantha Kumar****, Professor and Head, Department of Genetics and Plant Breeding,* ***Dr. S. P. Nataraju,*** *Professor, Department of Crop Physiology, College of Agriculture, Shimoga,* ***Dr. Basavaraj I. Halingali,*** *Associate professor, Department of Agricultural Statistics, College of Agriculture, Shivamogga and for their precious advice and timely suggestions during the period of research and for thesis manuscript. Also I intend to place on record my sincere heartfull thanks to* ***Dr. S. Ganga Prasad****, Professor, Department of Genetics and Plant Breeding and,* ***Dr. Pranesh****, Assistant professor (contract), Department of Genetics and Plant Breeding, for their valuable suggestions.*

On a personal note, I record my respectful indebtedness and gratitude to my beloved parents, ***Smt. Krishnaveni*** *and* ***Sri. Srinivas rao****, sister* **Annapurna** *and brother* **Shanth kumar** *whose love and affection have no equivalent and as an everlasting source of inspiration to me.*

The contribution of my Friends who open hearty spared their time and helped me in the completion of my research work touches my heart and I extend my heartfelt *thanks to them, especially to* ***megala, pooja, darshini, kavya, rashmi, rajeshwari, pradeep, harish, shankar, shilpa, kavita, akkamahadevi, rekha, savita, arifa*** *and* ***aruna.***

I am very much indebted to my beloved seniors, ***Abhiram****,* ***Netravati, Niranjan, Chetan, Nishanth, Raghavendra, Bhaganna, rekha, Sachin, Asha, Nandini*** *and* ***Sunil*** *for their invaluable technical guidance and immense cooperation. I really feel privileged and lucky to get those magnanimous hearts. Sincere appreciations and thanks to all staff members, my batch mate friends, juniors specially,* ***shubha, mega. H, chaitra, mega. G, jyothi, sheela, ashwini., lahari, navya, vittal, veerasena reddy, chandru*** *and other UG classmates, seniors and juniors to name a few from a ocean of friends in whose company I never felt my work a burden.*

I wish to express my sincere and heartfull thanks to Tobacco Scheme Workers ***chandrakala, rajappa****, also I would like to thank field assistant* ***Veerbhadrappa****,* ***Anil*** *and* ***suvarnamma*** *for their valuable support throughout study period.*

Also express my thanks to Sri Guru Raghavendra Digital copier and Sneha milana Xerox centre for thesis frame work and also to all the teaching and non teaching staff members.

Shivamogga

July, 2016 **(Sampurna D.)**

GENETIC INVESTIGATION IN TWO F_2 POPULATIONS OF FLUE-CURED VIRGINIA (FCV) TOBACCO (*Nicotiana tabacum* L.)

Sampurna.D.

ABSTRACT

The present investigation was carried out to elucidate the information on genetic variability, heritability, genetic advance, character association and path analysis in two F_2 populations and three parental cultivars of Flue cured virgina (FCV) tobacco. Two F_2 populations of the crosses, TB-70 × TB-102 and TB-100 × TB-102 and three parental cultivars *viz*., TB-70, TB-100 and TB-102 were evaluated at ZAHRS, Shivamogga during *kharif* 2015. Observations were recorded on fifteen characters. Descriptive statistical parameters were estimated which revealed wider range values for all the characters. High PCV, GCV were observed for the traits like specific leaf weight, leaf area per plant and total sugars in both the crosses. High heritability estimates were observed for all the characters investigated. The expected genetic gain expressed as per cent of mean was high for stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf area per plant and days to flowering in both the crosses. High heritability coupled with high genetic advance was noticed for stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf area per plant and days to flowering in both the crosses, indicating additive gene action in their genetic control. Correlation studies revealed significant correlation of green leaf yield with cured leaf yield followed by top grade equivalent, leaf area per plant and number of number of leaves per plant in both the crosses. The maximum possible direct effect on green leaf yield was exhibited by cured leaf yield in both the crosses. It can be concluded that selection of green leaf yield along with its component traits, particularly cured leaf yield, top grade equivalent, leaf area per plant and number of number of leaves per plant will be highly reliable for developing high yielding genotypes in further generations.

July, 2016

Department of Genetics and Plant Breeding
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Major advisor

ವರ್ಜೀನಿಯ ತಂಬಾಕು (ನಿಕೋಶಿಯಾನ ಟಬಾಕಮ್ ಲಿ.) ಬೆಳೆಯ ಎರಡು ಎರಡನೆ ಸಂತತಿಯಲ್ಲಿ ಅನುವಂಶೀಯ ಅಧ್ಯಯನ

ಸಂಪೂರ್ಣ, ಡಿ.

ಸಾರಾಂಶ

ವರ್ಜೀನಿಯ ತಂಬಾಕು ಬೆಳೆಯ ಎರಡು ಎರಡನೇ ಸಂತತಿ ಮತ್ತು ಮೂರು ಮೂಲ ತಂಬಾಕು ತಳಿಗಳ ಅನುವಂಶೀಯ ಭಿನ್ನತೆ, ಅನುವಂಶೀಯ ಸಾಮರ್ಥ್ಯ, ಅನುವಂಶೀಯ ಮುಂಚಲನ, ಗುಣಸಂಯೋಜನೆ ಮತ್ತು ಪಥವಿಶ್ಲೇಷಣೆಗಳ ಶೋಧನೆಯನ್ನು ಕೈಗೊಳ್ಳಲಾಗಿತ್ತು. 2015 ರ ಮುಂಗಾರಿನಲ್ಲಿ ವಲಯ ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ಸಂಶೋಧನಾ ಕೇಂದ್ರ, ಶಿವಮೊಗ್ಗದಲ್ಲಿ ಮೂರು ಮೂಲ ಹಾಗು (ಟಿಬಿ–70 X ಟಿಬಿ–102) ಮತ್ತು (ಟಿಬಿ–100 X ಟಿಬಿ–102) ಎರಡು ಸಂಕರಣಗಳನ್ನೊಳಗೊಂಡ ಎರಡನೆ ಸಂತಿಗಳ ಅಧ್ಯಯನವನ್ನು ನಡೆಸಲಾಗಿತ್ತು. ಹದಿನೈದು ಗುಣಗಳ ಮೇಲೆ ಅವಲೋಕನ ದಾಖಲಿಸಲಾಗಿತ್ತು. ಸಂಖ್ಯಾಶಾಸ್ತ್ರದ ವಿವರಣಾತ್ಮಕ ಸ್ಥಿರರಾಶಿಗಳ ಪ್ರಕಾರ ಎಲ್ಲಾ ಹದಿನೈದು ಗುಣಗಳು ವ್ಯಾಪಕವಾದ ಭಿನ್ನತೆಯನ್ನು ಹೊಂದಿರುತ್ತವೆ. ನಿರ್ಧಿಷ್ಟ ಎಲೆ ತೂಕ, ಒಂದು ಗಿಡದ ಎಲೆಯ ವಿಸ್ತೀರ್ಣ ಮತ್ತು ಸಕ್ಕರೆ ಅಂಶಗಳು ಅತಿ ಹೆಚ್ಚು ವ್ಯತ್ಯಾಸದ ವಿಭಿನ್ನವಾದ ಸಹಗುಣಾಂಕ (ಪಿ ಸಿ ವಿ) ಮತ್ತು ವ್ಯತ್ಯಾಸದ ವಂಶವಾಹಿ ಸಹಗುಣಾಂಕ (ಜಿ ಸಿ ವಿ)ಗಳನ್ನು ದಾಖಲಿಸಿರುತ್ತವೆ. ಸಂಶೋಧನೆ ಮಾಡಿದ ಎಲ್ಲಾ ಗುಣಗಳಲ್ಲಿ ಅನುವಂಶೀಯ ಸಾಮರ್ಥ್ಯ ಅತಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿರುತ್ತದೆ. ಕಾಂಡದ ಸುತ್ತಳತೆ, ಪತ್ರ ಹರಿತ್ತಿನ ಅಂಶ, ನಿರ್ಧಿಷ್ಟ ಎಲೆ ತೂಕ, ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಎಲೆಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡದ ಎಲೆ ವಿಸ್ತೀರ್ಣ ಮತ್ತು ಹೂ ಬಿಡುವ ದಿನಗಳು ನಿರೀಕ್ಷಿತ ಪ್ರಮಾಣದಲ್ಲಿ ಅನುವಂಶೀಯ ವೃದ್ಧೀಯು ಎರಡೂ ಸಂತತಿಯಲ್ಲಿ ಕಂಡುಬಂದಿರುತ್ತದೆ ಇದರಿಂದ ಸೇರ್ಪಡೆಕಾರಕ ವಂಶವಾಹಿ ಕ್ರಿಯೆಯು ಅನುವಂಶೀಯ ನಿಯಂತ್ರಣದಲ್ಲಿದೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ. ಕಾಂಡದ ಸುತ್ತಳತೆ, ಪತ್ರ ಹರಿತ್ತಿನ ಅಂಶ, ನಿರ್ಧಿಷ್ಟ ಎಲೆ ತೂಕ, ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಎಲೆಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡದ ಎಲೆ ವಿಸ್ತೀರ್ಣ ಮತ್ತು ಹೂ ಬಿಡುವ ದಿನಗಳು ಈ ಗುಣಗಳು ಅತಿ ಹೆಚ್ಚು ಅನುವಂಶೀಯ ಸಾಮರ್ಥ್ಯದ ಜೊತೆಗೆ ಅನುವಂಶೀಯ ಮುಂಚಲನವನ್ನು ಹೊಂದಿರುತ್ತವೆ. ಎರಡು ಸಂತತಿಯಲ್ಲಿ ಹಸಿರು ಎಲೆಯ ಇಳುವರಿಯು ಸಂಸ್ಕರಿಸಿದ ಎಲೆಯ ಇಳುವರಿ ಮತ್ತು ಉನ್ನತ ಶ್ರೇಣಿಗೆ ಸಮನಾಂತರ, ಪ್ರತಿ ಗಿಡದ ಎಲೆ ವಿಸ್ತೀರ್ಣ ಹಾಗು ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಎಲೆಗಳ ಸಂಖ್ಯೆಗಳಿಗೆ ಗಮನಾರ್ಹ ಸಂಬಂಧವನ್ನು ಹೊಂದಿರುತ್ತವೆ. ಎರಡು ಸಂತತಿಯಲ್ಲೂ ಹಸಿರು ಎಲೆಯ ಇಳುವರಿಯ ಮೇಲೆ ಸಂಸ್ಕರಿಸಿದ ಎಲೆಗಳ ಗುಣ ಅತ್ಯಂತ ಹೆಚ್ಚಿನ ಸಾಧ್ಯತೆಯ ನೇರ ಪರಿಣಾಮವನ್ನು ಹೊಂದಿರುತ್ತದೆ. ಈ ಸಂಶೋಧನೆಯಿಂದ ತಿಳಿಯುವುದೇನೆಂದರೆ ಹಸಿರು ಎಲೆಗಳ ಇಳುವರಿ ಮತ್ತು ಸಂಭಂಧಿತ ಗುಣಗಳು ವಿಶೇಷವಾಗಿ ಸಂಸ್ಕರಿಸಿದ ಎಲೆಗಳ ಇಳುವರಿ, ಉನ್ನತ ಶ್ರೇಣಿಗೆ ಸಮನಾಂತರ, ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಎಲೆಗಳ ಸಂಖ್ಯೆ ಮತ್ತು ಪ್ರತಿ ಗಿಡದ ಎಲೆ ವಿಸ್ತೀರ್ಣ ಈ ಗುಣಗಳ ಆಧಾರದ ಮೇಲೆ ಆಯ್ಕೆ ಮಾಡಿದಲ್ಲಿ ಮುಂದಿನ ಪೀಳಿಗೆಯಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಇಳುವರಿಯನ್ನು ನೀಡುವಂತಹ ತಳಿಗಳನ್ನು ಅಭಿವೃದ್ಧಿಪಡಿಸಬಹುದೆಂದು ತಿಳಿದುಬಂದಿದೆ.

ಜುಲೈ 2016

ಅನುವಂಶೀಯತೆ ಮತ್ತು ತಳಿ ಅಭಿವೃದ್ಧಿ ಶಾಸ್ತ್ರ

ಕೃಷಿ ಮಹಾವಿದ್ಯಾಲಯ, ನವಿಲೆ, ಶಿವಮೊಗ್ಗ.

H. D. [signature]

(ಹೆಚ್. ಡಿ. ಮೋಹನ್ ಕುಮಾರ್)

ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

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INTRODUCTION

I. INTRODUCTION

Tobacco (*Nicotiana tabacum* L.) is one of the world's most widely cultivated non-food commercial crop and is chosen by farmers in more than 120 countries because of its performance under widely varying climatic and soil conditions. India is one of the top ten countries cultivating tobacco (*Nicotiana* species) for domestic and international market. The major tobacco producing countries in the world are China, U.S.A., Brazil, India, Turkey and Bulgaria.

India is the only country where many different types of tobacco, *viz.,* flue-cured virginia (FCV), chewing, natu, cigar filler, cigar wrapper, cheroot, hookah, bidi and burley are grown under different agro-climatic conditions. Tobacco cultivation is mainly concentrated in Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu, Bihar, West Bengal and Uttar Pradesh, Karnataka being the third largest tobacco growing state and ranks second in FCV tobacco production.

Genus "Nicotiana" which belongs to family Solanaceae contains about sixty eight species of which only two species are cultivated *viz., Nicotiana tabacum* (L.) and *Nicotiana rustica*(L.). *Nicotiana tabacum* (L.) is the most commonly cultivated species. The Portuguese, about 400 years back, introduced this crop into India and has since been the life line for millions of people. Tobacco carries 48 chromosomes in its somatic cells (2n=48) and it is an unbranched annual plant growing to a height of three to six feet with long oval leaves and tap root system. The inflorescence in tobacco is terminal raceme. *Nicotiana tabacum* is a natural amphidiploid derived from hybridization between *N. sylvestris* and *N. tomentosiformis,* wild progenitor species (Gerstel, 1960 and Gerstel, 1963) and believed to be originated in tropical America (Akehurst, 1981). *Nicotiana tabacum* (L.) is cultivated throughout the world, but *N. rustica* is restricted to India, Russia and other Asian countries. Tobacco is normally self pollinated but is easy to cross pollinate also. Many genetic studies have been made with common tobacco (*N. tabacum)* and other species of genus nicotiana.

Tobacco is the only commercial non-food crop that enters world trade as a leaf and is priced for its aroma, taste and flavour. Tobacco is an important commercial crop in view of revenue generation, export earning and employment potential. It is aptly called as golden leaf (Anil, 2010). Tobacco provides livelihood security to 36 million people including 6 million farmers and 20 million farm labours engaged in tobacco farming besides 10 million people working in processing, manufacturing and exports. Annually, tobacco contributes ₹ 4,400 crores towards foreign exchange earnings accounting for 4 *per cent* of the country's total agriexports and ₹ 14,000 crores to excise revenue which is more than 10 *per cent* of the total excise revenue collection from all sources. It also produces nicotine sulphate which is used as an insecticide.

Tobacco seed contains 35-38 *per cent* nicotine free oil. It is used in making soap and colours. Its cake is used as a cattle feed. Cake contains 3 *per cent* N, 30-35 *per cent* crude protein and 20-27 *per cent* carbohydrates. Some species of tobacco are also utilized as an ornamental plant. Tobacco is claimed to be miracle crop because of its nature and properties, which is used for range of purposes right from narcotics, pesticides, stimulants and medicinal uses (Anil, 2010).

In India, tobacco is cultivated in an area of 0.45 M ha (0.27 % of the net cultivated area) producing ~ 750 M kg of tobacco leaf. India is the second largest producer and exporter after China and Brazil, respectively. The production of Flue Cured Virginia (FCV) tobacco is about 300 million kg from an area of 0.20 M ha. In the global scenario, Indian tobacco accounts for 10 *per cent* of the area and 9 *per cent* of the total production (Anon., 2015).

The low productivity of FCV tobacco in the state calls for identifying the breeding programmes to develop genotypes that have higher yield potential than the presently recommended varieties without sacrificing the quality. Thus there is need for involving new source material in the future breeding programmes, and when a new source material is to be involved, the prerequisite would be to estimate the genetic variability and related parameters to determine its worth as the source material for evolving improved varieties. Yield being a complex character is collectively influenced by various yield attributes which are polygenically inherited and highly subjected to environmental variation. Hence, in resorting to selection for yield, more emphasis needs to be considered on the attributes which are less influenced by environment.

Variability for different traits in the source population is a prerequisite for crop improvement, since all attempts of breeding and selection would be futile unless major portion of variability is heritable (Mruthunjaya and Mahadevappa, 1995). The measurement of genetic variation and mode of inheritance of quantitative and qualitative traits are of prime importance in planning the crop improvement programme efficiently and effectively. Heritability estimates provide information about the extent to which a particular character can be transmitted to the successive generations. Knowledge of heritability of a trait thus guides a plant breeder to predict behaviour of succeeding generations and helps in making desirable selections (Cheema *et al.*, 2006).

Most of the breeding programmes aimed at improving productivity have been directed towards hybridization followed by selection in segregating generations. Creation of variability by crossing between diverse parents and generating segregating population will give scope for assessing variability and studying association between characters. Early segregants express larger variability along with transgressive segregants.

Further, information on association of different characters with yield is very much essential as selection based on yield is very difficult when a large population is to be handled. If some visually appreciable characters like plant height, internodal length and number of leaves per plant are associated with yield, few plants could be selected first based on such characters and only those plant could be compared for yield to finally selecting promising genotypes. As quality is important in tobacco, and since it is very tedious and expensive to record quality characters in individual plants of a large population, information on association of quality characters with yield and the visually appreciable characters become more important in this crop.

Based on the situations explained in the foregoing paragraphs, the present investigation was undertaken by involving two F_2 populations, along with their parents with the following objectives:

1. To study the genetic variability, heritability and genetic advance for agronomic traits.

2. To assess correlation and path analysis for component characters of leaf yield.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Basic need for any breeding activity is variability. However, the improvement that can be brought about in a character depends entirely on the magnitude of the genetic variability for that character and its heritability. Success in breeding programmes can be achieved through understanding the extent of variability present in population and analyzing that into genetic and non-genetic causes and also due to interaction between these factors. Improving the plant type by effecting selection in a germplasm will not have long lasting effects, for which, early segregating populations are more desirable. A brief review of literature on the research work carried out in relation to the present investigation in flue-cured virginia (FCV) tobacco and related crops is presented under the following headings in this chapter.

2.1 Reviews on Genetic variability, heritability and genetic advance

2.2 Reviews on Correlation studies and path coefficient analysis

2.1 Reviews on Genetic variability, heritability and genetic advance

2.1.1 Reviews on Genetic variability, heritability and genetic advance in tobacco

Sastry and Gopinath (1968) in their genetic variability studies in natu tobacco reported that plant height has exhibited high values of genetic coefficient of variability (GCV) and heritability. Days to 50 percent flowering and leaf length exhibited low values of genetic coefficient of variability and genetic advance. The traits like number of leaves per plant and leaf breadth showed high heritability with medium genetic coefficient of variability and genetic advance.

Venkatarao *et al*. (1973) in their study on genetic variability and heritability in 28 flue cured tobacco introductions for the characters plant height, flowering time, curable leaf number, leaf length, leaf width, yields of green leaf and cured leaf reported that high GCV, GA and heritability values were obtained for cured leaf yields, while green leaf yield showed medium GCV and GA values. Plant height showed high GA and heritability. Low values of GCV and GA were obtained for flowering time, leaf length and width, indicating that the range of variability for these characters is less in the material studied.

Kim and Hwang (1981) in a study for heritability estimates involving six pure lines of aromatic tobacco varieties observed high heritability for number of leaves. However, the heritability for days to 50 *per cent* flowering was moderate.

Ibrahim and Avratovscukova (1982) in their study to determine the phenotypic and genotypic variation among five flue cured tobacco varieties(R 1349, LHSE, Virginia 71, Coker 139 and Virginia 31) with respect to flowering time, plant height, leaf length and width, number of leaves per plant and yield of fresh leaves reported that the highest genetic coefficient of variation (GCV) was observed for green leaf yield and plant height, whereas, flowering time and leaf length exhibited the lowest GCV. High heritability estimates were obtained for all characters. The expected genetic advance as percentage of mean was high for green leaf yield and plant height, moderate for number of leaves per plant and leaf breadth and low for flowering time and leaf length. A high heritability estimate associated with high GA for green leaf yields and plant height. Flowering time and leaf length exhibited high heritability estimates despite low values of both GCV and GA. Number of leaves per plant and leaf breadth showed high heritability estimates with values of GCV and GA.

Amarnath (1987) studied analysis of variance for different characters in chewing tobacco and reported highly significant differences for all the characters studied. Cured leaf yield showed medium genotypic coefficient of variation, and characters like leaf length and breadth recorded high percentage of heritability.

Dobhal (1987) studied 25 genotypes of cigar wrapper tobacco and observed high values of genetic coefficient of variability with high heritability and genetic advance for leaf width, leaf number, plant height and internodal length. Genetic advance values were low for leaf length and days to 50 *per cent* flowering.

Dobhal and Nageswara Rao (1988) studied 55 genotypes of rustica types and observed low genetic variability for leaf number and internodal length. High genotypic coefficient of variability was observed for cured leaf yield. Moderate to high heritability and genetic advance for cured leaf yield, plant height, internode length and days to flowering were also reported.

Dobhal and Dilip (1989) in their evaluation of genetic variability for yield and quality traits in germplasm lines of hookah and chewing tobacco reported that the magnitude of phenotypic coefficient of variability (PCV) was greater than corresponding GCV for all the traits *viz.*, days to flowering and cured leaf yield, suggesting major contribution of environmental factors for the expression of these traits. Low values of heritability coupled with low genetic advance for all the characters were also reported.

Rao (1989) studied variability for different traits in 42 genotypes of cigar filler tobacco and reported high genetic variability for number of leaves per plant.

Chaubey *et al*. (1990) in a study of variability in hookah tobacco reported highly significant differences among cultivars for all the traits studied except for cured leaf yield. The genotypes showed high range of variation for different characters. Number of leaves per plant and fresh leaf weight showed more GCV, whereas, cured leaf weight showed very low GCV , pointing out the necessity of creating variability for this attribute. Plant height and number of leaves per plant had high heritability as well as high genetic advance.

Lakshmish (1997) in their variability studies in diverse collections of FCV tobacco reported moderate values of phenotypic coefficient of variability for number of leaves per plant, leaf area per plant. High phenotypic coefficient variability values were observed for plant height, fresh leaf yield, cured leaf yield and top grade equivalent. Low genotypic coefficient of variability values were reported for number of leaves per plant, leaf area per plant, while moderate genotypic coefficient of variability was reported for plant height, fresh leaf yield, cured leaf yield and top grade equivalent. Number of leaves per plant, cured leaf yield, top grade equivalent and leaf area per plant had moderate heritability values with moderate genetic advance but fresh leaf yield had moderate heritability and high genetic advance, while, high heritability with high genetic advance was reported for plant height.

Rehman and Qureshi (1997a) in their study of genetic variability in four tobacco accessions reported that phenotypic coefficient of variability was higher for internodal distance, plant height, leaf yield and leaf size whereas GCV for leaf thickness and number of leaves per plant was low.

Rehman and Qureshi (1997b) conducted an experiment to study the variability in eight tobacco genotypes and observed high heritability estimates and high values of GA for plant height, leaf size and cured leaf yield indicating importance for additive gene action.

Hosseinzadeh *et al*. (2006) studied genetic variability in Oriental tobacco varieties and reported that broad sense heritability was highest for days to 50 per cent flowering and plant height.

Nagesh and Rangaiah (2008) in their study of genetic variability observed significant difference between genotypes included in their study and it revealed wide range variability and high heritability for all the characters *viz*., plant height, internodal length, leaves per plant, leaf length and leaf area, indicating additive gene action for these traits.

Syed *et al.* (2008) in their evaluation of some genotypes in FCV tobacco for genetic variability revealed highly significant differences between them for traits like plant height and number of leaves per plant.

Belul and Halit (2010) in their study of nature of inheritance in tobacco reported that additive genetic variance appeared to be more important in the inheritance of yield, leaf number and days to flower, while non-additive genetic variance appeared to play a greater role in the inheritance of leaf size and plant height.

Imtiaz *et al.* (2014) in their variability studies in varieties of FCV tobacco reported highly significant differences among varieties for plant height, and non-significant differences for number of leaves.

Sheraz *et al.* (2014) in their study of genetic variability in fifteen varieties of FCV tobacco revealed highly significant differences among the genotypes for plant height.

Katba *et al.* (2014) in their study of genetic variability in forty genotypes of tobacco reported highly significant differences for all the characters studied. High GCV and PCV were observed for cured leaf yield, days to flowering and number of leaves per plant. While moderate variability was observed for days to maturity, leaf length and leaf breadth. High heritability coupled with high genetic advance as per cent of mean was observed for all the characters studied.

Shah *et al*. (2015) in their F_2 population studies in FCV tobacco observed low to high magnitude of heritability for number of leaves per plant and medium to low heritability was observed for green leaf yield and cured leaf yield.

Suman *et al.* (2015) in their study of genetic variability, heritability and genetic advance in forty genotypes in rustica tobacco revealed significant differences among genotypes for all the characters studied. The moderate values of PCV and GCV, high genetic advance coupled with high heritability were observed for cured leaf yield, days to flowering, number of leaves per plant, plant height and leaf width.

2.1.2 Reviews on Genetic variability, heritability and genetic advance in related crops

Ghosh *et al.* (2010) in their study of genetic variability in F_2 populations of commercial tomato hybrids reported significant differences among genotypes. Very little differences were observed between PCV and GCV for the traits days to flowering, fruit length and fruit diameter. High heritability was observed for all the yield contributing characters except flowers per cluster.

Mogali and Sharanappa (2014) in their variability studies in F_2 population of tomato , reported highest GCV for fruits per plant and lowest GCV for 50 *per cent* flowering. While highest PCV was recorded for number of fruits per plant and lowest PCV was recorded for days to flowering. Highest heritability along with high GAM was recorded for number of fruits per plant, whereas lowest heritability along with high GAM was recorded for days to 50 *per cent* flowering.

2.2 Reviews on Correlation studies and path coefficient analysis

2.2.1 Reviews on Correlation studies

2.2.1.1 Reviews on Correlation studies in tobacco

Elliot and Birch (1958) in their study of chemical composition in various commercial grades of Canadian flue-cured tobacco reported that the total sugars had significant positive correlation with leaf yield.

Sastry and Gopinath (1969) in their correlation studies in natu tobacco noticed positive association between number of leaves per plant and plant height.

Hamid *et al*. (1975) in their correlation studies in tobacco found that leaf number, leaf length and leaf width were positively and significantly correlated with each other, and each showed high positive association with leaf yield.

Lukosevicius (1975) in their genetic studies in cigar tobacco reported that the highest positive correlation with yield was observed for the traits like days to flowering followed by leaf number. However negative correlation was observed between yield and grade index.

White *et al*. (1979) in their correlation studies in flue-cured Virginia tobacco observed significant correlation of dry leaf yield with days to flowering, leaf width and leaf number per plant.

Jung *et al*. (1980) in their evaluation of yield stability in flue-cured tobacco observed highly significant and positive correlation between yield and other characters *viz*., days to flowering, leaf area per plant and length of largest leaf in tobacco.

Kim and Hwang (1981) in their correlation studies in aromatic tobacco varieties observed positive correlation between yield and plant height. The same phenomenon was observed with days to flowering and number of leaves.

Patel *et al.* (1981) in their association studies in flue-cured Virginia tobacco noticed positive association of cured leaf yield with plant height, leaf number, leaf length, leaf breadth and leaf area per plant. The correlation coefficient of days to flowering with cured leaf yield was not significant and negative.

Ghulam and Mushtaq (1982) in their investigation of yield components in tobacco, reported significant positive correlation of yield with plant height and leaf index. Plant height was positively correlated with days to flowering, number of curable leaves per plant and leaf index. They also reported negative correlation of yield with days to flowering and number of curable leaves.

Kamel *et al*. (1985) studied phenotypic, genotypic and environmental correlations for different pairs of some characters contributing to leaf yield in flue cured tobacco. The characters *viz*., plant height, leaf number per plant, leaf length and leaf width exhibited positive and significant phenotypic correlations between themselves and leaf yield.

Smalcelt and Vasilji (1987) in their correlation studies in *Nicotiana tabacum,* found that the yield was positively correlated with leaf size and leaf length.

Dobhal and Nageshwara Rao (1988) in their character association studies in hookah and chewing tobacco observed the days to flowering, leaf length and width, curable leaf number were positively associated with cured leaf yield. Leaf length was positively associated with leaf width and curable leaf number and negatively with days to flowering. They also reported that curable leaf number was negatively associated with internode length.

Chaubey *et al.* (1990) in their association studies of leaf yield in hookah tobacco observed that cured leaf weight showed positive association with all the traits viz., plant height, days to flowering, stem girth, number of leaves per plant, leaf length, leaf width and fresh leaf weight per plant, and leaf width in turn was negatively associated with plant height and number of leaves per plant. Remaining traits had positive association to each other except leaf width with days to flowering and fresh leaf weight.

Janardhan and Nataraju (1990) in their path analysis study for yield in FCV tobacco found that the leaf area per plant had positive and greater degree of correlation with cured leaf yield.

Kara and Essendal (1996) in their correlation and path analysis studies for yield and yield components in Turkish tobacco observed that cured leaf yield was positively correlated with leaf area per plant and leaf width.

Rehman and Qureshi (1997b) in their correlation studies in tobacco accessions found that yield was positive and significantly associated with plant height, internodal length and leaf size.

Lakshmish and shivanna (1999) in their study of correlation and path analysis in FCV tobacco found that cured leaf yield was significantly and positively correlated with plant height, number of leaves per plant, fresh leaf yield, top grade equivalent and leaf area per plant.

Honarnejad and Shoai-deylami (2004) in their correlation studies of F_2 population in Burley tobacco observed significant correlation between dry leaf yield leaf area index and time to flowering.

Wenping *et al.* (2009) in correlation studies in tobacco germplasm found positive and significant correlations of dry leaf yield with leaf length and leaf number.

Association studies of yield component characters in tobacco F_2 population conducted by Hamid *et al.* (2011) revealed that the dry leaf yield was positively and significantly correlated with all the traits studied viz., fresh leaf yield, plant height, leaf number, leaf width, leaf length, stem girth and days to flowering. Significant and positive correlation was observed between plant height and all other traits except for leaf length and leaf width.

Mohammad (2012) in his correlation studies in 49 tobacco genotypes reported high positive and significant correlation of fresh leaf yield with number of leaves, leaf length, leaf width, leaf area index, plant height and days to flowering.

Ramchandra *et al.* (2014) in their correlation studies in 62 genotypes of bidi tobacco reported that leaf yield was positively and significantly correlated with plant height, number of leaves, leaf length, leaf breadth, leaf area and internodal length.

Sheraz *et al.* (2014) in their character association studies in fifteen varieties of FCV tobacco reported that yield was significantly correlated with plant height.

Suman *et al.* (2015) in their correlation studies in forty genotypes in rustica tobacco revealed positive and significant correlation of cured leaf yield with days to flowering, number of leaves per plant, plant height, leaf length, leaf width and days to maturity.

2.2.1.2 Reviews on Correlation studies in related crops

Kamani and Monpara (2006) in their correlation studies in F_2 generation of two brinjal crosses found that fruit per plant exhibited positive correlation with fruit yield per plant, fruit weight and fruit girth and negative association with fruit length only in one cross. Whereas association between fruit weight and fruit yield was significantly positive in both the crosses.

Ghosh *et al.* (2010) in their character association studies in F_2 populations of commercial tomato hybrids observed significant positive genotypic and phenotypic correlation of fruit yield per plant with plant height at first flowering, flowers per plant, fruits per cluster, fruit clusters per plant and fruits per plant.

Shende *et al.* (2014) conducted an experiment on correlation involving fifteen F_2 populations and eight parents and revealed positive and highly significant correlation of fruit yield per plant with number of fruits per cluster and number of fruits per plant at genotypic level.

2.2.2 Reviews on Path coefficient analysis

2.2.2.1 Reviews on Path coefficient analysis in tobacco

Venkatarao *et al*. (1973) conducted studies on the direct and indirect effects of plant height, curable leaf number, leaf length and width on the yield of green leaf and cured leaf yield in the Virginia tobacco. Curable leaf number and leaf width showed high direct effects on the yield of green and cured leaf. Indirect effects involving these characters were also higher than those involving plant height and leaf length. The plant height gave negative non-significant correlation with yield and its direct effect was also negative, but gave positive indirect effect through curable leaf number, which was much higher than its indirect effects through other characters. Curable leaves gave significant correlation with yield. Its direct effect was higher than the indirect effects. Leaf length gave nonsignificant positive correlation with green leaf yield and negative correlation with cured leaf yield. Its indirect effect on green leaf yield was more through leaf width, whereas that on cured leaf yield was more through curable leaf number with regard to curable leaf yield, the indirect effect through curable leaf number was more than the direct effect.

Panikar and Gopalaswamy (1976) in their path analysis studies reported low effect of plant height on the cured leaf yield of flue Virginia tobacco. Plant height had significant positive association with cured leaf weight and it had considerable direct as well as indirect effects through leaf area per plant on cured leaf yield. The number of leaves per plant having significant moderate association with cured leaf yield but this trait did influence moderately the cured leaf yield through plant height.

Path analysis study in tobacco by Keum and Jeh (1981) revealed that the number of leaves harvested and leaf width had a direct effect on yield.

Patel *et al.* (1981) in their path analysis studies in FCV tobacco reported that the leaf area per plant had high positive association with cured leaf yield and it also revealed very high direct influence on cured leaf yield. Leaf number showing moderate significant association with cured leaf yield had weak influence on leaf yield

Dobhal and Nageshwara Rao (1988) in their character association studies in hookah and chewing tobacco reported high positive direct effect of leaf width, curable leaf number and internode length on cured leaf yield and also reported that on the basis of direct and indirect effects of the characters, leaf length and width and curable leaf number were the strongest forces influencing cured leaf yield.

Krishnamurthy *et al.* (1989) reported that the correlation coefficients and direct effect of yield traits *viz*., green and cured leaf yield were negative.

Chaubey *et al.* (1990) in their path analysis studies of leaf yield traits in hookah tobacco reported that cured leaf weight showed positive association with all traits. Fresh leaf weight which ultimately affects cured leaf weight was exerting substantial direct effect. Its indirect effect was also positive. Number of leaves per plant had high positive association with cured leaf yield and also it had a substantial positive direct effect at phenotypic level but negative at genotypic level.

Cho and Chang (1990) in their study of path analysis of yield characters in tobacco reported that leaf length, leaf width, days to flowering and number of leaves per plant had exhibited strong direct effects on leaf yield. Leaf length and days to flowering exhibited high indirect effects on leaf yield via other characters.

Path analysis by Kara and Essendal (1996) for yield and yield components in Turkish tobacco revealed that leaf area per plant had high direct effect on cured leaf yield, followed by number of leaves per plant.

Rehman and Qureshi (1997b) in path analysis studies in tobacco reported that leaf size had maximum effect on cured leaf yield. High indirect contribution was also seen via plant height by most of the yield components.

Path analysis by Lakshmish and Shivanna (1999) in FCV tobacco revealed that leaf area per plant had high positive direct effect on cured leaf yield. Top grade equivalent had a moderate direct effect. Plant height and fresh leaf yield had a low direct effect, and number of leaves per plant, fresh leaf yield and top grade equivalent registered high positive indirect influence through leaf area per plant on cured leaf yield.

Honarnejad and Shoai-deylami (2004) found that number of leaves per plant and plant height had no direct effect on dry leaf yield.

Xiao *et al*. (2007) in their genetic studies in FCV tobacco found significant direct effect of plant height, stem girth, leaf number, leaf length and leaf width on total sugar content of tobacco leaf.

Wenping *et al*. (2009) in their path analysis study in FCV tobacco reported that fresh leaf yield had direct significant effect on dry leaf yield.

Hamid *et al.* (2011) in their study of direct and indirect effects of yield component characters in tobacco F_2 population, revealed that among all the traits studied fresh leaf yield produced highest direct effect on dry leaf yield. Stem girth, leaf width and plant height had moderate direct effect on dry leaf yield.

Path analysis studies in 49 tobacco genotypes by Mohammad (2012) showed significant direct effect of dry leaf yield with fresh leaf yield and number of leaves. Significant indirect effect of fresh leaf yield with dry leaf yield via plant height and leaf area index was also reported.

Ramchandra *et al.* (2014) in their path analysis studies in 62 genotypes of bidi tobacco revealed direct effect of number of leaves and leaf breadth on leaf yield, while indirect effect on leaf yield via plant height, leaf length and leaf area was also reported. Days to flowering and plant height showed negative direct effect on leaf yield but plant height exhibited positive indirect effects via number of leaves, leaf breadth and internodal length.

Suman *et al.* (2015) in their path analysis studies in forty genotypes in rustica tobacco revealed positive direct and significant association of cured leaf yield with leaf length, plant height and days to flowering.

2.2.2.2 Reviews on Path coefficient analysis in related crops

Ghosh *et al.* (2010) in their path analysis studies in F_2 populations of commercial tomato hybrids observed highest positive direct effect of fruit yield per plant with fruits per plant followed by flowers per plant, fruits per cluster and individual fruit weight. Negative direct effect of yield per plant with flowers per cluster, fruit clusters per plant, fruit diameter, days to first flowering, plant height at first flowering, branches per plant and fruit length was also observed.

Shende *et al.* (2014) conducted an experiment on path analysis involving fifteen F_2 populations and eight parents and revealed that length of fruit, number of fruits per cluster, plant height, days to last picking, average weight of fruit and number of fruits per plant has maximum direct and indirect effects on fruit yield.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 EXPERIMENTAL SITE

The present field experiment was carried out at College of Agriculture, Navile, Shivamogga during *Kharif* season of 2015.

3.2 EXPERIMENTAL MATERIAL

The material for the present study comprised of two F_2 populations derived from crosses TB-70 × TB-102 and TB-100 × TB-102 and three parents TB-70, TB-100 and TB-102 of FCV tobacco. Parent material was obtained from CTRI Rajahmundry.

3.3 CLIMATIC CONDITIONS

The present investigation was carried out during 2015, *kharif* season at the College of Agriculture, Shivamogga, Karnataka which is geographically situated between 13^o 27' to 14^o 39' N latitude and 74^o 37' to 75^o 52' E longitude with an altitude of 650 m above the MSL. Shivamogga is situated in Southern transition Zone (Zone –7). A total rainfall of 1232.8 mm was received during the year of investigation. The monthly rainfall received at Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga, during 2015-16 is presented in Appendix 1. The highest rainfall occurred in the month of June (294.8 mm) followed by September (214.4 mm). The soil of experimental site belongs to sandy loam textural class with the soil class of *Typic Haplustalf*. The soil was low in available Nitrogen, high in available phosphorous and medium in available potassium (Sunil, 2014).

3.4 EXPERIMENTAL LAYOUT

Seedlings were grown in the nursery on the raised seed beds. The seedlings of F_2 populations of two crosses TB-70 × TB-102 and TB-100 × TB-102 and their parents were planted with a spacing of 90 x 60 cm during *kharif* 2015. Crop was raised as per the recommended package of practices.

3.5 SAMPLING AND OBSERVATIONS

F_2 population is normally highly variable, as they will be segregating for genes at each loci for which parents differ. Leaves were harvested by priming method as and when they assume yellowish green colour. Six pickings were done for harvesting of all curable leaves. The pre and post harvest observations as mentioned below were recorded on 150 plants selected at random from each F_2 population and 15 plants in case of parent varieties. The details of method adopted for recording observations are presented here under.

3.5.1 Plant height (cm): Height of the plant was measured in centimeters at maturity from the base of the plant to the tip of the plant of randomly selected plants.

3.5.2 Internodal length (cm): Internodal length was calculated by taking average of 3 internodal lengths per plant.

3.5.3 Stem girth (mm): Stem girth was measured using digital vernier calipers and recorded in millimeter as the thickness of the stem at the first internode from the base of the plant.

3.5.4 Number of leaves per plant: Total number of curable leaves in a plant were counted from randomly selected plants in each genotype and recorded as leaves per plant.

3.5.5 Leaf length (cm): The length of all curable leaves in a plant was measured and expressed in centimeters. The average length of leaves in randomly selected plants was calculated.

3.5.6 Leaf breadth (cm): The breadth of all curable leaves in a plant was measured and expressed in centimeters. The average breadth of leaves in randomly selected plants was calculated.

3.5.7 Leaf area per plant (dm^2): Leaf area of all curable leaves from randomly selected plants was measured by adopting Stickler's linear measurement method (Stickler and Pauli, 1961) as given below. The multiplying factor for tobacco leaves is 0.6345 (Suggs *et al.,* 1960).

Leaf area per plant was calculated and expressed in dm^2 (decimeter square)

Leaf area (dm^2) = L x B x 0.6345

Where, L = maximum length of leaf (dm),

B = maximum breadth of leaf (dm)

3.5.8 Days to flowering: The number of days taken for the emergence of first flowers in plants from the date of sowing was recorded.

3.5.9 Days to maturity: It was recorded as the number of days taken from sowing to more than 90 per cent capsules in each genotype turning their colour from green to yellow or brown.

3.5.10 Chlorophyll content: Chlorophyll content was recorded using Chlorophyll Content Meter. Selected leaf of tobacco was clamped avoiding the mid rib region into the sensor head of Chlorophyll Content Meter. A gentle stroke was given to record the reading and the average of such five strokes per leaflet was considered. The values recorded by Chlorophyll Content Meter are unit less.

3.5.11 Specific leaf weight (mg cm^{-2}): The specific leaf weight (SLW) indicates the average leaf thickness and was determined by the method suggested by Radford (1967). Specific leaf weight was expressed in milligram per cm^2.

$$\text{SLW (mg cm}^{-2}\text{)} = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

3.5.12 Green leaf yield (kg/ha): The weight of freshly harvested curable leaves before curing was recorded as fresh leaf yield.

3.5.13 Cured leaf yield (kg/ha): The weight of leaves after curing was recorded as cured leaf yield.

3.5.14 Top grade equivalent (TGE) (kg/ha): The weight of top graded and quality leaves among cured leaves.

3.5.15 Total sugars: Total sugars in the leaf was estimated by using anthrone reagent method (Sadasivam and Manickam, 1992). From the standard graph, the amount of total sugars present was calculated using the formula:

$$\text{Amount of total sugars in the sample(\%)} = \frac{\text{mg of total sugars (value from graph)}}{\text{mg of test sample}} \times 100$$

3.6 STATISTICAL ANALYSIS

3.6.1 Descriptive Statistics

The following descriptive statistics was calculated as per Sunder Raj *et al*. (1972).

3.6.1.1 Mean

Mean is the sum of all observations in sample divided by the number of observations (n).

Mean = $\sum Xi / n$

Where, $\sum Xi$ = i^{th} observation of a population.

N = number of observation.

3.6.1.2 Range

Range is the minimum and maximum values of the observations in a sample.

3.6.1.3 Standard Error

It is the measure of uncontrolled variation present in a sample. This is estimated by dividing the standard deviation by square root of number of observations in the sample and is denoted by SE.

Thus, SE = $SD / \sqrt{n}$

Where, SD = Standard deviation and n = Number of observations.

3.6.1.4 Variance

Variance is defined as the average of the squared deviation of individual observation from the mean or it is the square of standard deviation. It is expressed as the sum of squares of the deviations of all observations of a sample from mean and divided by (n-1), where n is the number of observations. It is estimated by following formula,

$$\text{Variance} = \frac{\sum Xi2 - (\sum Xi)2/n}{n-1}$$

Where,

X_i = i^{th} observation of a population

n = number of observations

3.6.1.5 Standard deviation (SD)

Standard deviation is a measure of the dispersion of a set of data from its mean. Standard deviation is calculated as the square root of variance.

$$SD = \sqrt{Variance} = \frac{\sum d2}{n}$$

Where,

d = deviation of individual value from mean

n = Number of observations

3.6.2 Components of variance

Phenotypic and genotypic components of variance were computed according to the formula given by Lush (1949). The total variance of observations for a character in F_2 was considered as its phenotypic variance. The environmental variance for each character was estimated from the mean variance of the non-segregating parental population.

$$1) \quad V_e = \frac{V_{p1} + V_{p2}}{2}$$

Where,

V_e is environmental variance

Vp_1 is the variance of parent 1

Vp_2 is the variance of parent 2

The genotypic variance was separated from the total phenotypic variance by subtracting the environmental variance as per the method of Weber and Murthy (1952).That is,

$$2) \quad V_g = V_p - V_e$$

Where,

V_g is the genotypic variance

V_p is the phenotypic (total) variance

V_e is the environmental variance

3.6.3 Coefficients of Variation

The co-efficient of variability both at phenotypic and genotypic levels for all the characters were computed by applying the formula as suggested by Burton and De Vane (1953).

3.6.3.1 Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sigma_g}{\bar{x}} \times 100$$

3.6.3.2 Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sigma_p}{\bar{x}} \times 100$$

Where,

$\bar{x}$ = General mean

σ_p = Phenotypic standard deviation

σ_g = Genotypic standard deviation

GCV and PCV were classified as suggested by Robinson *et al.* (1949) into Low (0 - 10%), Moderate (10.1% - 20%) and High (>20%).

3.6.4 Heritability (h^2)

Heritability in broad sense for all the characters was computed by the formula suggested by Lush (1945).

$$h^2 = \frac{V_g}{V_p} \times 100$$

Where,

h^2 = Heritability per cent (Broad sense)

V_g = Genotypic variance

V_p = Phenotypic variance

The heritability was classified as suggested by Robinson *et al.* (1949) into Low (0 - 30%), Moderate (30.1% - 60%) and High (>60%).

3.6.5 Genetic advance (GA)

Predicted genetic advance

The predicted genetic advance was estimated according to the formula given by Johnson *et al.* (1955).

Genetic advance (GA) = $k \times h^2 \times \sigma_p$

Where,

K= Selection differential at given intensity

h^2= Broad sense heritability

σ_p= Phenotypic standard deviation

3.6.6 Genetic Advance as per cent mean (GAM)

The expected GA as per cent of mean (GAM) was estimated as given below

$$\text{Expected GAM} = \frac{\text{GA}}{\overline{\text{X}}} \times 100$$

Where,

GA = Genetic advance

$\overline{X}$ = Grand mean for the character

The genetic advance as per cent of mean was categorized as suggested by Johnson *et al.* (1955) into, Low (0 - 10%), Moderate (10.1% - 20%) and High (20% and above)

3.6.7 Correlation co-efficient

To determine the degree of association of characters with yield and also among the yield components, the correlation coefficients were calculated. Phenotypic coefficients of correlation between two characters were determined by using variance and covariance components as suggested by Al- Jibouri *et al.* (1958).

$$r_p\ (xy) = \frac{Cov_p\ (xy)}{(\sqrt{Var_x}) \times (\sqrt{Var_y})}$$

Where,

r_p (xy) is the phenotypic correlation coefficient.

Cov_p is the phenotypic co-variances of x and y.

Var_x and Var_y are the phenotypic variance of x and y.

The calculated value of 'r' was compared with 't' table value with n-2 degree of freedom at 5% and 1% level of significance where ' n' refers to number of pairs of observations.

3.6.8 Path coefficient analysis

Path coefficient analysis was carried out using the phenotypic correlation coefficients to know the direct and indirect effects of the yield components on yield following the method suggested by Wright (1921) and as illustrated by Dewey and Lu (1959).

The standard path coefficients, which are nothing but the standardized partial regression coefficients were obtained by solving the following set of 'P' simultaneous equations through the use of 'DOO-LITTLE TECHNIQUE' as described by Goulden (1959).

$P_{01} + P_{01} r_{12} +$ ----------------------------- $+ P_{op} r_{1p} = r_{o1}$

$P_{02} + P_{02} r_{22} +$ ----------------------------- $+ P_{op} r_{2p} = r_{o2}$

$P_{01} r_{1p} + P_{02} r_{2p} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + P_{op} = r_{op}$

Where,

P_{01}, P_{02} -------------P_{op} are the direct path coefficients of variables 1, 2, 3, -----p on the dependent variable 0.

r_{12}, r_{13}…….r_{1p},…$r_{p(p-1)}$ are possible correlation coefficients between various independent variables, and r_{01}, $_{02}$………..r_{op} are the correlations between dependent and independent variables. The indirect effect of i^{th} variable *via* the j^{th} variable was obtained as (P_{oj} x r_{ij}).

The contribution of the remaining unknown factors is measured as the residual factor, which is calculated as given below.

$P^2_{ox} = 1 - [P^2_{01} + 2P_{01} P_{02} r_{12} + 2P_0 P_{03} r_{13} + \ldots\ldots + P^2_{02} + 2P_{02}P_{03} r_{13} + \ldots + P^2_{op}]$

Residual factor = $\sqrt{p^2_{Ox}}$.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The present investigation was carried out with the aim of estimating the genetic variability parameters, correlation between different quantitative characters and path analysis for different characters related to yield and its attributing traits in two F_2 populations of FCV tobacco. The experimental results obtained in the present investigation are presented in this chapter under the following broad headings.

4.1 Descriptive statistical parameters of fifteen quantitative characters in two F_2 populations and parents.

4.2 Genetic variability studies of two F_2 populations.

4.3 Association analysis through correlation coefficient analysis.

4.4 Path coefficient analysis.

4.5 Identification of desirable transgressive segregants for green leaf yield.

4.1 Descriptive statistical parameters of fifteen quantitative characters in two F_2 populations and parents.

The descriptive statistical parameters viz., mean, range, skewness and kurtosis with respect to all the 15 quantitative characters in F_2 population of two crosses of FCV tobacco viz., TB-70 × TB-102 and TB-100 × TB-102 are tabulated in Table 1 and Table 2 and are briefly presented below:

4.1.1 Plant height (cm)

Plant height ranged from 25 to 100 cm with a mean of 71.74 cm in the population TB-70 × TB-102. The parental means were 47.80 cm (TB-70) and 47.47 cm (TB-102). The frequency distribution for this trait was platykurtic (0.988) and negatively skewed (-0.77) (Fig. 1).

In the population TB-100 × TB-102, it ranged from 40 to 80 cm with a mean of 70.43 cm. The parental means were 36.13 cm (TB-100) and 47.47 cm (TB-102). The frequency distribution for this trait was platykurtic (0.297) and negatively skewed (-1.052) (Fig. 1).

Table 1: Descriptive statistical parameters for fifteen quantitative characters in F_2 population derived from cross TB-70 × TB-102 of FCV tobacco

Character	Mean ± SE	RANGE		Skewness	Kurtosis
		Min	Max		
X_1	71.74 ± 1.16	25.00	100.00	-0.77	0.988
X_2	3.75 ± 0.05	2.50	5.67	0.114	-0.024
X_3	25.12 ± 0.37	12.30	35.64	-0.011	-0.080
X_4	14.24 ± 0.32	6.60	25.90	0.511	-0.186
X_5	4.10 ± 0.13	1.75	20.25	6.85	6.85
X_6	12.04 ± 0.18	5.00	18.00	-0.12	0.630
X_7	44.93 ± 0.47	28.61	58.53	-0.457	0.460
X_8	24.89 ± 0.21	15.30	30.58	-0.487	0.741
X_9	8986.12 ± 209.14	2499.93	16097.90	-0.153	-0.190
X_{10}	122.56 ± 1.3	96.00	162.00	0.345	0.51
X_{11}	157.98 ± 1.26	126.00	195.00	0.160	0.128
X_{12}	9532.83 ± 181.46	3907.41	16703.70	-0.28	0.029
X_{13}	1440.34 ± 27.56	593.93	2547.31	0.002	0.080
X_{14}	1005.35 ± 19.35	416.64	1804.77	0.018	0.129
X_{15}	14.14 ± 0.38	4.20	24.70	-0.084	-0.546

X_1- Plant height (cm)

X_2- Internodal length (cm)

X_3- Stem girth (mm)

X_4-chlorophyll content

X_5- Specific leaf weight (mg/cm^2)

X_6- No. of leaves per plant

X_7- Leaf length (cm)

X_8- Leaf breadth (cm)

X_9- Leaf area per plant (dm^2)

X_{10}- Days to flowering

X_{11}- Days to maturity

X_{12}- Green leaf yield (Kg/ha)

X_{13}- Cured leaf yield (Kg/ha)

X_{14}- Top Grade Equivalent (Kg/ha)

X_{15}-Total sugar(%)

Table 2: Descriptive statistical parameters for fifteen quantitative characters in F_2 population derived from cross TB-100 × TB-102 of FCV tobacco

Character	Mean ± SE	RANGE		Skewness	Kurtosis
		Min	Max		
X_1	70.43 ± 0.93	40.00	85.00	-1.052	0.297
X_2	2.54 ± 0.04	1.33	3.83	-0.075	-0.991
X_3	25.10 ± 0.27	10.72	32.47	-0.410	1.080
X_4	4.37 ± 0.088	2.50	8.25	0.856	1.234
X_5	16.95 ± 0.54	3.70	42.30	1.176	2.316
X_6	11.06 ± 0.17	5.00	18.00	-0.099	0.411
X_7	51.54 ± 0.45	37.36	62.00	-0.334	-0.445
X_8	28.34 ± 0.24	19.82	38.23	0.219	0.800
X_9	103.344 ± 1.989	49.212	192.488	0.198	0.625
X_{10}	131.98 ± 1.27	94.00	168.00	-0.313	0.779
X_{11}	170.80 ± 1.32	128.00	213.00	-0.228	0.484
X_{12}	7968.27 ± 162.73	2648.15	12037.04	-0.155	-0.653
X_{13}	1204.27 ± 24.76	403.84	1829.63	-0.151	-0.655
X_{14}	840.41 ± 17.29	280.27	1296.29	-0.159	-0.648
X_{15}	12.46 ± 0.34	4.10	21.80	0.173	-0.764

X_1- Plant height (cm)

X_2- Internodal length (cm)

X_3- Stem girth (mm)

X_4-chlorophyll content

X_5- Specific leaf weight (mg/cm^2)

X_6- No. of leaves per plant

X_7- Leaf length (cm)

X_8- Leaf breadth (cm)

X_9- Leaf area per plant (dm^2)

X_{10}- Days to flowering

X_{11}- Days to maturity

X_{12}- Green leaf yield (Kg/ha)

X_{13}- Cured leaf yield (Kg/ha)

X_{14}- Top Grade Equivalent (Kg/ha)

X_{15}-Total sugar (%)

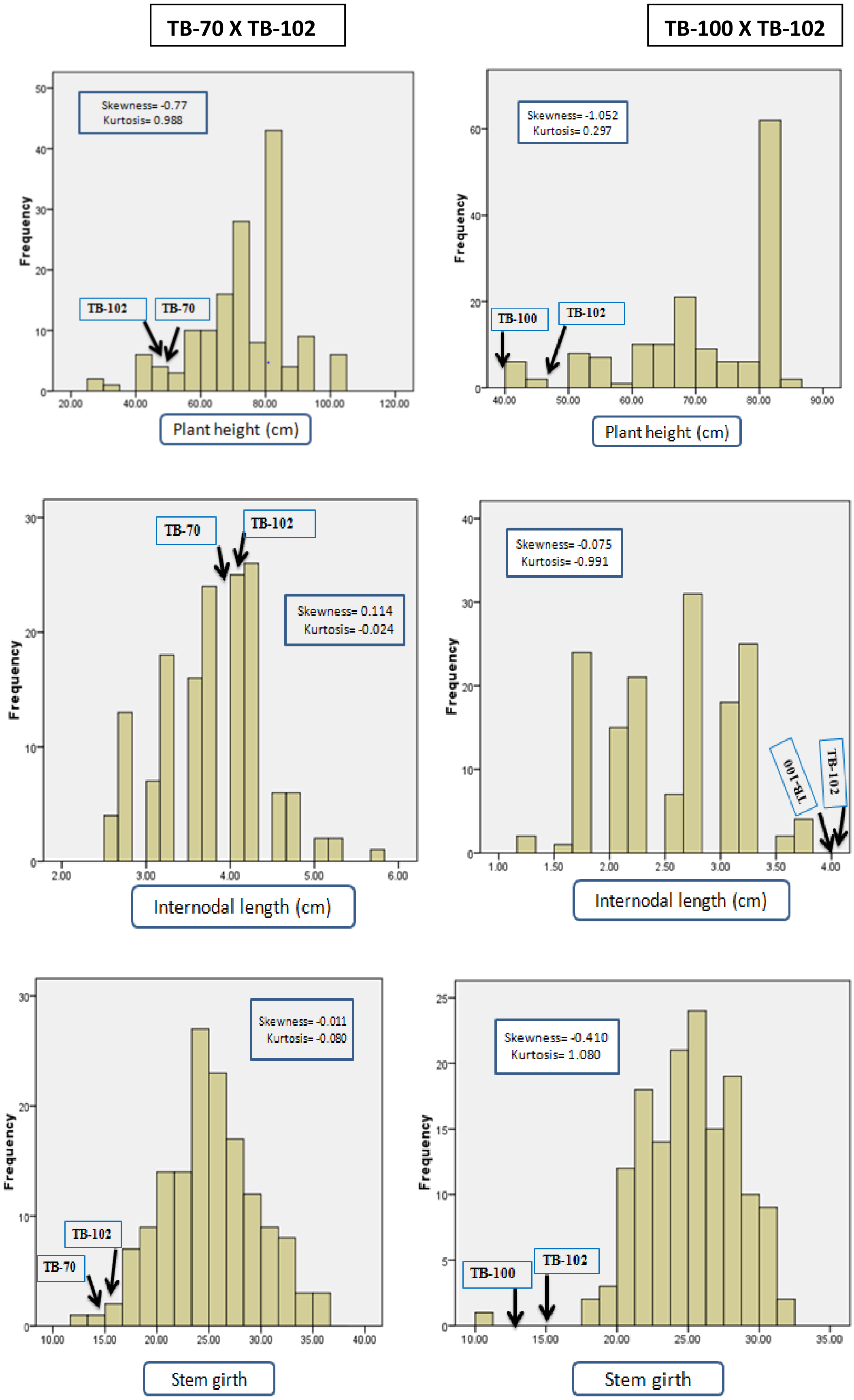

Fig. 1: Frequency distribution of F_2 population of the crosses 'TB-70×TB-102' and 'TB- 100×TB-102' for plant height, internodal length and stem girth.

4.1.2 Internodal length (cm)

Internodal length varied from 2.50 to 5.67 cm with a mean of 3.75 cm in the population TB-70 × TB-102. The parental means were 3.93 cm (TB-70) and 4.24 cm (TB-102). The frequency distribution for this trait was platykurtic (-0.024) and positively skewed (0.114) (Fig. 1).

In the population TB-100 × TB-102, it varied from 1.33 to 3.83 cm with a mean of 2.54 cm. The parental means were 4.01 cm (TB-100) and 4.24 cm (TB-102). The frequency distribution for this trait was platykurtic (-0.991) and negatively skewed (-0.075) (Fig. 1).

4.1.3 Stem girth (mm)

Stem girth ranged between 12.30 to 35.64 mm with a mean of 25.12 mm in the population TB-70 × TB-102. The parental means were 14.84 mm (TB-70) and 15.06 mm (TB-102). The frequency distribution for this trait was platykurtic (-0.080) and negatively skewed (-0.011) (Fig. 1).

In the population TB-100 × TB-102, it ranged between 10.72 to 32.47 mm with a mean of 25.10 mm. The parental means were 13.54 mm (TB-70) and 15.06 mm (TB-102). The frequency distribution for this trait was platykurtic (1.080) and negatively skewed (-0.410) (Fig. 1).

4.1.4 Chlorophyll content

Chlorophyll content ranged from 6.60 to 25.90 with a mean of 14.24 in the population TB-70 × TB-102. The parental means were 22.65 (TB-70) and 28.89 (TB-102). The frequency distribution for this trait was platykurtic (-0.186) and positively skewed (0.511) (Fig. 2).

In the population TB-100 × TB-102, it ranged between 2.50 to 8.25 with a mean of 4.37. The parental means were 22.87 (TB-70) and 28.89 (TB-102). The frequency distribution for this trait was platykurtic (1.234) and positively skewed (0.856) (Fig. 2).

4.1.5 Specific leaf weight (mg/ cm^2)

Specific leaf weight varied between 1.75 to 20.25 mg/ cm^2 with a mean of 4.10 mg/ cm^2 in the population TB-70 × TB-102. The parental means were

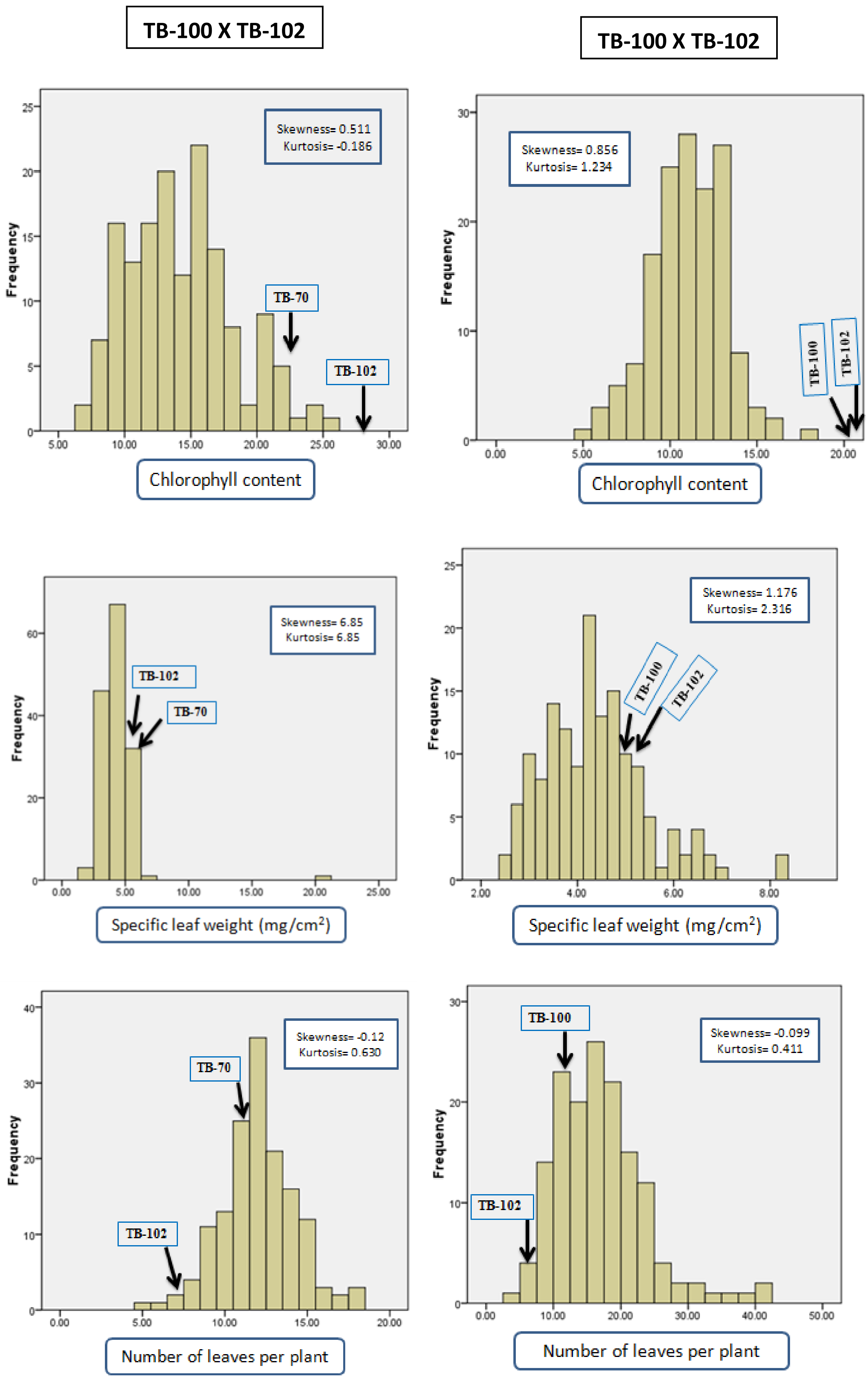

Fig. 2: Frequency distribution of F_2 population of the crosses 'TB-70×TB-102' and 'TB-100×TB-102' for chlorophyll content, specific leaf weight and number of leaves per plant.

5.78 mg/ cm^2 (TB-70) and 5.20 mg/ cm^2 (TB-102). The frequency distribution for this trait was leptokurtic (6.85) and positively skewed (6.85) (Fig. 2).

In the population TB-100 × TB-102, it ranged between 3.70 to 42.30 mg/ cm^2 with a mean of 16.95 mg/ cm^2. The parental means were 5.05 mg/ cm^2 (TB-70) and 5.20 mg/ cm^2 (TB-102). The frequency distribution for this trait was platykurtic (2.316) and positively skewed (1.176) (Fig. 2).

4.1.6 Number of leaves per plant

Number of leaves per plant ranged from 5.00 to 18.00 with a mean of 12.04 in the population TB-70 × TB-102. The parental means were 11.20 (TB-70) and 7.53 (TB-102). The frequency distribution for this trait was platykurtic (0.630) and negatively skewed (-0.12) (Fig. 2).

In the population TB-100 × TB-102, it ranged from between 5.00 to 18.00 with a mean of 11.06. The parental means were 11.00 (TB-70) and 7.53 (TB-102). The frequency distribution for this trait was platykurtic (0.411) and negatively skewed (-0.099) (Fig. 2).

4.1.7 Leaf length (cm)

Leaf length ranged from 28.61 to 58.53 cm with a mean of 44.93 cm in the population TB-70 × TB-102. The parental means were 28.95 cm (TB-70) and 31.32 cm (TB-102). The frequency distribution for this trait was platykurtic (0.460) and negatively skewed (-0.457) (Fig. 3).

In the population TB-100 × TB-102, it ranged from 37.36 to 62.00 cm with a mean of 51.54 cm. The parental means were 26.91 cm (TB-70) and 31.32 cm (TB-102). The frequency distribution for this trait was platykurtic (-0.445) and negatively skewed (-0.334) (Fig. 3).

4.1.8 Leaf breadth (cm)

Leaf breadth varied from 15.30 to 30.58 cm with a mean of 24.89 cm in the population TB-70 × TB-102. The parental means were 14.39 cm (TB-70) and 18.02 cm (TB-102). The frequency distribution for this trait was platykurtic (0.741) and negatively skewed (-0.487) (Fig. 3).

In the population TB-100 × TB-102, it ranged from 19.82 to 38.23 cm with a mean of 28.34 cm. The parental means were 12.94 cm (TB-70) and 18.02 cm

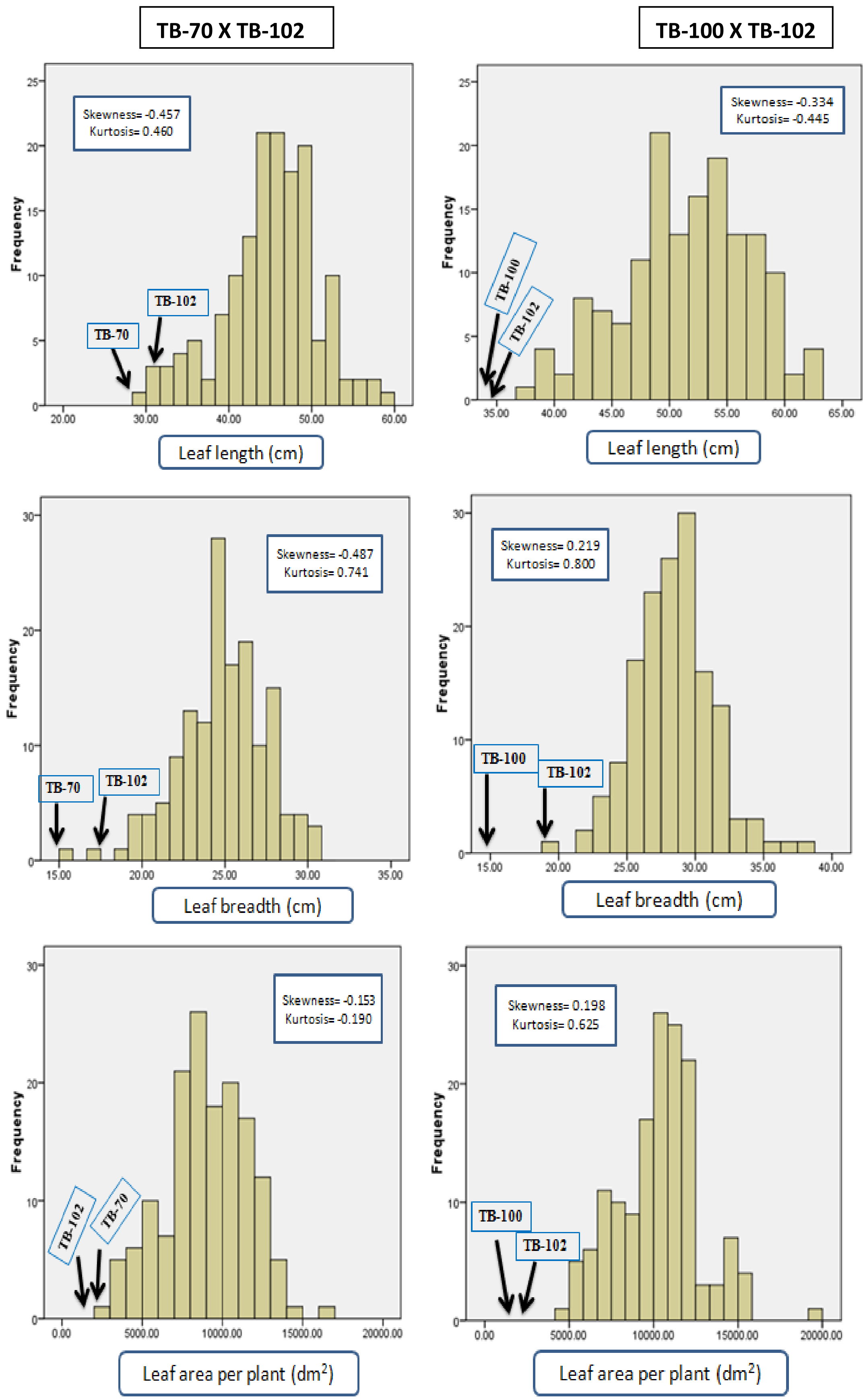

Fig. 3: Frequency distribution of F_2 population of the crosses 'TB-70×TB-102' and 'TB- 100×TB-102' for leaf length, leaf breadth and leaf area per plant.

(TB-102). The frequency distribution for this trait was platykurtic (0.8) and positively skewed (0.219) (Fig. 3).

4.1.9 Leaf area per plant (dm^2)

Leaf area per plant varied between 24.99 to 160.97 dm^2 with a mean of 89.86 dm^2 in the population TB-70 × TB-102. The parental means were 31.07 dm^2 (TB-70) and 28.88 dm^2 (TB-102). The frequency distribution for this trait was platykurtic (-0.190) and negatively skewed (-0.153) (Fig. 3).

In the population TB-100 × TB-102, it ranged between 49.21 to 192.48 dm^2 with a mean of 103.34 dm^2. The parental means were 25.29 dm^2 (TB-70) and 28.88 dm^2 (TB-102). The frequency distribution for this trait was platykurtic (0.625) and positively skewed (0.198) (Fig. 3).

4.1.10 Days to flowering

Days to flowering ranged from 96 to 162 with a mean of 122.56 in the population TB-70 × TB-102. The parental means were 97.93 (TB-70) and 118.07 (TB-102). The frequency distribution for this trait was platykurtic (0.51) and positively skewed (0.345) (Fig. 4).

In the population TB-100 × TB-102, it ranged from 94 to 168 with a mean of 131.98. The parental means were 115.20 (TB-70) and 118.07 (TB-102). The frequency distribution for this trait was platykurtic (0.779) and negatively skewed (-0.313) (Fig. 4).

4.1.11 Days to maturity

Days to maturity varied between 126 and 195 with a mean of 157.98 in the population TB-70 × TB-102. The parental means were 135.67 (TB-70) and 154.47 (TB-102). The frequency distribution for this trait was platykurtic (0.128) and positively skewed (0.160) (Fig. 4).

In the population TB-100 × TB-102, it ranged from 128 to 213 with a mean of 170.80. The parental means were 152.40 (TB-70) and 154.47 (TB-102). The frequency distribution for this trait was platykurtic (0.484) and negatively skewed (-0.228) (Fig. 4).

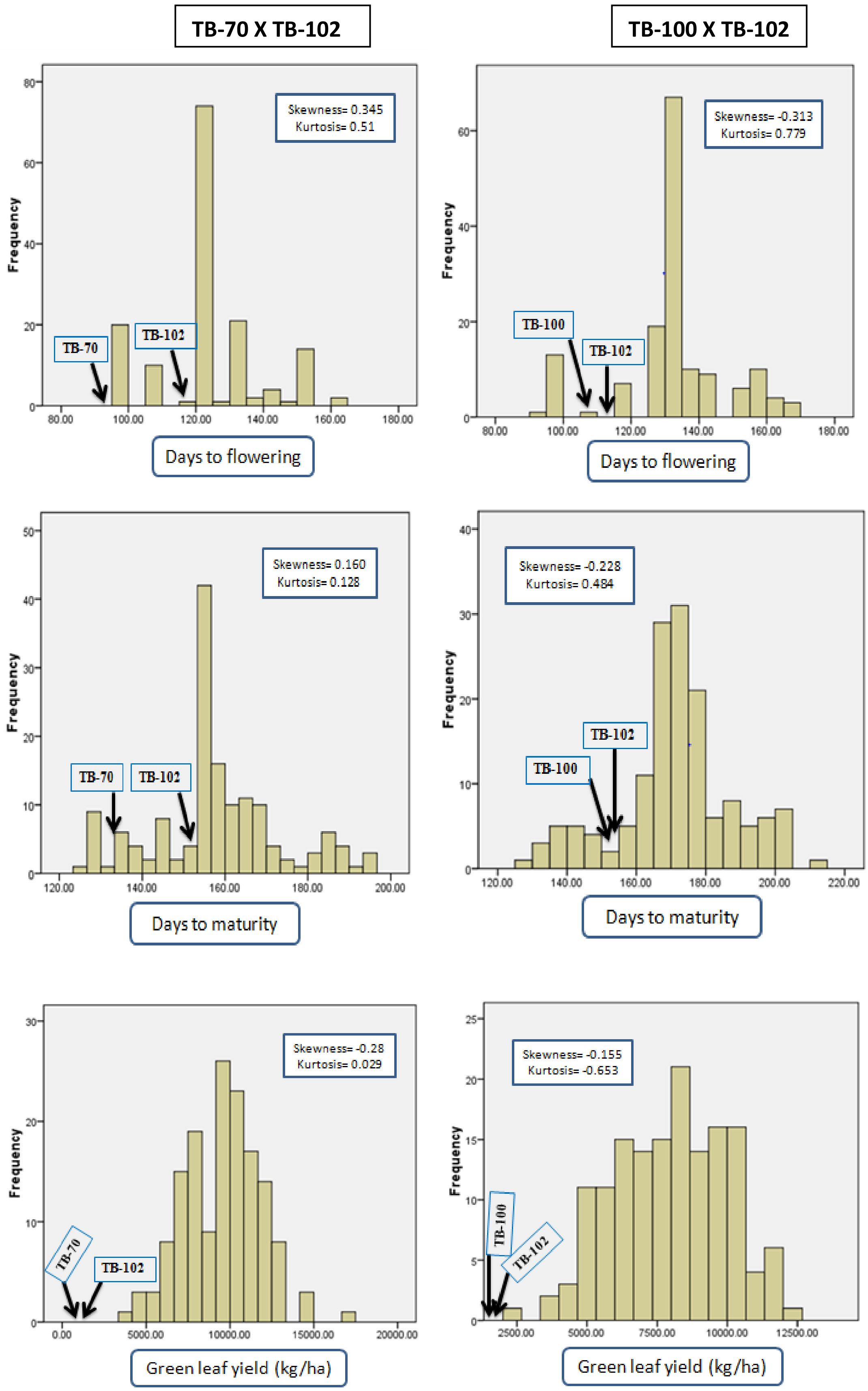

Fig. 4: Frequency distribution of F_2 population of the crosses 'TB-70×TB-102' and 'TB- 100×TB-102' for days to flowering, days to maturity and green leaf yield.

4.1.12 Green leaf yield (Kg/ha)

Green leaf yield ranged from 3907.41 to 16703.70 kg/ha with a mean of 9532.83 kg/ha in the population TB-70 × TB-102. The parental means were 1409.95 kg/ha (TB-70) and 1264.87 kg/ha (TB-102). The frequency distribution for this trait was platykurtic (0.029) and negatively skewed (-0.28) (Fig. 4).

In the population TB-100 × TB-102, it ranged between 2648.15 to 12037.04 kg/ha with a mean of 7968.27 kg/ha. The parental means were 1199.30 kg/ha (TB-70) and 1264.87 kg/ha (TB-102). The frequency distribution for this trait was platykurtic (-0.653) and negatively skewed (-0.155) (Fig. 4).

4.1.13 Cured leaf yield (Kg/ha)

Cured leaf yield ranged from 593.93 to 2547.31 kg/ha with a mean of 1440.34 kg/ha in the population TB-70 × TB-102. The parental means were 213.95 kg/ha (TB-70) and 190.57 kg/ha (TB-102). The frequency distribution for this trait was platykurtic (0.080) and positively skewed (0.002) (Fig. 5).

In the population TB-100 × TB-102, it ranged between 403.84 to 1829.63 kg/ha with a mean of 1204.27 kg/ha. The parental means were 181.89 kg/ha (TB-70) and 190.57 kg/ha (TB-102). The frequency distribution for this trait was platykurtic (-0.655) and negatively skewed (-0.155) (Fig. 5).

4.1.14 Top Grade Equivalent (Kg/ha)

Top Grade Equivalent varied between 416.64 to 1804.77 kg/ha with a mean of 1005.35 kg/ha in the population TB-70 × TB-102. The parental means were 149.04 kg/ha (TB-70) and 132.78 kg/ha (TB-102). The frequency distribution for this trait was platykurtic (0.129) and positively skewed (0.018) (Fig. 5).

In the population TB-100 × TB-102, it ranged between 280.27 to 1296.29 kg/ha with a mean of 840.41 kg/ha. The parental means were 126.79 kg/ha (TB-70) and 132.78 kg/ha (TB-102). The frequency distribution for this trait was platykurtic (-0.648) and negatively skewed (-0.159) (Fig. 5).

4.1.15 Total sugars (%)

Total sugars ranged from 4.20 to 24.70 *per cent* with a mean of 14.14 *per cent* in the population TB-70 × TB-102. The parental means were 16.13 % (TB-70) and

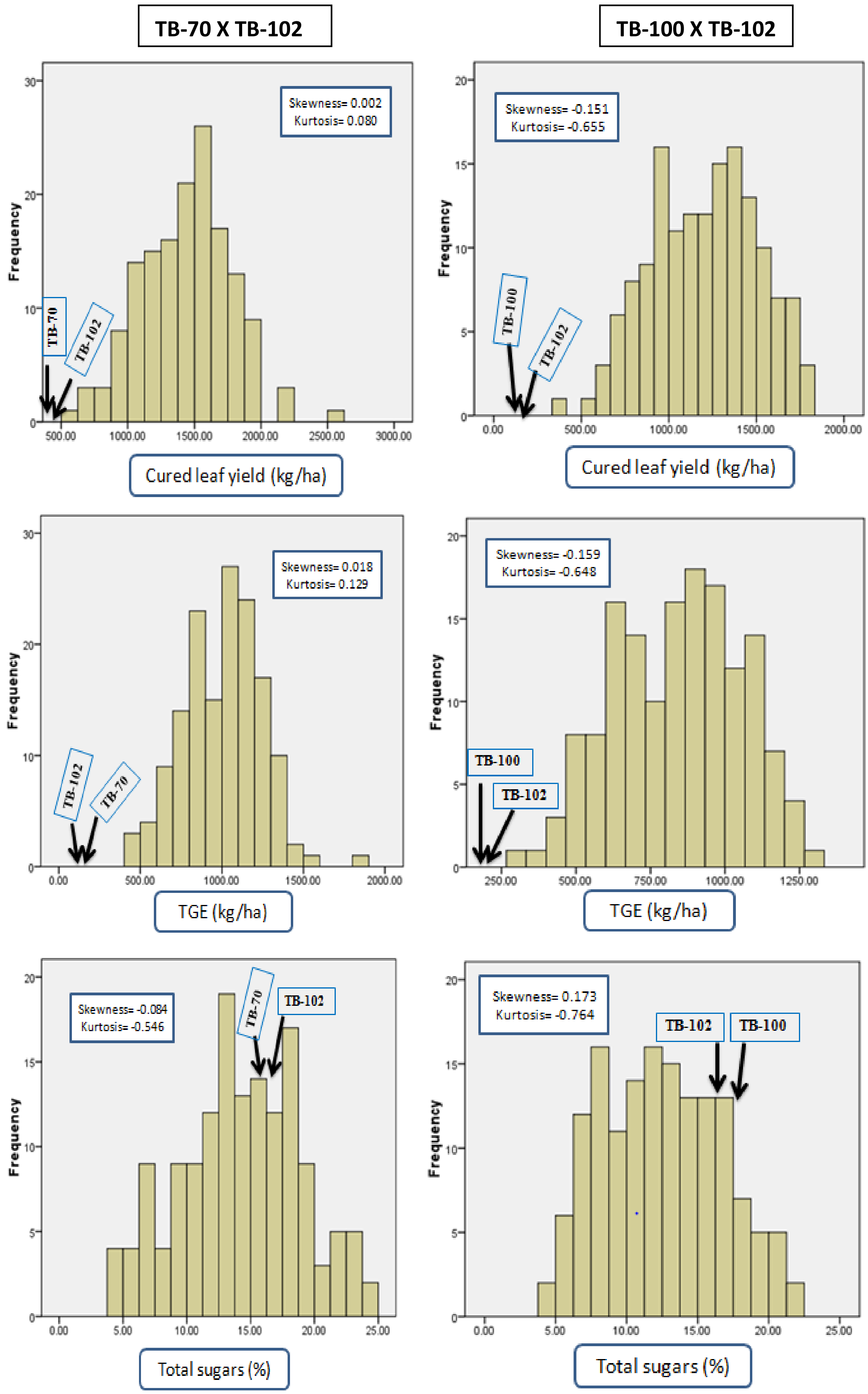

Fig. 5: Frequency distribution of F_2 population of the crosses 'TB-70×TB-102' and 'TB-100×TB-102' for cured leaf yield, Top Grade Equivalent (TGE) and total sugars.

16.44 *per cent* (TB-102). The frequency distribution for this trait was platykurtic (-0.546) and negatively skewed (-0.084) (Fig. 5).

In the population TB-100 × TB-102, it ranged between 4.10 to 21.80 *per cent* with a mean of 12.46 *per cent*. The parental means were 17.35 *per cent* (TB-70) and 16.44 *per cent* (TB-102). The frequency distribution for this trait was platykurtic (-0.764) and positively skewed (0.173) (Fig. 5).

4.2 Genetic variability studies of two F_2 populations.

Variability parameters *viz.,* phenotypic co-efficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability (h^2) and genetic advance as per cent of mean (GAM) in respect of green leaf yield and its attributing characters in two F_2 populations of FCV tobacco *viz*., 'TB-70 × TB-102' and 'TB-100 × TB-102'are tabulated in Table 3 and Table 4 and are briefly outlined below.

4.2.1 Plant height (cm)

The PCV and GCV values were moderate (19.91 *per cent* and 17.20 *per cent*, respectively) for plant height in the population TB-70 × TB-102. Estimates of broad sense heritability (74.64 *per cent*) and genetic advance as per cent of mean (30.61 *per cent*) were high.

In the population TB-100 × TB-102, the PCV and GCV values are moderate (18.54 *per cent* and 13.39 *per cent*, respectively) for plant height. Estimates of broad sense heritability (52.17 *per cent*) and genetic advance as per cent of mean (19.92 *per cent*) were high and moderate, respectively.

4.2.2 Internodal length (cm)

The PCV and GCV values were high (47.62 *per cent* and 41.09 *per cent,* respectively) for internodal length in the population TB-70 × TB-102. Estimates of broad sense heritability (74.48 *per cent*) and genetic advance as per cent of mean (73.06 *per cent*) were also high.

In the population TB-100 × TB-102, the PCV and GCV values were low (1.85 *per cent* and 1.75 *per cent,* respectively) for internodal length. Estimates of broad sense heritability (89.35 *per cent*) and genetic advance as per cent of mean (3.40 *per cent*) were high and low, respectively.

Table 3: Variability parameters for fifteen quantitative characters in F_2 population derived from cross TB-70 × TB-102 of FCV tobacco

Character	PCV (%)	GCV (%)	h^2_{bs} (%)	GA as per cent mean (%)
X_1	19.91	17.20	74.64	30.61
X_2	47.62	41.09	74.48	73.06
X_3	18.24	14.06	59.47	22.34
X_4	28.08	24.73	77.55	44.86
X_5	39.18	33.03	71.06	57.36
X_6	18.93	15.52	67.26	26.23
X_7	12.93	8.64	44.61	11.89
X_8	11.07	9.43	72.59	16.55
X_9	28.50	27.41	92.48	54.30
X_{10}	13.03	12.88	97.71	26.22
X_{11}	9.79	9.45	93.27	18.81
X_{12}	3.12	2.85	83.23	5.35
X_{13}	7.41	6.90	86.55	13.22
X_{14}	7.46	6.94	86.60	13.30
X_{15}	33.53	25.90	59.68	41.22

X_1- Plant height (cm)

X_2- Internodal length (cm)

X_3- Stem girth (mm)

X_4-chlorophyll content

X_5- Specific leaf weight (mg/cm^2)

X_6- No. of leaves per plant

X_7- Leaf length (cm)

X_8- Leaf breadth (cm)

X_9- Leaf area per plant (dm^2)

X_{10}- Days to flowering

X_{11}- Days to maturity

X_{12}- Green leaf yield (Kg/ha)

X_{13}- Cured leaf yield (Kg/ha)

X_{14}- Top Grade Equivalent (Kg/ha)

X_{15}-Total sugar(%)

Table 4: Variability parameters for fifteen quantitative characters in F_2 population derived from cross TB-100 × TB-102 of FCV tobacco

Character	PCV (%)	GCV (%)	h^2_{bs} (%)	GA as per cent mean (%)
X_1	18.54	13.39	52.17	19.92
X_2	1.85	1.75	89.35	3.40
X_3	13.48	12.44	85.18	23.66
X_4	19.55	14.41	54.31	21.87
X_5	24.69	20.45	68.56	34.88
X_6	39.52	37.60	90.53	73.69
X_7	10.85	8.63	63.34	14.16
X_8	10.44	9.61	84.78	18.23
X_9	23.57	22.08	87.69	42.58
X_{10}	11.83	11.55	95.28	23.22
X_{11}	9.52	9.23	93.95	18.43
X_{12}	2.50	2.06	67.97	3.50
X_{13}	2.52	2.24	79.06	4.10
X_{14}	2.52	2.40	90.82	4.72
X_{15}	34.12	25.46	55.67	39.13

X_1- Plant height (cm)

X_2- Internodal length (cm)

X_3- Stem girth (mm)

X_4-chlorophyll content

X_5- Specific leaf weight (mg/cm^2)

X_6- No. of leaves per plant

X_7- Leaf length (cm)

X_8- Leaf breadth (cm)

X_9- Leaf area per plant (dm^2)

X_{10}- Days to flowering

X_{11}- Days to maturity

X_{12}- Green leaf yield (Kg/ha)

X_{13}- Cured leaf yield (Kg/ha)

X_{14}- Top Grade Equivalent (Kg/ha)

X_{15}-Total sugar(%)

4.2.3 Stem girth (mm)

Moderate values of PCV (18.24 *per cent*) and GCV (14.06 *per cent*) coupled with high broad sense heritability (59.47 *per cent*) and high genetic advance expressed as per cent of mean (22.34 *per cent*) were observed in the population TB-70 × TB-102.

Moderate values of PCV (13.48 *per cent*) and GCV (12.44 *per cent*) coupled with high broad sense heritability (85.18 *per cent*) and high genetic advance expressed as per cent of mean (23.66 *per cent*) were observed in the population TB-100 × TB-102.

4.2.4 Chlorophyll content

The PCV and GCV values were high (28.08 *per cent* and 24.73 *per cent,* respectively) for Chlorophyll content in the population TB-70 × TB-102. Estimates of broad sense heritability (77.55 *per cent*) and genetic advance as per cent of mean (44.86 *per cent*) were also high.

In the population TB-100 × TB-102, the PCV and GCV values were moderate (19.55 *per cent* and 14.41 *per cent,* respectively) for chlorophyll content. Estimates of broad sense heritability (54.31 *per cent*) and genetic advance as per cent of mean (21.87 *per cent*) were high.

4.2.5 Specific leaf weight (mg/cm^2)

The PCV and GCV values were high (39.18 *per cent* and 33.03 *per cent,* respectively) for specific leaf weight in the population TB-70 × TB-102. Estimates of broad sense heritability (71.06 *per cent*) and genetic advance as per cent of mean (57.36 *per cent*) were also high.

In the population TB-100 × TB-102, the PCV and GCV values were high (24.69 *per cent* and 20.45 *per cent,* respectively) for specific leaf weight. Estimates of broad sense heritability (68.56 *per cent*) and genetic advance as per cent of mean (34.88 *per cent*) were also high.

4.2.6 Leaves per plant

The PCV and GCV values were moderate (18.93 *per cent* and 15.52 *per cent,* respectively) for number of leaves per plant in the population TB-70 × TB-102.

Estimates of broad sense heritability (67.26 *per cent*) and genetic advance as per cent of mean (26.23 *per cent*) were high.

In the population TB-100 × TB-102, the PCV and GCV values were high (39.52 *per cent* and 37.60 *per cent*, respectively) for the trait number of leaves per plant. Estimates of broad sense heritability (90.53 *per cent*) and genetic advance as per cent of mean (73.69 *per cent*) were also high.

4.2.7 Leaf length (cm)

Moderate PCV (12.93 *per cent*) and low GCV (8.64 *per cent*) was observed for the trait leaf length in the population TB-70 × TB-102. Estimates of broad sense heritability (44.61 *per cent*) and genetic advance as per cent of mean (11.89 *per cent*) were high and moderate, respectively.

In the population TB-100 × TB-102, moderate PCV (10.85 *per cent*) and low GCV (8.63 *per cent*) for the trait leaf length was observed. Estimates of broad sense heritability (63.34 *per cent*) and genetic advance as per cent of mean (14.16 *per cent*) were high and moderate, respectively.

4.2.8 Leaf breadth (cm)

Moderate PCV (11.07 *per cent*) and low GCV (9.43 *per cent*) was observed for the trait leaf breadth in the population TB-70 × TB-102. Estimates of broad sense heritability (72.59 *per cent*) and genetic advance as per cent of mean (16.55 *per cent*) were high and moderate, respectively.

In the population TB-100 × TB-102, Moderate PCV (10.44 *per cent*) and low GCV (9.61 *per cent*) were observed for the trait leaf breadth. Estimates of broad sense heritability (84.78 *per cent*) and genetic advance as per cent of mean (18.23 *per cent*) were high and moderate, respectively.

4.2.9 Leaf area/plant (dm^2)

The PCV and GCV values were high (28.50 *per cent* and 27.41 *per cent*, respectively) for leaf area per plant in the population TB-70 × TB-102. Estimates of broad sense heritability (92.48 *per cent*) and genetic advance as per cent of mean (54.30 *per cent*) were also high.

In the population TB-100 × TB-102, the PCV and GCV values were high (23.57 *per cent* and 22.08 *per cent*, respectively) for leaf area per plant. Estimates of broad sense heritability (87.69 *per cent*) and genetic advance as per cent of mean (42.58 *per cent*) were also high.

4.2.10 Days to flowering

Moderate values of PCV (13.03 *per cent*) and GCV (12.88 *per cent*) coupled with high broad sense heritability (97.71 *per cent*) and high genetic advance expressed as per cent of mean (26.22 *per cent*) were observed in the population TB-70 × TB-102.

In the population TB-100 × TB-102, moderate values of PCV (11.83 *per cent*) and GCV (11.55 *per cent*) coupled with high broad sense heritability (95.28 *per cent*) and high genetic advance expressed as per cent of mean (23.22 *per cent*) were observed for this trait.

4.2.11 Days to maturity

Lower values of PCV and GCV (9.79 *per cent* and 9.45 *per cent*, respectively) were observed in the population TB-70 × TB-102. Estimates of broad sense heritability (93.27 *per cent*) and genetic advance as per cent of mean (18.81 *per cent*) were high and moderate, respectively.

In the population TB-100 × TB-102, lower values of PCV and GCV (9.52 *per cent* and 9.23 *per cent*, respectively) were observed for this trait. Estimates of broad sense heritability (93.95 *per cent*) and genetic advance as per cent of mean (18.43 *per cent*) were high and moderate, respectively.

4.2.12 Green leaf yield (kg/ha)

Lower values of PCV and GCV (3.12 *per cent* and 2.85 *per cent*, respectively) were observed in the population TB-70 × TB-102. Estimates of broad sense heritability (83.23 *per cent*) and genetic advance as per cent of mean (5.35 *per cent*) were high and low, respectively.

In the population TB-100 × TB-102, lower values of PCV and GCV (2.50 *per cent* and 2.06 *per cent,* respectively) were observed for this trait. Estimates of broad sense heritability (67.97 *per cent*) and genetic advance as per cent of mean (3.50 *per cent*) were high and low, respectively.

4.2.13 Cured leaf yield (kg/ha)

Lower values of PCV and GCV (7.41 *per cent* and 6.90 *per cent*, respectively) were observed in the population TB-70 × TB-102. Estimates of broad sense heritability (86.55 *per cent*) and genetic advance as per cent of mean (13.22 *per cent*) were high and moderate, respectively.

In the population TB-100 × TB-102, lower values of PCV and GCV (2.52 *per cent* and 2.24 *per cent*, respectively) were observed for this trait. Estimates of broad sense heritability (79.06 *per cent*) and genetic advance as per cent of mean (4.10 *per cent*) were high and low, respectively.

4.2.14 Top Grade Equivalent (kg/ha)

Lower values of PCV and GCV (7.46 *per cent* and 6.94 *per cent*, respectively) were observed in this population TB-70 × TB-102. Estimates of broad sense heritability (86.60 *per cent*) and genetic advance as per cent of mean (13.30 *per cent*) were high and moderate, respectively.

In the population TB-100 × TB-102, lower values of PCV and GCV (2.52 *per cent* and 2.40 *per cent,* respectively) were observed for this trait. Estimates of broad sense heritability (90.82 *per cent*) and genetic advance as per cent of mean (4.72 *per cent*) were high and low, respectively.

4.2.15 Total sugars (%)

The PCV and GCV values were high (33.53 *per cent* and 25.90 *per cent,* respectively) for total sugars in the population TB-70 × TB-102. Estimates of broad sense heritability (59.68 *per cent*) and genetic advance as per cent of mean (41.22 *per cent*) were also high.

In the population TB-100 × TB-102, PCV and GCV values were high (34.12 *per cent* and 25.46 *per cent,* respectively) for total sugars. Estimates of broad sense heritability (55.67 *per cent*) and genetic advance as per cent of mean (39.13 *per cent*) were also high.

4.3 Association analysis through Correlation studies.

Selection for specific character is known to result in correlated response in certain other characters. Generally, plant breeders make selection for one or two attributes at a time. So it becomes important to know the effect on other characters.

Improvement on green leaf yield is the most important target trait in FCV tobacco. This can be achieved through direct selection of easily observable characters. But, this needs a good understanding of association of different traits with green leaf yield and their association among themselves. Phenotypic correlation coefficients for yield and its attributing traits for two F_2 populations are presented in Table 5 and Table 6.

4.3.1 Cross TB-70 × TB-100

Association of green leaf yield with its component characters

Association of green leaf yield was highly significant and positive with cured leaf yield (0.9986) followed by top grade equivalent (0.9978), leaf area per plant (0.5571), number of leaves per plant (0.4518), leaf length (0.4018), leaf breadth (0.3501) and stem girth (0.2953). Contrary to this, plant height exhibited low positive but significant correlation (0.2023) with green leaf yield. The association of days to maturity with green leaf yield was very low and negative (-0.1076). The association of specific leaf weight with green leaf yield was positive and low (0.1030), whereas with days to flowering was low (-0.1008) and negative, and with chlorophyll content was negative and negligible (-0.0829). The correlation of green leaf yield with internodal length (0.0385) and total sugars (0.0068) was positive and negligible.

4.3.1.1 Plant height (cm)

Highly significant positive association was observed between plant height and stem girth (0.5939) followed by leaf breadth (0.4038), leaf length (0.3393) and leaf area per plant (0.3164). Significantly positive correlation of plant height was noticed with top grade equivalent (0.2207), cured leaf yield (0.2002) and specific leaf weight (0.1953). However, its association was low, positive but non-significant with number of leaves per plant (0.1075), internodal length (0.0787), days to flowering (0.0604), and days to maturity (0.0424), while it exhibited very low, non significant negative correlation with total sugars (-0.0703) and chlorophyll content (-0.0264).

4.3.1.2 Internodal length (cm)

Significant positive association was observed between internodal length and number of leaves per plant (0.257) whereas low negative but significant association was observed with days to maturity (-0.1972). However correlation between internodal length and top grade equivalent (0.0469), cured leaf yield (0.0401), leaf area per plant (0.0186) was low positive but non-significant, while it exhibited low

Table 5: Estimates of phenotypic correlation coefficients for fifteen yield contributing characters in F_2 population derived from cross TB-70 × TB-102 of FCV tobacco

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{13}	X_{14}	X_{15}	X_{12}
X_1	**1.000**	0.0787	0.5939**	-	0.1953*	0.1075	0.3393**	0.4038**	0.3164**	0.0424	0.0604	0.2002*	0.2007*	-0.0703	0.2023*
X_2		1.**000**	-0.0348	-	-0.1072	0.257*	-0.1137	-0.1409	0.0186	-0.1545	-0.1972*	0.0401	0.0469	-0.0163	0.0385
X_3			1.**000**	0.0663	0.2285**	0.2006*	0.4705**	0.4732**	0.5001**	0.076	0.0514	0.2958**	0.2894**	-0.0240	0.2953**
X_4				1.**000**	0.1404	0.0879	-0.0428	-0.0333	0.0401	0.0412	0.0036	-0.0788	-0.0800	-0.0156	-0.0829
X_5					1.**000**	0.0493	0.1372	0.0925	0.0089	0.0484	0.0566	0.1053	0.1063	0.0607	0.1030
X_6						1.**000**	0.2342**	0.0368	0.6760**	0.0684	0.0312	0.4529**	0.4538**	-0.0032	0.4518**
X_7							1.**000**	0.7968**	0.8056**	0.1860*	0.2204**	0.3957**	0.911**	-0.0377	0.4018**
X_8								1.**000**	0.6781**	0.0846	0.1251	0.3437**	0.3389**	-0.0239	0.3501**
X_9									1.**000**	0.1466	0.1417	0.5529**	0.5489**	-0.0393	0.5571**
X_{10}										1.**000**	0.9047**	-0.0994	-0.0996	-0.0841	-0.1008
X_{11}											1.**000**	-0.1061	-0.1068	-0.0978	-0.1076
X_{13}												1.**000**	0.9991**	0.0103	0.9986**
X_{14}													1.**000**	0.0063	0.9978**
X_{15}														**1.000**	0.0068
X_{12}															**1.000**

**Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

X_1- Plant height (cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4-chlorophyll content
X_5- Specific leaf weight (mg/cm^2)

X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering

X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- Top Grade Equivalent (Kg/ha)
X_{15}- Total sugars (%)

Table 6: Estimates of phenotypic correlation coefficients for fifteen yield contributing characters in F_2 population derived from cross TB-100 × TB-102 of FCV tobacco

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{13}	X_{14}	X_{15}	X_{12}
X_1	**1.000**	0.0945	0.1460	-0.1337	0.0276	0.0970	0.0490	0.1504	0.2125**	0.0560	0.0357	0.0067	0.0025	0.1429	-0.0030
X_2		**1.000**	0.2651**	-0.0782	-0.0028	-0.0477	-0.0548	0.2007*	0.1038	-0.0081	-0.0256	0.1848*	0.1902*	0.1283	0.1834*
X_3			**1.000**	0.0975	0.0462	0.0421	0.1305	0.2591**	0.2739**	-0.0488	-0.0515	0.1633*	0.1649*	0.0821	0.1628*
X_4				**1.000**	0.0077	-0.0880	0.1046	-0.0733	-0.0795	-0.0137	-0.0106	-0.0920	-0.0986	0.0752	-0.0917
X_5					**1.000**	-0.0722	-0.0201	-0.0618	-0.0660	-0.0789	-0.0331	0.1215	0.1210	0.0473	0.1207
X_6						**1.000**	-0.2803**	-0.1683*	0.6240**	0.0420	0.0337	0.2815**	0.2791**	-0.0618	0.2839**
X_7							**1.000**	0.6687**	0.4172**	0.0135	0.0196	0.0689	0.0680	0.1228	0.0709
X_8								**1.000**	0.5802**	-0.0234	-0.0323	0.0816	0.0796	0.1662*	0.0834
X_9									**1.000**	0.0603	0.0533	0.2692**	0.2679**	0.0791	0.2712**
X_{10}										**1.000**	0.9543**	-0.1049	-0.1034	0.0564	-0.1057
X_{11}											**1.000**	-0.0709	-0.0695	0.0562	-0.0711
X_{13}												**1.000**	0.9993**	0.1150	0.9988**
X_{14}													**1.000**	0.1124	0.9983**
X_{15}														**1.000**	0.1114
X_{12}															**1.000**

**Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

X_1- Plant height (cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4-chlorophyll content
X_5- Specific leaf weight (mg/cm^2)

X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering

X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- Top Grade Equivalent (Kg/ha)
X_{15}- Total sugars (%)

negative but non-significant correlation with days to flowering (-0.1545), leaf breadth (-0.1409), leaf length (-0.1137) and specific leaf weight (-0.1072). Contrary to this, the trait exhibited very low negative but non-significant correlation with cured leaf yield (-0.0348), total sugars (-0.0163) and top grade equivalent (-0.0031).

4.3.1.3 Stem girth (mm)

Highly significant positive association was observed between stem girth and leaf area per plant (0.5001) followed by leaf breadth (0.4732), leaf length (0.4705), cured leaf yield (0.2958), top grade equivalent (0.2894) and specific leaf weight (0.2285). While significant positive association was observed with number of leaves per plant (0.2006). However very low positive but non-significant association was observed with days to flowering (0.076), chlorophyll content (0.0663) and days to maturity (0.0514). Contrary to this, the trait exhibited very low negative but non-significant correlation with total sugars (-0.0240).

4.3.1.4 Chlorophyll content

This trait exhibited low but positive non-significant correlation with specific leaf weight (0.1404), whereas very low but positive non-significant correlation was observed with number of leaves per plant (0.0879), days to flowering (0.0412), leaf area per plant (0.0401) and days to maturity (0.0036). However very low negative but non-significant association was observed with top grade equivalent (-0.08), cured leaf yield (-0.0788), leaf length (-0.0428), leaf breadth (-0.0333) and total sugars (-0.0156).

4.3.1.5 Specific leaf weight (mg/cm^2)

This trait exhibited low but positive non-significant correlation with leaf length (0.1372), top grade equivalent (0.1063) and cured leaf yield (0.1053), whereas very low positive but non-significant correlation was observed with leaf breadth (0.0925), total sugars (0.0607), days to maturity (0.0566), number of leaves per plant (0.0493), days to flowering (0.0484) and leaf area per plant (0.0089).

4.3.1.6 Number of leaves per plant

Highly significant positive association was observed between number of leaves per plant and leaf area per plant (0.6760) followed by top grade equivalent (0.4538), cured leaf yield (0.4529) and leaf length (0.2342). However very low, positive but non-significant correlation was observed with days to flowering (0.0684), leaf breadth (0.0368) and days to maturity (0.0312). Contrary to this, very low negative but non-significant correlation was observed with total sugars (-0.0032).

4.3.1.7 Leaf length (cm)

Highly significant positive association was observed between leaf length and top grade equivalent (0.911) followed by leaf area per plant (0.8056), leaf breadth (0.7968), cured leaf yield (0.3957) and days to maturity (0.2204). This trait exhibited low positive but significant correlation with days to flowering (0.1860). However very low negative but non-significant correlation was observed with total sugars (-0.0377).

4.3.1.8 Leaf breadth (cm)

Highly significant positive association was observed between leaf breadth and leaf area per plant (0.6781) followed by cured leaf yield (0.3437) and top grade equivalent (0.3389). This trait exhibited low positive but non-significant correlation with days to maturity (0.1251), whereas very low positive but non-significant correlation was observed with days to flowering (0.0846). However very low negative but non-significant correlation was observed with total sugars (-0.0239).

4.3.1.9 Leaf area per plant (dm^2)

Highly significant positive association was observed between leaf area per plant and cured leaf yield (0.5529) followed by top grade equivalent (0.5489). This trait exhibited low positive but non-significant correlation with days to flowering (0.1466) and days to maturity (0.1417). However very low negative but non-significant correlation was observed with total sugars (-0.0393).

4.3.1.10 Days to flowering

Highly significant positive association was observed between days to flowering and days to maturity (0.9047). This trait exhibited very low negative but non-significant correlation with top grade equivalent (-0.0996), cured leaf yield (-0.0994) and total sugars (-0.0841).

4.3.1.11 Days to maturity

This trait exhibited low negative but non-significant correlation with top grade equivalent (-0.1068) and cured leaf yield (-0.1061), whereas it exhibited very low negative and non-significant correlation with total sugars (-0.0978).

4.3.1.12 Cured leaf yield (kg/ha)

Highly significant positive association was observed between cured leaf yield and top grade equivalent (0.9991), whereas very low positive but non-significant correlation was observed with total sugars (0.0103).

4.3.1.13 Top Grade Equivalent (kg/ha)

This trait exhibited very low positive but non-significant correlation with total sugars (0.0063).

4.3.2 Cross TB-100 × TB-102

Association of green leaf yield with its component characters

The association of green leaf yield was highly significant and positive with cured leaf yield (0.9986) followed by top grade equivalent (0.9983), number of leaves per plant (0.2839) and leaf area per plant (0.2712). This trait exhibited low positive but significant correlation with internodal length (0.1834) and stem girth (0.1628), while low positive but non-significant correlation was observed with specific leaf weight (0.1207), total sugars (0.1114), leaf breadth (0.0834) and leaf length (0.0709). However very low negative but non-significant correlation was observed with days to flowering (-0.1057), chlorophyll content (-0.0917), days to maturity (-0.0711) and plant height (-0.0030).

4.3.2.1 Plant height (cm)

Highly significant positive association was observed between plant height and leaf area per plant (0.2125). However, its association was low, positive but non-significant with leaf breadth (0.1504), stem girth (0.1460) and total sugars (0.1429).while it exhibited very low, non significant positive correlation with number of leaves per plant (0.0970) followed by internodal length (0.0945), days to flowering (0.0560), leaf length (0.490), days to maturity (0.0357), specific leaf weight (0.0276), cured leaf yield (0.0067) and top grade equivalent (0.0025). This trait exhibited low negative but non-significant correlation with chlorophyll content (-0.1337).

4.3.2.2 Internodal length (cm)

Highly significant positive association was observed between internodal length and stem girth (0.2651). Significant positive correlation was observed with leaf breadth (0.2007), top grade equivalent (0.1902) and cured leaf yield (0.1848). However correlation between internodal length and total sugars (0.1283) and leaf area per plant (0.1038) was low positive but non-significant, while it exhibited very low negative but non-significant correlation with chlorophyll content (-0.0782), leaf length (-0.0548), number of leaves per plant (-0.0477), days to maturity (-0.0256), days to flowering (-0.0081) and specific leaf weight (-0.0028).

4.3.2.3 Stem girth (mm)

Highly significant positive association was observed between stem girth and leaf area per plant (0.291) followed by leaf breadth (0.2591). While low significant positive association was observed with top grade equivalent (0.1649) and cured leaf yield (0.1633). However very low positive but non-significant association was observed with leaf length (0.1305), chlorophyll content (0.0975), total sugars (0.0821), specific leaf weight (0.0462) and number of leaves per plant (0.0421). Contrary to this, the trait exhibited very low negative but non-significant correlation with days to maturity (-0.0515) and days to flowering (-0.0488).

4.3.2.4 Chlorophyll content

This trait exhibited very low but positive non-significant correlation with leaf length (0.1046) followed by total sugars (0.0752) and specific leaf weight (0.0077), whereas, very low but negative non-significant correlation was observed with top grade equivalent (-0.0986), cured leaf yield (-0.0920), number of leaves per plant (-0.0880), leaf breadth (-0.0733), days to flowering (-0.0137) and days to maturity (-0.0106).

4.3.2.5 Specific leaf weight (mg/cm^2)

This trait exhibited low but positive non-significant correlation with cured leaf yield (0.1215) and top grade equivalent (0.1210) whereas very low positive but non-significant correlation was observed with total sugars (0.0473). This trait exhibited very low negative but non-significant correlation with days to flowering (-0.0789), number of leaves per plant (-0.0722), leaf area per plant (-0.0660), leaf breadth (-0.0618), days to maturity (-0.0331) and leaf length (-0.0201).

4.3.2.6 Number of leaves per plant

Highly significant positive association was observed between number of leaves per plant and leaf area per plant (0.6240) followed by cured leaf yield (0.0.2815) and top grade equivalent (0.2791). However very low, positive but non-significant correlation was observed with days to flowering (0.0420) and days to maturity (0.0337). Contrary to this negative but highly significant correlation was observed with leaf length (-0.2803), while low negative but significant association was observed with leaf breadth (-0.1683). This trait exhibited very low negative but non-significant association with total sugars (-0.0618).

4.3.2.7 Leaf length (cm)

Highly significant positive association was observed between leaf length and leaf breadth (0.6687) followed by leaf area per plant (0.4172). This trait exhibited low positive but non-significant correlation with total sugars (0.1228). However very low positive but non-significant correlation was observed with cured leaf yield (0.0689), top grade equivalent (0.0680), days to maturity (0.0196) and days to flowering (0.0135).

4.3.2.8 Leaf breadth (cm)

Highly significant positive association was observed between leaf breadth and leaf area per plant (0.5802). This trait exhibited low positive but significant correlation with total sugars (0.1662), whereas very low positive but non-significant correlation was observed with cured leaf yield (0.0816) and top grade equivalent (0.0796). However very low negative but non-significant correlation was observed with days to flowering (-0.0234) and days to maturity (-0.0323).

4.3.2.9 Leaf area per plant (dm^2)

Highly significant positive association was observed between leaf area per plant and cured leaf yield (0.2692) followed by top grade equivalent (0.2679). This trait exhibited very low positive but non-significant correlation with total sugars (0.0791), days to flowering (0.0603) and days to maturity (0.0533).

4.3.2.10 Days to flowering

Highly significant positive association was observed between days to flowering and days to maturity (0.9543). This trait exhibited very low positive but non-significant correlation with total sugars (0.0564). However low negative but non-significant correlation was observed with cured leaf yield (-0.1049) and top grade equivalent (-0.1034).

4.3.2.11 Days to maturity

This trait exhibited very low positive but non-significant correlation with total sugars (0.0562). Whereas it exhibited very low negative and non-significant correlation with cured leaf yield (-0.0709) and top grade equivalent (-0.0695).

4.3.2.12 Cured leaf yield (kg/ha)

Highly significant positive association was observed between cured leaf yield and top grade equivalent (0.9993), whereas low positive but non-significant correlation was observed with total sugars (0.1150).

4.3.2.13 Top Grade Equivalent (kg/ha)

This trait exhibited low positive but non-significant correlation with total sugars (0.1124).

4.4 Path coefficient analysis

Path coefficient analysis was carried out to partition the correlation coefficients in to direct and indirect effects of component traits on green leaf yield in F_2 population of two crosses and results are presented in Table 7 and Table 8.

4.4.1 Cross TB-70 × TB-102

4.4.1.1 Plant height (cm)

The direct effect of plant height on green leaf yield was positive and negligible (0.0025). Positive but low indirect effect of plant height was exhibited through cured leaf yield (0.187). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through top grade equivalent (0.012), leaf area per plant (0.0025), leaf length (0.0012), leaf breadth (0.0011), total sugars (0.0002) and chlorophyll content (0.0001). Negligible negative indirect effect was exhibited by stem girth (-0.0032), internodal length (-0.0002), specific leaf weight (-0.0003), number of leaves per plant (-0.0003) and days to maturity (-0.0003). No indirect effect of plant height through days to flowering was exhibited.

Table 7: Estimates of direct and indirect effects of yield components on green leaf yield at phenotypic level in F_2 population derived from cross TB-70 × TB-102 of FCV tobacco

	X_1	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**	**X_7**	**X_8**	**X_9**	**X_{10}**	**X_{11}**	**X_{13}**	**X_{14}**	**X_{15}**
X_1	0.**0025**	0.0002	0.0015	-0.0001	0.0005	0.0003	0.0009	0.0010	0.0008	0.0001	0.0002	0.0005	0.0005	-0.0002
X_2	-0.0002	-0.**0021**	0.0001	0.0000	0.0002	-0.0004	0.0002	0.0003	0.0000	0.0003	0.0004	-0.0001	-0.0001	0.0000
X_3	-0.0032	0.0002	-0.**0053**	-0.0004	-0.0012	-0.0011	-0.0025	-0.0025	-0.0027	-0.0003	-0.0003	-0.0016	-0.0015	0.0001
X_4	0.0001	0.0000	-0.0002	-0.**0037**	-0.0005	-0.0003	0.0002	0.0001	-0.0001	-0.0002	0.0000	0.0003	0.0003	0.0001
X_5	-0.0003	0.0002	-0.0004	-0.0003	-0.**0018**	-0.0001	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	-0.0002	-0.0002	-0.0001
X_6	-0.0003	-0.0006	-0.0006	-0.0003	-0.0001	-0.**0029**	-0.0007	-0.0001	-0.0019	-0.0002	-0.0001	-0.0013	-0.0013	0.0000
X_7	0.0012	-0.0004	0.0016	-0.0001	0.0005	0.0008	0.**0035**	0.0028	0.0028	0.0006	0.0008	0.0014	0.0014	-0.0001
X_8	0.0011	-0.0004	0.0013	-0.0001	0.0002	0.0001	0.0021	0.**0026**	0.0018	0.0002	0.0003	0.0009	0.0009	-0.0001
X_9	0.0025	0.0001	0.0039	0.0003	0.0009	0.0053	0.0063	0.0053	0.**0078**	0.0011	0.0011	0.0043	0.0043	-0.0003
X_{10}	0.0000	-0.0002	0.0001	0.0000	0.0001	0.0001	0.0002	0.0001	0.0002	0.**0011**	0.0010	-0.0001	-0.0001	-0.0001
X_{11}	-0.0003	0.0011	-0.0003	0.0000	-0.0003	-0.0002	-0.0013	-0.0007	-0.0008	-0.0051	-0.**0057**	0.0006	0.0006	0.0006
X_{13}	0.1870	0.0375	0.2763	-0.0736	0.0984	0.4232	0.3696	0.3211	0.5166	-0.0928	-0.0992	0.**9343**	0.9334	0.0096
X_{14}	0.0120	0.0028	0.0173	-0.0048	0.0063	0.0271	0.0233	0.0202	0.0328	-0.0059	-0.0064	0.0596	0.**0597**	0.0004
X_{15}	0.0002	0.0000	0.0001	0.0000	-0.0002	0.0000	0.0001	0.0001	0.0001	0.0003	0.0003	0.0000	0.000	-0.**0030**
r values	**0.2023**	**0.0385**	**0.2953**	**-0.0829**	**0.1030**	**0.4518**	**0.4018**	**0.3501**	**0.5571**	**-0.1008**	**-0.1076**	**0.9986**	**0.9978**	**0.0068**

Residual effect = 0.0513 **r =** correlation coefficient of green leaf yield

X_1- Plant height (cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4-chlorophyll content
X_5- Specific leaf weight (mg/cm^2)
X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering
X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- Top Grade Equivalent (Kg/ha)
X_{15}- Total sugars (%)

Table 8: Estimates of direct and indirect effects of yield components on green leaf yield at phenotypic level in F_2 population derived from cross TB-100 × TB-102 of FCV tobacco

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{13}	X_{14}	X_{15}
X_1	**-0.0088**	-0.0008	-0.0013	0.0012	-0.0002	-0.0009	-0.0004	-0.0013	-0.0019	-0.0005	-0.0003	-0.0001	0.0000	-0.0013
X_2	0.0000	**-0.0002**	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
X_3	0.0001	0.0003	**0.0010**	0.0001	0.0000	0.0000	0.0001	0.0003	0.0003	0.0000	-0.0001	0.0002	0.0002	0.0001
X_4	-0.0001	-0.0001	0.0001	**0.0007**	0.0000	-0.0001	0.0001	0.0000	-0.0001	0.0000	0.0000	-0.0001	-0.0001	0.0000
X_5	0.0000	0.0000	0.0000	0.0000	**0.0010**	-0.0001	0.0000	-0.0001	-0.0001	-0.0001	0.0000	0.0001	0.0001	0.0000
X_6	0.0021	-0.0010	0.0009	-0.0019	-0.0015	**0.0214**	-0.0060	-0.0036	0.0133	0.0009	0.0007	0.0060	0.0060	-0.0013
X_7	0.0003	-0.0004	0.0010	0.0008	-0.0002	-0.0022	**0.0077**	0.0051	0.0032	0.0001	0.0002	0.0005	0.0005	0.0009
X_8	0.0021	0.0028	0.0036	-0.0010	-0.0009	-0.0023	0.0092	**0.0138**	0.0080	-0.0003	-0.0004	0.0011	0.0011	0.0023
X_9	-0.0041	-0.0020	-0.0053	0.0015	0.0013	-0.0121	-0.0081	-0.0112	**-0.0194**	-0.0012	-0.0010	-0.0052	-0.0052	-0.0015
X_{10}	-0.0004	0.0001	0.0004	0.0001	0.0006	-0.0003	-0.0001	0.0002	-0.0004	**-0.0072**	-0.0069	0.0008	0.0007	-0.0004
X_{11}	0.0003	-0.0002	-0.0004	-0.0001	-0.0002	0.0002	0.0001	-0.0002	0.0004	0.0069	**0.0072**	-0.0005	-0.0005	0.0004
X_{13}	0.0053	0.1466	0.1295	-0.0730	0.0964	0.2233	0.0546	0.0647	0.2136	-0.0832	-0.0563	**0.7932**	0.7926	0.0912
X_{14}	0.0005	0.0386	0.0335	-0.0200	0.0246	0.0567	0.0138	0.0162	0.0544	-0.0210	-0.0141	0.2030	**0.2031**	0.0228
X_{15}	-0.0003	-0.0003	-0.0002	-0.0001	-0.0001	0.0001	-0.0002	-0.0003	-0.0002	-0.0001	-0.0001	-0.0002	-0.0002	**-0.0020**
r values	**-0.0030**	**0.1834**	**0.1628**	**-0.0917**	**0.1207**	**0.2839**	**0.0709**	**0.0834**	**0.2712**	**-0.1057**	**-0.0711**	**0.9988**	**0.9983**	**0.1114**

Residual effect = 0.0472 **r =** correlation coefficient of green leaf yield

X_1- Plant height (cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4-chlorophyll content
X_5- Specific leaf weight (mg/cm^2)

X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering

X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- Top Grade Equivalent (Kg/ha)
X_{15}- Total sugars (%)

4.4.1.2 Internodal length (cm)

Internodal length exhibited negligible negative direct effect (-0.0021) on green leaf yield; whereas, its indirect contribution *via* cured leaf yield (0.0375), top grade equivalent (0.0028), days to maturity (0.0011), plant height (0.0002), stem girth (0.0002), specific leaf weight (0.0002) and leaf area per plant (0.0001) were positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via* number of leaves per plant (-0.0006), leaf length (-0.0004), leaf breadth (-0.0004) and days to flowering (-0.0002) were negative but negligible. This trait had no indirect effect through chlorophyll content and total sugars.

4.4.1.3 Stem girth (mm)

Stem girth exhibited negligible negative direct effect (-0.0053) on green leaf yield. Positive and moderate indirect effect of stem girth was exhibited through cured leaf yield (0.2763) whereas, its indirect contribution *via* top grade equivalent (0.0173), days to flowering (0.0039), leaf length (0.0016), plant height (0.0015), leaf breadth (0.0013), internodal length (0.0001), days to flowering (0.0001) and total sugars (0.0001) were positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via*, number of leaves per plant (-0.0006), specific leaf weight (-0.0004), days to maturity (-0.0003) and chlorophyll content (-0.0002) were negative but negligible.

4.4.1.4 Chlorophyll content

Chlorophyll content exhibited negligible negative direct effect (-0.0037) on green leaf yield; whereas, its indirect contribution *via* leaf area per plant (0.0003) was positive but negligible leading to non significant positive correlation with green leaf yield. On the other hand, its indirect effect *via*, cured leaf yield (-0.0736), top grade equivalent (-0.0048), stem girth (-0.0004), specific leaf weight (-0.0003), number of leaves per plant (-0.0003), leaf length (-0.0001), leaf breadth (-0.0001) and plant height (-0.0001) were negative but negligible. This trait had no indirect effect through internodal length, days to flowering, days to maturity and total sugars.

4.4.1.5 Specific leaf weight (mg/cm^2)

Specific leaf weight exhibited negligible negative direct effect (-0.0018) on green leaf yield; whereas, it’s indirect contribution *via* cured leaf yield (0.0984), top grade equivalent (0.0063), specific leaf weight (0.0009), plant height (0.0005), leaf length (0.0005), internodal length (0.0002), leaf breadth (0.0002) and days to flowering (0.0001) was positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via*, stem girth (-0.0012), chlorophyll content (-0.0005), days to maturity (-0.0003), total sugars (-0.0002) and number of leaves per plant (-0.0001) was negative but negligible.

4.4.1.6 Number of leaves per plant

Number of leaves per plant exhibited negligible negative direct effect (-0.0029) on green leaf yield. Its indirect effect via cured leaf yield (0.4232) was positive and very high whereas, its indirect effect *via*, top grade equivalent (0.0271), specific leaf weight (0.0053), leaf length (0.0008), plant height (0.0003), leaf breadth (0.0001) and days to flowering (0.0001) was positive but negligible. Its indirect effect via stem girth (-0.0011), internodal length (-0.0004) chlorophyll content (-0.0003), days to maturity (-0.0002) and specific leaf weight (-0.0001) were negative but negligible. This trait had no indirect effect *via* total sugars.

4.4.1.7 Leaf length (cm)

The direct effect of leaf length on green leaf yield was positive and negligible (0.0035). The indirect effect of leaf length on green leaf yield *via*, cured leaf yield was very high and positive (0.3696). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through top grade equivalent (0.0233), leaf area per plant (0.0063), leaf breadth (0.0021), plant height (0.0009), internodal length (0.0002), chlorophyll content (0.0002) and total sugars (0.0001). Negligible negative indirect effect was exhibited through stem girth (-0.0025), days to maturity (-0.0013), number of leaves per plant (-0.0007) and specific leaf weight (-0.0002).

4.4.1.8 Leaf breadth (cm)

The direct effect of leaf breadth on green leaf yield was positive and negligible (0.0026). The indirect effect of leaf breadth on green leaf yield *via*, cured leaf yield (0.3211) was very high and positive. However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through top grade equivalent (0.0202), leaf area per plant (0.0053), leaf length (0.0028), plant height (0.0010), internodal length (0.0003), chlorophyll content (0.0001), days to flowering (0.0001) and total sugars (0.0001). Negligible negative indirect effect was exhibited *via* stem girth (-0.0025), days to maturity (-0.0007), specific leaf weight (-0.0002) and number of leaves per plant (-0.0001)

4.4.1.9 Leaf area per plant (dm^2)

The direct effect of leaf area per plant on green leaf yield was positive and negligible (0.0078). The indirect effect of leaf area per plant on green leaf yield was very high and positive *via*, cured leaf yield (0.5166). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through top grade equivalent (0.0328), leaf length (0.0028), leaf breadth (0.0018), plant height (0.0008), days to flowering (0.0002) and total sugars (0.0001). Negligible negative indirect effect was exhibited by stem girth (-0.0027), number of leaves per plant (-0.0019), days to maturity (-0.0008), specific leaf weight (-0.0002) and chlorophyll content (-0.0001). No indirect effect of leaf area per plant was exhibited *via* internodal length.

4.4.1.10 Days to flowering

The direct effect of days to flowering on green leaf yield was positive and negligible (0.0011). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through leaf area per plant (0.0011), leaf length (0.0006), internodal length (0.0003), total sugars (0.0003), leaf breadth (0.0002) and plant height (0.0001). Negligible negative indirect effect was exhibited *via* cured leaf yield (-0.0928), top grade equivalent (-0.0059), days to maturity (-0.0051), stem girth (-0.0003), chlorophyll content (-0.0002), number of leaves per plant (-0.0002) and specific leaf weight (-0.0001).

4.4.1.11 Days to maturity

Days to maturity exhibited negligible negative direct effect (-0.0057) on green leaf yield whereas, its indirect contribution *via* leaf area per plant (0.0011), days to flowering (0.0010), leaf length (0.0008), internodal length (0.0004), leaf breadth (0.0003), total sugars (0.0003) and plant height (0.0002) was positive but negligible. On the other hand, its indirect effect *via* cured leaf yield (-0.0992), top grade equivalent (-0.0064), stem girth (-0.0003), specific leaf weight (-0.0001) and number of leaves per plant (-0.0001) was negative but negligible. This trait had no indirect effect through chlorophyll content.

4.4.1.12 Cured leaf yield (kg/ha)

Cured leaf yield registered highest positive direct effect (0.9343) on green leaf yield. However, positive significant correlation of this trait with green leaf yield may be attributed to its positive indirect effect *via* top grade equivalent (0.0596) followed by leaf area per plant (0.0043), leaf length (0.0014), cured leaf yield (0.0009), days to maturity (0.0006), plant height (0.0005) and chlorophyll content (0.0003). Negligible positive indirect effect was exhibited *via* stem girth (-0.0016), number of leaves per plant (-0.0013), specific leaf weight (-0.0002), internodal length (-0.0001) and days to flowering (-0.0001). This trait had no indirect effect through total sugars.

4.4.1.13 Top Grade Equivalent (kg/ha)

The direct effect of top grade equivalent on green leaf yield was positive and negligible (0.0597). The indirect effect of top grade equivalent on green leaf yield was very high and positive *via*, cured leaf yield (0.9334). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through leaf area per plant (0.0043), leaf length (0.0014), leaf breadth (0.0009), days to maturity (0.0006), plant height (0.0005) and chlorophyll content (0.0003). Negligible negative indirect effect was exhibited by stem girth (-0.0015), number of leaves per plant (-0.0013), specific leaf weight (-0.0002), internodal length (-0.0001) and days to flowering (-0.0001). This trait had no indirect effect through total sugars.

4.4.1.14 Total sugars (%)

Total sugars exhibited negligible negative direct effect (-0.0030) on green leaf yield whereas, it’s indirect contribution *via* cured leaf yield (0.0096), days to maturity (0.0006), top grade equivalent (0.0004), stem girth (0.0001) and chlorophyll content (0.0001) was positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via* leaf area per plant (-0.0003), plant height (-0.0002), specific leaf weight (-0.0001), leaf length (-0.0001), leaf breadth (-0.0001) and days to flowering (-0.0001) was negative but negligible. This trait had no indirect effect via internodal length and number of leaves per plant.

4.4.2 Cross TB-100 × TB-102

4.4.2.1 Plant height (cm)

The direct effect of plant height on green leaf yield was negative and negligible (-0.0088). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through cured leaf yield (0.0053), number of leaves per plant (0.0021), leaf breadth (0.0021), top grade equivalent (0.0005), leaf length (0.0003), days to maturity (0.0003) and stem girth (0.0001). On the other hand, its indirect effect *via* leaf area per plant (-0.0041), days to flowering (-0.0004), total sugars (-0.0003) and chlorophyll content (-0.0001) was negative but negligible. Internodal length and specific leaf weight had no indirect effect *via* plant height.

4.4.2.2 Internodal length (cm)

Internodal length exhibited negligible negative direct effect (-0.0002) on green leaf yield. Its indirect effect *via* cured leaf yield (0.1466) was low and positive. However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through top grade equivalent (0.0386), leaf breadth (0.0028), stem girth (0.0003) and days to flowering (0.0001). On the other hand, its indirect effect *via* leaf area per plant (-0.002), number of leaves per plant (-0.001), plant height (-0.0008), leaf length (-0.0004), total sugars (-0.0003), days to maturity (-0.0002) and chlorophyll content (-0.0001) was negative but negligible.

4.4.2.3 Stem girth (mm)

Stem girth exhibited negligible positive direct effect (0.0010) on green leaf yield. Its indirect effect *via* cured leaf yield (0.1295) was low and positive. Whereas, its indirect contribution *via* top grade equivalent (0.0335), leaf breadth (0.0036), leaf length (0.0010), number of leaves per plant (0.0009), days to flowering (0.0004) and chlorophyll content (0.0001) was positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via*, leaf area per plant (-0.0053), plant height (-0.0013), days to maturity (-0.0004), total sugars (-0.0002) and internodal length (-0.0001) was negative but negligible. This trait had no indirect effect through specific leaf weight.

4.4.2.4 Chlorophyll content

Chlorophyll content exhibited negligible positive direct effect (0.0007) on green leaf yield Whereas, its indirect contribution *via* leaf area per plant (0.0015), plant height (0.0012), leaf length (0.0008), stem girth (0.0001) and days to flowering (0.0001) was positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via*, cured leaf yield (-0.0730), top grade equivalent (-0.0200), number of leaves per plant (-0.0019), leaf breadth (-0.0010), days to maturity (-0.0001) and total sugars (- 0.0001) was negative but negligible. This trait had no indirect effect *via* internodal length and specific leaf weight.

4.4.2.5 Specific leaf weight (mg/cm^2)

Specific leaf weight exhibited negligible positive direct effect (0.001) on green leaf yield. Whereas, it's indirect contribution *via* cured leaf yield (0.0964), top grade equivalent (0.0246), leaf area per plant (0.0013) and days to flowering (0.0006) was positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via*, number of leaves per plant (-0.0015), leaf breadth (-0.0009), plant height (-0.0002), leaf length (-0.0002), days to maturity (-0.0002) and total sugars (-0.0001) was negative but negligible. This trait had no indirect effect *via* internodal length, stem girth and Chlorophyll content.

4.4.2.6 Number of leaves per plant

Number of leaves per plant exhibited negligible positive direct effect (0.0214) on green leaf yield. This trait exhibited high positive indirect effect *via* cured leaf yield (0.2233). Whereas, its indirect effect *via*, top grade equivalent (0.0567), days to maturity (0.0002) and total sugars (0.0001) was positive but negligible. On the other hand, its indirect effect *via*, leaf area per plant (-0.0121), leaf breadth (-0.0023), leaf length (-0.0022), plant height (-0.0009), days to flowering (-0.0003), chlorophyll content (-0.0001) and specific leaf weight (-0.0001) was negative but negligible. This trait had no indirect effects *via* internodal length and stem girth.

4.4.2.7 Leaf length (cm)

The direct effect of leaf length on green leaf yield was negative and negligible (-0.0077). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through cured leaf yield (0.0546), top grade equivalent (0.0138), leaf breadth (0.0092), stem girth (0.0001), chlorophyll content (0.0001) and days to maturity (0.0001). Negligible negative indirect effect was exhibited *via* leaf area per plant (-0.0081) number of leaves per plant (-0.0060), plant height (-0.0004), total sugars (-0.0002) and days to flowering (-0.0001). This trait exhibited no indirect effects *via* internodal length and specific leaf weight.

4.4.2.8 Leaf breadth (cm)

The direct effect of leaf breadth on green leaf yield was positive and negligible (0.0138). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through cured leaf yield (0.0647), top grade equivalent (0.0162), leaf length (0.0051), stem girth (0.0003) and days to flowering (0.0002). Negligible negative indirect effect was exhibited *via* leaf area per plant (-0.0112), number of leaves per plant (-0.0036), plant height (-0.0013), total sugars (-0.0003), days to maturity (-0.0002) and specific leaf weight (-0.0001). This trait exhibited no indirect effects *via* internodal length and chlorophyll content.

4.4.2.9 Leaf area per plant (dm^2)

The direct effect of leaf area per plant on green leaf yield was negative and negligible (-0.0194). This trait exhibited high positive indirect effect *via* cured leaf yield (0.2136). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through top grade equivalent (0.0544), number of leaves per plant (0.0133), leaf breadth (0.0080) leaf length (0.0032) days to maturity (0.0004) and stem girth (0.0003). Negligible negative indirect effect was exhibited plant height (-0.0019), days to flowering (-0.0004), total sugars (-0.0002) chlorophyll content (-0.0001) and specific leaf weight (-0.0001). The trait exhibited no indirect effects *via* internodal length.

4.4.2.10 Days to flowering

The direct effect of days to flowering on green leaf yield was negative and negligible (-0.0072). However, the positive and negligible association of this trait with green leaf yield may be attributed mainly to its indirect effect through days to maturity (0.0069), number of leaves per plant (0.0009) and leaf length (0.0001). Negligible negative indirect effect was exhibited *via* cured leaf yield (-0.0832), top grade equivalent (-0.0210), leaf area per plant (-0.0012), plant height (-0.0005), leaf breadth (-0.0003), specific leaf weight (-0.0001) and total sugars (-0.0001). The trait exhibited no indirect effects *via* plant height, stem girth and chlorophyll content.

4.4.2.11 Days to maturity

Days to maturity exhibited negligible positive direct effect (0.0072) on green leaf yield; whereas, it's indirect contribution *via* number of leaves per plant (0.0007) and leaf length (0.0002) was positive but negligible. On the other hand, its indirect effect *via* cured leaf yield (-0.0563), top grade equivalent (-0.0141), days to flowering (-0.0069), leaf area per plant (-0.0010), leaf breadth (-0.0004), plant height (-0.0003), stem girth (-0.0001) and total sugars (-0.0001) was negative but negligible. The trait exhibited no indirect effects *via* internodal length, chlorophyll content and specific leaf weight.

4.4.2.12 Cured leaf yield (kg/ha)

Cured leaf yield registered highest positive direct effect (0.7932) on green leaf yield. However, positive significant correlation of this trait with green leaf yield may be attributed to its high positive indirect effect *via* top grade equivalent (0.2030). Negligible positive indirect effect was exhibited *via* number of leaves per plant (0.0060, leaf breadth (0.0011), days to flowering (0.0008), leaf length (0.0005), stem girth (0.0002) and specific leaf weight (0.0001). On the other hand, its indirect effect *via* leaf area per plant (-0.0052), days to maturity (-0.0005), total sugars (-0.0002), plant height (-0.0001) and chlorophyll content (-0.0001) was negative but negligible. The trait exhibited no indirect effects *via* internodal length.

4.4.2.13 Top Grade Equivalent (kg/ha)

The direct effect of top grade equivalent on green leaf yield was positive and high (0.2031). However, the positive and significant association of this trait with green leaf yield may be attributed mainly to its indirect effect through cured leaf yield (0.7926). Negligible positive indirect effect was exhibited *via* number of leaves per plant (0.0060), leaf breadth (0.0011), days to flowering (0.0007), leaf length (0.0005), stem girth (0.0002) and specific leaf weight (0.0001). Negligible negative indirect effect was exhibited by leaf area per plant (-0.0052), days to maturity (-0.0005), total sugars (-0.0002) and chlorophyll content (-0.0001). The trait exhibited no indirect effects *via* plant height and internodal length.

4.4.2.14 Total sugars (%)

Total sugars exhibited negligible negative direct effect (-0.0020) on green leaf yield; whereas, it's indirect contribution *via* cured leaf yield (0.0912), top grade equivalent (0.0228), leaf breadth (0.0023), leaf length (0.0009), days to maturity (0.0004) and stem girth (0.0001) was positive but negligible leading to non significant low positive correlation with green leaf yield. On the other hand, its indirect effect *via* leaf area per plant (-0.0015), number of leaves per plant (-0.0013) and days to flowering (-0.0004) was negative and negligible. The trait exhibited no indirect effects *via* internodal length, chlorophyll content and specific leaf weight.

4.5 Identification of desirable transgressive segregants

Accumulation of favourable alleles from both the parents into progeny in segregating population results in occurrence of transgressive segregants. Top ten segregants which exceeded their parent (better parent) in terms of their green leaf yield were identified in both the F_2 populations and are presented in Table 9 and Table 10. Details of the transgressive segregants from different crosses were briefly described under the following headings.

4.5.1 Cross TB-70 X TB-102

Top ten segregants identified in this cross are presented in the Table 9. Plant number 55 exhibited highest green leaf yield (16703.70 kg/ha), followed by plant number 46 (14296.30 kg/ha), plant number 25 (14166.67 kg/ha), plant number 36 (14166.67 Kg/ha), plant number 109 (12944.44 kg/ha), plant number 108 (12907.41 kg/ha), plant number 43 (12833.33 kg/ha), plant number 89 (12759.26 kg/ha), plant number 135 (12685.19 kg/ha) and plant number 45 (12611.11 kg/ha).

4.5.2 Cross TB-100 X TB-102

Top ten segregants identified in this cross are presented in the Table 10. Plant number 36 exhibited highest green leaf yield (12037.04 kg/ha), followed by plant number 27 (11666.67 kg/ha), plant number 111 (11611.11 kg/ha), plant number 42 (11518.52 kg/ha), plant number 11 (11462.96 kg/ha), plant number 131 (11407.41 k/ha), plant number 22 (11370.37 k/ha), plant number 40 (11185.19 k/ha), plant number 134 (11111.11 k/ha) and plant number 60 (11018.52 k/ha).

Table 9: List of top 10 desirable segregants in F_2 population of the cross TB-70 × TB-102 with higher green leaf yield

Sl. No.	Plant No.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	55	80.00	5.00	26.55	15.60	4.75	18.00	48.50	25.83	125.69	125.00	167.00	16703.70	2547.31	1804.77	13.60
2	46	85.00	4.00	25.90	15.10	4.75	15.00	44.13	24.93	108.32	96.00	137.00	14296.30	2173.04	1498.31	20.50
3	25	80.00	4.33	29.70	15.90	4.00	11.00	48.36	25.54	90.17	120.00	155.00	14166.67	2160.42	1499.33	19.50
4	36	72.00	4.00	23.81	15.70	5.25	15.00	48.73	24.80	122.05	120.00	154.00	14166.67	2153.33	1525.64	22.50
5	109	80.00	4.50	29.39	16.50	5.00	12.00	55.41	30.58	131.44	108.00	144.00	12944.44	1935.19	1343.02	16.30
6	108	68.00	2.83	21.27	15.00	4.50	12.00	49.66	28.33	112.12	154.00	186.00	12907.41	1961.93	1352.75	13.20
7	43	80.00	4.67	20.26	17.20	3.75	13.00	51.76	25.46	111.63	133.00	173.00	12833.33	1918.58	1322.86	17.80
8	89	80.00	3.50	33.88	17.30	6.25	16.00	39.88	24.56	115.73	96.00	135.00	12759.26	1907.51	1328.58	22.40
9	135	80.00	4.00	31.10	16.10	3.75	11.00	52.36	29.09	109.01	120.00	158.00	12685.19	1934.49	1342.54	15.00
10	45	66.00	4.33	27.14	17.10	3.00	17.00	47.64	23.76	122.81	142.00	183.00	12611.11	1923.19	1339.50	4.20
Mean of parents and F_2 population																
TB-70		47.80	3.93	14.84	22.65	5.78	11.20	28.95	14.39	31.07	97.93	135.67	1409.95	213.92	149.04	16.13
TB-102		47.47	4.24	15.06	28.89	5.20	7.53	31.32	18.02	28.88	118.07	154.47	1264.87	190.57	132.78	16.44
F_2		71.75	3.76	25.13	14.25	4.10	12.04	44.94	24.90	89.86	122.56	157.99	9532.84	1440.35	1005.36	14.15

X_1- Plant height (cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4- Chlorophyll content
X_5- Specific leaf weight (mg/cm^2)

X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering

X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- Top Grade Equivalent (Kg/ha)
X_{15}- Total sugars (%)

Table 10: List of top 10 desirable segregants in F_2 population of the cross TB-100 × TB-102 with higher green leaf yield

Sl. No.	Plant No.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	36	80.00	2.67	27.31	9.00	4.00	14.00	54.21	31.43	157.85	132.00	174.00	12037.04	1829.63	1296.29	14.00
2	27	80.00	2.17	22.55	9.60	3.00	12.00	52.58	27.50	114.63	132.00	175.00	11666.67	1768.67	1219.50	6.60
3	111	68.00	1.67	23.04	25.70	5.25	15.00	54.29	26.86	113.09	132.00	167.00	11611.11	1770.69	1220.89	14.20
4	42	65.00	2.67	24.31	13.40	4.25	13.00	42.69	28.23	107.29	132.00	168.00	11518.52	1698.98	1183.34	9.00
5	11	60.00	3.00	23.81	13.70	5.75	14.00	48.50	26.64	120.35	156.00	198.00	11462.96	1742.37	1209.21	14.30
6	131	54.00	3.83	25.88	20.50	4.25	13.00	45.83	25.08	94.10	132.00	173.00	11407.41	1705.41	1187.82	8.30
7	22	80.00	3.17	27.25	14.20	4.75	10.00	54.00	32.20	110.34	98.00	141.00	11370.37	1733.98	1195.58	10.90
8	40	80.00	3.33	30.45	10.50	3.50	12.00	48.75	30.42	119.59	126.00	160.00	11185.19	1700.15	1204.55	7.50
9	134	80.00	3.33	25.14	11.50	6.75	7.00	60.50	33.67	81.06	94.00	136.00	11111.11	1684.44	1169.00	15.60
10	60	80.00	3.00	30.80	15.80	5.25	13.00	54.31	29.31	137.76	136.00	174.00	11018.52	1670.41	1163.44	6.00
Mean of parents and F_2 population																
TB-100		36.13	4.01	13.54	23.87	5.05	11.00	26.91	12.94	25.29	115.20	152.40	1199.30	181.89	126.79	17.35
TB-102		47.47	4.24	15.06	28.89	5.20	7.53	31.32	18.02	28.88	118.07	154.47	1264.87	190.57	132.78	16.44
F_2		70.43	2.54	25.11	16.95	4.38	11.06	51.54	28.35	103.34	131.99	170.80	7968.27	1204.31	840.42	12.46

X_1- Plant height (cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4- Chlorophyll content
X_5- Specific leaf weight (mg/cm^2)
X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering
X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- Top Grade Equivalent (Kg/ha)
X_{15}- Total sugars (%)

DISCUSSION

V. DISCUSSION

In the present study, mean, variability and association for yield and its related traits in two F_2 populations of FCV tobacco *viz*., TB-70 × TB-102 and TB-100 × TB-102 are used to identify superior crosses and selecting genotypes for advancing generation. The results obtained thereof are discussed under the following headings.

5.1 Genetic variability studies

5.2 Correlation coefficient studies and Path coefficient analysis

5.3 Study of superior transgressive segregants

5.1 Genetic variability studies

Variability is the basic platform for crop improvement. Breeder should have a large number of variable populations to begin breeding activities. In the process of improvement, desirable plants are continuously selected from genetically variable population. The knowledge of genetic variability present in a crop species with respect to yield and its attributes, their association, nature and relative contribution towards yield has to be analyzed because, this is very much important for effective selection. Therefore, in the F_2 generation variability parameters like mean, range, skewness and kurtosis were estimated in two F_2 populations of FCV tobacco.

5.1.1 Range, skewness and kurtosis

The F_2 population of cross TB-70 × TB-102 exhibited considerable amount of variability for all the fifteen characters. The range being 25 to 100 cm for plant height, 2.50 to 5.67 cm for internodal length, 12.30 to 35.64 mm for stem girth, 6.60 to 25.90 for chlorophyll content, 1.75 to 20.25 mg/ cm^2 for specific leaf weight, 5.00 to 18.00 for number of leaves per plant, 28.61 to 58.53 cm for leaf length, 15.30 to 30.58 cm for leaf breadth, 24.99 to 160.97 dm^2 for leaf area per plant, 96 to 162 for days to flowering, 126 to 195 for days to maturity, 3907.41 to 16703.70 kg/ha for green leaf yield, 593.93 to 2547.31 kg/ha for cured leaf yield, 416.64 to 1804.77 kg/ha for Top Grade Equivalent and 4.20 to 24.70 *per cent* for total sugars.

Similarly, the F_2 population of cross TB-100 × TB-102 also exhibited considerable amount of variability for all the fifteen characters. The range being 40 to 80 cm for plant height, 1.33 to 3.83 cm for internodal length, 10.72 to 32.47 mm for stem girth, 2.50 to 8.25 for chlorophyll content, 3.70 to 42.30 mg/ cm^2 for specific leaf weight, 5.00 to 18.00 for number of leaves per plant, 37.36 to 62.00 cm for leaf length, 19.82 to 38.23 cm for leaf breadth, 49.21 to 192.48 dm^2 for leaf area per plant, 94 to 168 for days to flowering, 128 to 213 for days to maturity, 2648.15 to 12037.04 kg/ha for green leaf yield, 403.84 to 1829.63 kg/ha for cured leaf yield, 280.27 to 1296.29 kg/ha for Top Grade Equivalent and 4.10 to 21.80 *per cent* for total sugars. Thus the variability was quite wide for all characters studied in both the populations.

The study of distribution properties such as co-efficients of skewness (third degree statistic) and kurtosis (fourth degree statistic) provides insight about the nature of gene action (Fisher *et al*., 1932) and number of genes controlling the traits (Robson, 1956), respectively. The parameter'd' and 'h' in the genetic expectations of skewness (-3/2 d2 h) represents additive gene effects and dominance gene effects, respectively. Skewness and kurtosis are more powerful than first and second degree statistics which reveal interaction genetic effects (Choo and Reinbergs, 1982). The skewed distribution of a trait in general suggests that the trait is under the control of non-additive gene action, especially epistasis and influenced by environmental variables (Pooni *et al*., 1977; Kimberg and Bingham, 1998 and Roy, 2000). Positive skewness is associated with complementary interaction and negative skewness is associated with duplicate (additive × additive) gene interactions predominantly in the same directions. Complete ambi-directional epistasis however produces kurtosis while distribution stays symmetrical around mean (Pooni *et al*., 1977). The genes controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effects on the expression of the trait. In general, the distribution pattern of F_2 populations of two crosses suggested dominance and dominance based epistasis as the major causes for significant variation and asymmetrical distribution of majority of the traits investigated in the present study. The traits with leptokurtic and platykurtic distribution are controlled by fewer and a large number of genes, respectively. Kurtosis is negative or close to zero in the absence of gene interactions and is positive in the presence of gene interactions (Pooni *et al*., 1977; Choo and Reinbergs, 1982). The inferences on the relative number of genes and nature of genetic control of different traits in F_2 generation of two FCV tobacco crosses are discussed below.

Platykurtic and positively skewed distribution suggested the involvement of relatively large number of segregating genes with majority of them having decreasing effects and dominance based complementary type of interaction in the inheritance of internodal length, chlorophyll content, days to flowering, days to maturity, cured leaf yield and top grade equivalent in cross TB-70 X TB-102, and specific leaf weight, leaves per plant, leaf breadth, leaf area per plant and total sugars in cross TB-100 X TB-102 exhibiting this kind of inheritance. Maximizing the genetic gain in respect of the traits with positively skewed distribution requires intense selection from the existing variability.

However, negatively skewed platykurtic distribution is an evidence for involvement of a large number of dominant genes with majority of them having increasing effects and duplicate type of epistasis in the inheritance of plant height, stem girth, leaf length and green leaf yield in both the crosses while, leaves per plant, leaf breadth, leaf area per plant and total sugars in cross TB-70 X TB-102, and internodal length, chlorophyll content, days to flowering, days to maturity, cured leaf yield and top grade equivalent in cross TB-100 X TB-102 exhibited this kind of inheritance. These traits have evolved with dominance and dominance based duplicate epistasis which helps to protect the individual plant from deleterious alleles arising from existing variability (Roy, 2000).

Positively skewed leptokurtic distribution suggested the involvement of relatively fewer number of segregating genes with majority of them having decreasing effects in the inheritance of specific leaf weight in the cross TB-70 X TB-102.

5.1.2 Co-efficient of variation

The coefficient of variation (CV) also known as “relative variability. The CV for a single variable aims to describe the dispersion of the variable in a way that does not depend on the variable's measurement unit. Higher the CV, greater is the dispersion in the variable and *vice- versa*. Genetic variability parameters like Phenotypic Co-efficient of Variation (PCV) and Genotypic Co-efficient of Variation (GCV) were estimated in two crosses in F_2 populations. The range of variation was quite high for most of the characters in the two crosses studied, suggesting that these traits may be improved by individual plant selection. The range and mean values donot reflect the total variance in the material studied. Hence, actual variance was estimated for the characters to know the existing variability.

The genotypic variance measures the magnitude of genetic variability present in crop and phenotypic variance indicates the amount of variation which is due to difference in phenotypic values. The absolute values of phenotypic and genotypic variances cannot be used for comparison among the characters for variability. Hence, the coefficient of variation was calculated by considering respective means. A higher estimate of these parameters indicates wider variability and vice-versa. In the same context narrow difference between the Phenotypic Co-efficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) implies lesser impact of environment on the expression of character.

5.1.2.1 Phenotypic coefficient of variation

In the population TB-70 × TB-102, the PCV estimates were relatively high for internodal length, chlorophyll content, specific leaf weight, leaf area per plant and total sugars. Whereas in the population TB-100 × TB-102, high PCV estimates were observed for specific leaf weight, number of leaves per plant, leaf area per plant and total sugars. This indicate higher magnitude of variability present in both the populations.

In the population TB-70 × TB-102, moderate values were observed for plant height, stem girth, number of leaves per plant, leaf length, leaf breadth and days to flowering. Whereas in the population TB-100 × TB-102, moderate values were observed for plant height, stem girth, chlorophyll, leaf breadth and days to flowering.

In the population TB-70 × TB-102, low values of PCV were observed for days to maturity, green leaf yield, cured leaf yield and top grade equivalent. While in the population TB-100 × TB-102, low values of PCV were observed for internodal length, days to maturity, green leaf yield, cured leaf yield and top grade equivalent.

Present results are in accordance with high PCV for internodal length (Rehman and Qureshi, 1997a), moderate PCV for number of leaves per plant (Lakshmish, 1997).

5.1.2.2 Genotypic coefficient of variation

In the population TB-70 × TB-102, high values of GCV were observed for internodal length, chlorophyll content, specific leaf weight, leaf area per plant and total sugars. While in the population TB-100 × TB-102, high values of GCV were observed for specific leaf weight, number of leaves per plant, leaf area per plant and total sugars.

In the population TB-70 × TB-102, moderate values were observed for plant height, stem girth, number of leaves per plant and days to flowering. Whereas in the population TB-100 × TB-102, moderate values were observed for plant height, stem girth, chlorophyll content and days to flowering.

In the population TB-70 × TB-102, low values of GCV were observed for leaf length, leaf breadth, days to maturity, green leaf yield, cured leaf yield and top grade equivalent. Whereas in the population TB-100 × TB-102, low values were observed for internodal length, leaf length, leaf breadth, days to maturity, green leaf yield, cured leaf yield and top grade equivalent.

Present results are in accordance with high GCV for internodal length (Dobhal, 1987), number of leaves per plant (Chaubey *et al*., 1990), moderate GCV for plant height (Lakshmish, 1997), number of leaves per plant (Sastry and Gopinath, 1969), low GCV for internodal length (Devanand, 2002), cured leaf yield (Dobhal and Nageswara Rao, 1988 and Devanand, 2002), leaf length and leaf breadth (Venkatarao *et al*., 1973).

5.1.3 Heritability

The degree to which the phenotypic variation that can be explained as variation in genotype is estimated as the ratio of genotypic variability to the total phenotypic variability and is called heritability in broad sense, which is otherwise known as “degree of genetic determination.” Estimation of heritability for each character in all the crosses will guide for opting selection for different traits. It is necessary to estimate heritability for each character. This will give an exact idea of the heritable portion of variability. Broad sense heritability gives an idea about portion of observed variability attributable to genetic differences. In other words, heritability indicates the accuracy with which a genotype can be inferred from its phenotype.

The difference between PCV and GCV estimates indicates the relative influence of environment on the characters, which in turn decides the extent of their heritability. If the difference for any character is low, the environmental effect is low and hence it results in high heritability, while wide differences between PCV and GCV indicates considerable influence by the environmental factors leading to low heritability estimates. Heritability estimates represent the relative strength of the characters and indicate the efficiency of selection systems. Broad sense heritability gives an idea of about observed variability attributable to genetic difference.

In both the populations, TB-70 × TB-102 and TB-100 × TB-102, high heritability was observed for all the characters studied *viz.*, plant height, internodal length, stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf length, leaf breadth, leaf area per plant, days to flowering, days to maturity, green leaf yield, cured leaf yield, top grade equivalent and total sugars.

Present results are in accordance with high heritability for plant height (Sastry and Gopinath, 1968, Venkatarao *et al*., 1973, Ibrahim and Avratovskucova, 1982, Chaubey *et al*., 1990 and Kim *et al*., 1981, Hosseinzadeh *et al*., 2006), internodal length, (Nagesh and Rangaiah, 2008) days to flowering (Sastry and Gopinath, 1968, Ibrahim and Avratovskucova, 1982, Hosseinzadeh *et al*., 2006), number of leaves per plant (Sastry and Gopinath, 1969), leaf length (Nagesh and Rangaiah, 2008), leaf breadth (Sastry and Gopinath, 1969, Ibrahim and Avratovskucova, 1982, Amarnath, 1987), leaf breadth (Ibrahim and Avratovskucova, 1982, Amarnath, 1987), leaf area per plant (Nagesh and Rangaiah, 2008), cured leaf yield and fresh leaf yield (Venkatarao et al., 1973 and Ibrahim and Avratovskucova, 1982).

5.1.4 Genetic Advance as per cent mean (GAM)

In the population TB-70 × TB-102, high GAM was observed for plant height, internodal length, stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf area per plant, days to flowering and total sugars. While in the population TB-100 × TB-102, high GAM was observed for stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf area per plant and days to flowering.

In the population TB-70 × TB-102, GAM was moderate for leaf length, leaf breadth, days to maturity, cured leaf yield and top grade equivalent. While in the population TB-100 × TB-102, moderate GAM was observed for plant height, leaf length, leaf breadth, days to maturity, total sugars and top grade equivalent.

In the population TB-70 × TB-102, low GAM was observed only for green leaf yield. While in the population TB-100 × TB-102, low GAM was observed for internodal length, green leaf yield, cured leaf yield, and top grade equivalent.

Present results are in line with the findings of Ibrahim and Avratovskucova, (1982) who reported high GAM for plant height and moderate GAM for leaf breadth.

As could be seen from the foregoing paragraphs, the results of the present investigation pertaining to PCV, GCV, h^2 and GAM agreed with some of the earlier findings. Such differences are quite expected, as the variability parameters are the genetic properties of the population i.e., they differ from one population to another depending on the gene and genotypic frequencies (Falconer, 1981).

5.2 Correlation coefficient studies and path co-efficient analysis

Plant breeders commonly select for yield components which indirectly increase the yield. Thus, breeding for increase in green leaf yield would be most effective if components involved were highly heritable and genetically independent or positively correlated in early generations. Green leaf yield component trait predominantly governed by large number of genes and is greatly influenced by environmental fluctuations. Therefore, selection based on yield ma3y not be effective. Improvement in yield can be brought out by effecting indirect selection for yield related traits, whose heritability is high and show strong association with yield. From the breeder view point, the type of association of green leaf yield and its component traits is of paramount importance. So correlation coefficients between green leaf yield and other traits have been studied.

The results pertaining to correlations and path coefficients are to be viewed simultaneously to have reliable information about the association of characters, which the breeder has to look for in selecting the dependent characters in the desirable direction.

As the correlation is the net direct result of direct and indirect effects, when an independent character is showing positive correlation with the dependent character, it means that the selection for the character has to be in the positive direction for the improvement in the dependent character irrespective of the direction and magnitude of its direct and indirect effects. Similarly when the correlation between an independent character and dependent character is negative, the selection for that independent character has to be negative. When the correlation between a dependent character and an independent character is not significant, the direction of selection for that independent character has to be decided based on the magnitude and direction of its direct effect ; and also on the direction in which its majority of indirect effects (of considerable magnitude) are operating. The correlations have to be significant and the direct and indirect effects have to be of substantial magnitude. Keeping the foregoing points in the view, the association of the fresh leaf yield with other characters is discussed below:

5.2.1 Association of green leaf yield with other characters

Plant height exhibited positive significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102, except cured leaf yield which exhibited low indirect effect. Whereas this exhibited negative non-significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-100 × TB-102. So selection for this trait doesn't affect the green leaf yield in both the crosses.

Internodal length exhibited non-significant positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102. Whereas it exhibited positive significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-100 × TB-102, except low indirect effect via cured leaf yield. So selection for this trait may not increase the green leaf yield.

Stem girth showed highly significant and positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102. Whereas it exhibited positive significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-100 × TB-102, except low indirect effect via cured leaf yield. Most of the direct and indirect effects were positive, so selection for this trait may increase the green leaf yield in both the crosses.

Chlorophyll content exhibited non-significant negative correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in both the crosses TB-70 × TB-102 and TB-100 × TB-102. Selection for this trait doesn't affect the green leaf yield.

Specific leaf weight showed non-significant positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in both the crosses, TB-70 × TB-102 and TB-100 × TB-102.

Number of leaves per plant exhibited highly significant and positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in both the crosses, TB-70 × TB-102 and TB-100 × TB-102. However high indirect effect via cured leaf yield in TB-70 × TB-102 and moderate indirect effect was recorded via cured leaf yield in TB-70 × TB-102. But most of the direct and indirect effects were positive, so selection for more number of leaves can increase the green leaf yield in both the crosses TB-70 × TB-102 and TB-100 × TB-102.

Leaf length showed highly significant and positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102, except high indirect effect *via* cured leaf yield. Whereas it exhibited positive non-significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-100 × TB-102. But most of the direct and indirect effects were positive revealing that selection for leaf length increases the green leaf yield in both the crosses.

Leaf breadth exhibited highly significant and positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102, except high indirect effect *via* cured leaf yield. Whereas it exhibited positive non-significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-100 × TB-102. But most of the direct and indirect effects were positive indicating that selection for leaf length increases the green leaf yield in both the crosses.

Leaf area per plant showed highly significant and positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in both the crosses, TB-70 × TB-102 and TB-100 × TB-102, except that high indirect effect via cured leaf yield in cross TB-70 × TB-102 and moderate indirect effect via cured leaf yield in cross TB-100 × TB-102. But most of the direct and indirect effects were positive revealing that selection for the trait leaf area per plant increases the green leaf yield in both the crosses.

Days to flowering and days to maturity exhibited negative non-significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in both the crosses, TB-70 × TB-102 and TB-100 × TB-102.

Cured leaf yield exhibited highly significant and positive correlation with green leaf yield and it had considerably high positive direct and indirect effects in both the crosses, TB-70 × TB-102 and TB-100 × TB-102. It exhibited moderate indirect effect on green leaf yield *via* top grade equivalent in the cross, TB-100 × TB-102. Thus selection for this trait can increase the green leaf yield.

Top Grade Equivalent exhibited highly significant and positive correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in the cross TB-70 × TB-102, except the high indirect effect *via* cured leaf yield. While it exhibited positive significant correlation with green leaf yield and the trait had moderate direct and high indirect effects *via* cured leaf yield and all other indirect effects being negligible in the cross TB-100 × TB-102. Hence, this can be considered as one of the traits where selection can operate to get high green leaf yielding lines in further generations in both the crosses.

As total sugars showed positive non-significant correlation with green leaf yield and its direct and indirect effects were of negligible magnitude irrespective of their direction in both the crosses, TB-70 × TB-102 and TB-100 × TB-102, selection for this trait would have no effect on increasing green leaf yield.

As in present study, positive correlations of fresh leaf yield with plant height (Kim and Hwang, 1981, Patel *et al.*, 1981, Kamel *et al*., 1985, Rehman and Qureshi, 1997b) ,internodal length (Rehman and Qureshi, 1997b), number of leaves per plant (Lukosevicius, 1975, Hamid *et al*., 1975, White *et al*., 1979, Kim and Hwang, 1981, Patel *et al.,* 1981, Kamel *et al*., 1985), leaf length (Hamid *et al*., 1975, White *et al*., 1979, Patel *et al.,* 1981, Kamel *et al*., 1985, Smalcelt and Vasilj, 1987), leaf breadth (Hamid *et al*., 1975, Patel *et al.,* 1981), leaf area per plant (Jung *et al*., 1980, Patel *et al.,* 1981), cured leaf yield (Chaubey *et al*., 1990 and Lakshmish and Shivanna, 1999), top grade equivalent (Lakshmish and Shivanna, 1999) were recorded by earlier workers. Negative correlations of fresh leaf yield with days to flowering (Patel *et al.,* 1981) was also obtained previously.

Similar results with respect to path coefficient analysis, positive direct and indirect effects on green leaf yield with number of leaves per plant and leaf breadth (Venkatarao *et al*.,1973, Keum and Jeh, 1981) and negative direct and indirect effects with plant height (Venkatarao *et al*.,1973) supports this study.

It was observed that most of the yield components contributed indirectly towards green leaf yield. Low residual effect indicated that the selection of the traits for path coefficient analysis was appropriate and no character was neglected. In the present investigation , cured leaf yield, top grade equivalent, number of leaves per plant and leaf area per plant were important component characters which must be given due weightage when plant breeder practices selection in both the populations.

5.3 Study of superior transgressive segregants

Transgressive segregants are those genotypes, which surpassed the limits of both the parents in desirable direction for any of the character in segregating generations, especially in F_2 population. Combinations of favourable genes (positive alleles) from different parents and additive gene action are the main reasons for the occurrence of transgressive segregants.

The significant superior performance of segregants may be due to the contribution of some component characters. In cross TB-70 X TB-102, plant number 55 exhibited highest green leaf yield which may be due to the contribution of component characters like plant height, internodal length, number of leaves per plant, leaf area per plant, days to flowering and days to maturity. While superior performance of plant number 46 may be due to component traits like plant height, number of leaves per plant and leaf area per plant. Whereas superior performance of plant number 25 may be due to component traits like plant height, stem girth, chlorophyll content, leaf area per plant, days to flowering and days to maturity.

In cross TB-100 X TB-102, plant number 36 exhibited highest green leaf yield due to the contribution of component characters like plant height, stem girth, number of leaves per plant, leaf length, leaf area per plant, days to flowering and days to maturity. While superior performance of plant number 27 may be due to component traits like plant height, leaf length, leaf area per plant, days to flowering and days to maturity. Whereas superior performance of plant number 111 may be due to component traits like stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf length, leaf area per plant, days to flowering and days to maturity.

The present investigation lead to the identification of superior promising individual plants in F_2 segregating generations in the two crosses of FCV tobacco *viz.,* TB-70 X TB-102 and TB-100 X TB-102. It would be worthwhile to evaluate the performance of progenies derived from desirable transgressive segregants in future generations for their further use in breeding programmes.

Future line of work

1. In the present study higher estimates of PCV, GCV, heritability and GA as per cent of mean were observed for the traits like specific leaf weight, leaf area per plant and total sugars, therefore selection for segregants with these traits along with green leaf yield may be done in segregating generations of both crosses.
2. Superior plants recovered from two crosses which exhibited high green leaf yield can be further forwarded to F_3 and further generations through pedigree method.
3. Segregants superior for physiological traits can also be used in breeding for physiological efficiency.

SUMMARY

VI. SUMMARY

The present investigation was envisaged to study the nature and magnitude of genetic variability, the pattern of character association, the direct and indirect effects of component characters on green leaf yield in two FCV tobacco crosses *viz.*, TB-70 × TB-102 and TB-100 × TB-102, having contrasting parentages for yield and yield attributing characters. The F_2 populations of the above mentioned crosses along with the parents were grown at College of Agriculture, Navile, Shivamogga during *Kharif* season of 2015. Observations were recorded on fifteen metric traits in both the crosses.

Different parameters such as mean, range, genotypic and phenotypic coefficients of variance and correlation as well as path analysis of important characters towards green leaf yield have been worked out for both the crosses. As per mean performance among the crosses in F_2 generation, cross TB-70 × TB-102 followed by TB-100 × TB-102 showed high green leaf yield, cured leaf yield, top grade equivalent.

The study revealed wide range of variability for most of the characters studied. Characters like plant height, leaf length, leaf breadth, leaf area per plant and green leaf yield exhibited wider range values. The estimates of PCV and GCV were high for specific leaf weight, leaf area per plant and total sugars in both the crosses, but internodal length and chlorophyll content in case of cross TB-70 × TB-102 and number of leaves per plant in the cross TB-100 × TB-102 were high whereas internodal length had recorded low PCV and GCV values in the cross TB-100 × TB-102. The traits like days to maturity, green leaf yield, cured leaf yield and top grade equivalent recorded low values of PCV and GCV in both the crosses. Leaf breadth and leaf length exhibited a range of moderate to low PCV and GCV values among both the segregating populations indicating moderate to less variability for these characters, suggesting that individual plant selections can be practiced for the above mentioned characters in the F_3 generation for higher yield. The differences between PCV and GCV for the characters *viz*., leaf breadth, leaf area per plant, days to flowering, days to maturity, cured leaf yield and top grade equivalent was narrow in both the two crosses indicating lesser influence of environment on these characters.

Therefore, phenotypic values are reliable in selecting the genotypes for these characters.

High heritability estimates were observed for all the characters investigated *viz*., plant height, internodal length, stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf length, leaf breadth, leaf area per plant, days to flowering, days to maturity, green leaf yield, cured leaf yield, top grade equivalent and total sugars in both the crosses TB-70 × TB-102 and TB-100 × TB-102. These results indicate that direct selection for yield attributing characters will improves green leaf yield.

The expected genetic gain expressed as per cent of mean was high for stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf area per plant and days to flowering in both the crosses. Leaf length, leaf breadth and days to maturity recorded moderate genetic gain in both the crosses, whereas, plant height and total sugars exhibited high GAM in the cross TB-70 × TB-102 and moderate GAM in the cross TB-100 × TB-102. The remaining characters showed moderate to low genetic advance as per cent of mean values. High heritability coupled with high genetic advance was noticed for stem girth, chlorophyll content, specific leaf weight, number of leaves per plant, leaf area per plant and days to flowering in both the crosses. Plant height, internodal length and total sugars had high heritability coupled with high genetic advance in the cross TB-70 × TB-102. This indicates that these traits are mainly governed by additive gene action and hence responsive to selection.

Green leaf yield had strong positive correlation with cured leaf yield, top grade equivalent, leaf area per plant and number of leaves per plant in both the crosses TB-70 × TB-102 and TB-100 × TB-102. Negative correlation with days to flowering and chlorophyll content was observed for both the crosses.

Cured leaf yield showed high direct positive association with green leaf yield in both the crosses while high indirect positive association via top grade equivalent was noticed in the cross TB-100 × TB-102. Most of the traits have shown high and moderate indirect effects *via* cured leaf yield.

Plant numbers 55, 46 and 25 in cross TB-70 × TB-102 and plant numbers 36, 27, and 111 in cross TB-100 × TB-102 were found to be promising in terms of green leaf yield and can be further advanced through pedigree selection.

Thus it can be concluded that analyzing the variability in segregating generations and making selection out of it for forwarding into further generations are key steps in varietal development. Adoption of indirect selection in segregating generations of FCV tobacco based on both green leaf yield and its related component traits, particularly cured leaf yield, top grade equivalent, leaf area per plant and number of leaves per plant rather than direct selection for green leaf yield will be highly reliable for developing high yielding genotypes in further generations. Performance of desirable superior transgressive segregants will have to be evaluated in further generations for their further use in breeding programmes.

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*Originals not seen.

APPENDICES

Appendix I: Normal (1986-2014) and actual (2015) mean monthly meteorological data for the experimental period (2015) at ZAHRS, Navile, Shivamogga

Month	Total rainfall (mm)			Maximum temperature(^{0}C)			Minimum temperature (^{0}C)			Relative Humidity (%)			Sunshine Hours (hours)			Number of rainy days
	N	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	
January	0.4	0.0	-0.4	31.2	31.1	-0.1	15.5	17.2	1.7	59.2	77.6	18.4	9.1	8.8	-0.3	0
February	0.2	0.0	-0.2	33.3	33.2	-0.1	18.3	17.7	-0.6	56.9	69.4	12.5	9.0	9.0	0.0	0
March	3.2	58.4	55.2	35.7	35.1	-0.6	21.6	21.1	-0.5	54.0	67.9	13.9	7.5	4.8	-2.7	1
April	45.0	48.6	3.6	36.3	34.6	-1.7	22.3	22.1	-0.2	59.7	64.2	4.5	7.7	7.7	0.0	3
May	70.6	196	125.4	34.7	33.2	-1.5	21.8	22.7	0.9	65.9	78.4	12.5	7.5	6.3	-1.2	9
June	114.5	294.8	180.3	29.4	28.7	-0.7	20.8	21.5	0.7	69.4	81.1	11.7	3.4	2.9	-0.5	19
July	203.3	121	-82.3	27.7	28.5	0.8	19.4	21.1	1.7	83.5	82.3	-1.2	2.3	4.0	1.7	11
August	140.7	83.2	-57.5	27.6	29.7	2.1	20.0	22.3	2.3	83.4	81.4	-2.0	4.0	7.0	3.0	11
September	105.2	214.4	109.2	29.3	30.1	0.8	21.4	22.0	0.6	79.5	80.4	0.9	4.8	5.2	0.4	9
October	146.1	135	-11.1	30.2	31.3	1.1	20.2	21.9	1.7	77.5	76.8	-0.7	6.4	7.2	0.8	6
November	42.9	79.4	36.5	29.8	29.2	-0.6	19.5	19.4	-0.1	69.7	76.0	6.3	7.3	4.6	-2.7	4
December	11.2	2.0	-9.2	29.8	31.8	2.0	17.9	18.0	0.1	62.3	72.4	10.1	8.6	8.6	0.0	0
Total	**883.3**	**1232.8**	**349.5**	**---**	**----**	**---**	**---**	**---**	**-----**	**---**	**---**	**---**	**---**	**---**	**--**	**73**

N - Normal meteorological data (1986-2014) **A** - Actual meteorological data (2015) **D** - Deviation from the Normal (A-N)

APPENDIX-II

Plant-wise observations of Parents and F_2 populations

Parent- TB-70

Plant No./ Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	68.00	6.17	15.80	17.17	5.50	12.00	34.83	16.50	46.61	94.00	126.00	1306.67	192.73	135.20	14.50
2	46.00	3.83	11.90	16.90	6.00	9.00	24.33	10.44	14.80	94.00	129.00	939.99	140.53	99.56	14.00
3	56.00	5.00	15.60	23.00	5.25	10.00	31.20	13.40	26.92	106.00	142.00	1329.99	201.63	139.93	17.40
4	53.00	4.33	10.59	13.20	5.00	14.00	28.21	13.57	29.80	94.00	132.00	1776.65	270.94	188.71	16.50
5	62.00	6.17	16.49	15.60	6.00	9.00	25.44	12.00	18.08	102.00	137.00	1115.55	169.56	118.95	14.30
6	41.00	3.00	13.22	17.60	6.50	8.00	29.38	13.50	20.16	94.00	126.00	1506.67	229.77	159.46	19.00
7	37.00	3.67	15.58	30.60	6.00	7.00	27.43	13.14	16.61	105.00	145.00	1106.66	168.21	117.16	17.40
8	47.00	2.83	16.28	28.90	5.50	15.00	29.67	16.40	46.23	99.00	137.00	1766.65	267.82	184.66	18.60
9	32.00	4.17	16.16	23.70	7.75	11.00	28.00	14.18	28.30	94.00	137.00	1279.99	195.20	138.30	20.00
10	39.00	3.50	11.56	24.70	7.50	13.00	29.69	17.23	42.25	94.00	137.00	1525.14	231.82	160.88	12.40
11	59.00	3.50	18.22	19.70	5.00	11.00	30.82	18.55	41.52	96.00	130.00	1453.33	221.63	152.82	15.80
12	34.00	3.00	11.18	25.10	6.00	12.00	28.33	13.17	29.62	109.00	150.00	1419.99	216.55	150.28	14.20
13	62.00	3.17	21.32	29.90	5.00	12.00	31.08	15.67	39.03	96.00	135.00	1586.65	241.17	167.98	16.00
14	47.00	3.83	16.50	28.50	5.00	13.00	28.31	15.00	38.39	96.00	135.00	1773.32	268.83	185.36	14.70
15	34.00	2.83	12.25	25.20	4.75	12.00	27.50	13.08	27.73	96.00	137.00	1262.07	192.47	136.36	17.20
Mean	**47.80**	**3.93**	**14.84**	**22.65**	**5.78**	**11.20**	**28.95**	**14.39**	**31.07**	**97.93**	**135.67**	**1409.95**	**213.92**	**149.04**	**16.13**

Parent- TB-100

Plant No./ Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	40.00	4.17	16.33	21.70	5.00	16.00	27.25	12.25	33.27	97.00	137.00	1196.67	182.49	126.65	20.70
2	46.00	5.17	16.60	20.90	5.00	9.00	28.56	13.11	21.62	97.00	138.00	903.32	136.94	95.38	16.00
3	43.00	4.50	16.30	15.90	5.25	13.00	30.08	14.38	37.28	122.00	156.00	1166.66	177.91	122.67	14.30
4	51.00	4.33	20.16	21.30	5.00	15.00	28.00	12.87	35.53	112.00	144.00	1236.65	187.97	131.86	18.00
5	34.00	3.83	12.13	28.50	4.25	13.00	24.69	11.23	24.00	97.00	134.00	1038.96	157.51	111.59	16.50
6	25.00	3.17	13.86	17.70	7.50	11.00	30.36	14.82	31.74	142.00	175.00	1280.00	194.56	135.51	13.60
7	28.00	3.83	10.56	25.70	5.50	9.00	29.33	15.11	25.65	142.00	173.00	1209.99	183.43	126.48	19.40
8	35.00	3.33	12.33	13.50	4.25	10.00	25.20	12.00	19.44	110.00	147.00	1486.65	226.71	157.34	17.90
9	37.00	4.50	11.28	17.20	5.25	12.00	27.75	14.08	31.99	97.00	131.00	1736.65	263.28	183.37	15.10
10	31.00	4.17	11.87	24.30	4.75	9.00	28.56	15.11	25.20	110.00	142.00	1561.77	238.17	164.22	16.80
11	32.00	3.50	12.42	46.30	6.00	7.00	28.86	13.43	17.25	120.00	160.00	910.00	134.23	95.10	21.20
12	37.00	4.17	11.22	26.10	3.75	10.00	22.70	10.00	14.88	115.00	160.00	1109.99	165.94	115.16	15.00
13	34.00	3.83	13.21	11.60	4.75	12.00	21.83	10.67	19.65	115.00	160.00	1099.99	166.76	116.15	14.00
14	34.00	3.67	11.70	16.10	5.25	9.00	23.00	10.33	13.97	140.00	177.00	929.99	141.82	99.49	22.20
15	35.00	4.00	13.14	51.30	4.25	10.00	27.50	14.70	27.94	112.00	152.00	1122.21	170.58	120.85	19.60
Mean	**36.13**	**4.01**	**13.54**	**23.87**	**5.05**	**11.00**	**26.91**	**12.94**	**25.29**	**115.20**	**152.40**	**1199.30**	**181.89**	**126.79**	**17.35**

Parent- TB-102

Plant No./ Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	51.00	5.17	12.78	26.50	4.00	9.00	35.56	18.11	37.45	102.00	134.00	1136.67	173.34	119.52	14.00
2	50.00	3.83	13.34	30.60	4.75	8.00	31.25	17.38	27.98	108.00	142.00	1493.32	226.98	160.82	19.70
3	48.00	5.33	15.78	33.80	7.00	7.00	35.71	20.71	33.82	142.00	173.00	1166.66	176.86	122.74	21.50
4	49.00	4.33	20.46	24.80	4.75	7.00	31.71	19.00	26.99	142.00	174.00	1236.65	182.41	127.05	12.00
5	37.00	3.83	13.54	28.40	4.75	6.00	25.00	11.67	11.84	155.00	175.00	1038.96	155.32	107.10	15.20
6	40.00	3.50	12.96	25.50	5.50	5.00	31.20	16.80	16.71	116.00	157.00	1113.33	169.78	118.25	16.00
7	53.00	5.33	20.14	22.90	4.50	6.00	31.67	18.83	22.87	102.00	143.00	1206.65	183.41	126.46	13.50
8	33.00	4.17	11.63	25.40	5.50	9.00	31.33	19.44	35.20	114.00	151.00	1406.65	207.48	142.44	18.60
9	54.00	4.00	14.81	20.70	5.25	10.00	29.70	17.40	33.43	103.00	145.00	1159.99	173.42	121.65	20.30
10	40.00	4.50	19.20	37.60	6.75	8.00	30.25	19.38	30.27	114.00	155.00	1388.61	210.51	149.15	19.80
11	55.00	4.00	19.73	33.70	4.50	8.00	33.14	20.71	33.12	116.00	156.00	1600.00	243.20	169.39	9.30
12	39.00	3.50	11.70	31.00	4.00	6.00	31.67	19.50	32.41	104.00	138.00	986.66	145.53	100.34	15.40
13	53.00	4.17	13.38	23.90	5.00	7.00	26.14	14.57	19.22	114.00	156.00	1409.99	210.79	145.34	17.20
14	56.00	4.33	18.41	36.90	5.50	10.00	36.00	20.00	49.86	114.00	156.00	1563.32	237.00	166.25	13.10
15	54.00	3.67	7.97	31.60	6.25	7.00	29.43	16.86	22.00	125.00	162.00	1065.60	162.50	115.13	21.00
Mean	**47.47**	**4.24**	**15.06**	**28.89**	**5.20**	**7.53**	**31.32**	**18.02**	**28.88**	**118.07**	**154.47**	**1264.87**	**190.57**	**132.78**	**16.44**

X_1- Plant height(cm)
X_2- Internodal length (cm)
X_3- Stem girth (mm)
X_4- Chlorophyll content
X_5- Specific leaf weight (mg/cm^2)
X_6- Number of leaves per plant
X_7- Leaf length (cm)
X_8- Leaf breadth (cm)
X_9- Leaf area per plant (dm^2)
X_{10}- Days to flowering
X_{11}- Days to maturity
X_{12}- Green leaf yield (Kg/ha)
X_{13}- Cured leaf yield (Kg/ha)
X_{14}- TGE (Kg/ha)
X_{15}- Total sugars (%)

TB-70 × TB-102 (F_2 population)

Plant No./ Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	73.00	4.50	23.10	9.90	4.50	14.00	46.00	24.00	100.72	120.00	152.00	10407.41	1535.09	1076.87	15.70
2	90.00	4.00	26.53	13.40	3.50	12.00	45.33	25.41	91.29	120.00	150.00	10833.33	1619.58	1147.47	18.20
3	91.00	4.17	30.55	12.60	4.25	13.00	47.38	26.84	109.27	96.00	128.00	11092.59	1681.64	1167.06	12.60
4	72.00	4.00	25.83	17.40	4.75	14.00	35.07	20.50	72.01	108.00	142.00	10944.44	1669.03	1162.48	12.90
5	55.00	3.17	26.82	11.00	3.25	16.00	52.81	25.87	136.06	120.00	156.00	11500.00	1748.00	1226.22	11.80
6	80.00	3.83	22.18	20.10	4.00	13.00	49.61	25.84	107.83	120.00	154.00	11555.56	1751.82	1241.17	16.40
7	59.00	3.67	25.62	20.60	2.25	17.00	47.58	25.17	121.18	120.00	152.00	9666.67	1474.17	1023.07	8.20
8	80.00	3.83	26.50	16.10	5.25	15.00	45.26	26.46	117.45	134.00	165.00	9925.93	1508.74	1050.84	6.70
9	40.00	3.67	25.21	14.60	3.25	12.00	42.58	24.08	79.59	134.00	155.00	10611.11	1608.64	1109.16	16.60
10	72.00	3.83	24.28	11.30	4.75	18.00	43.72	24.61	109.69	96.00	128.00	11314.81	1725.51	1222.52	14.50
11	53.00	4.33	17.14	11.40	3.00	13.00	42.69	23.15	83.14	96.00	130.00	11055.56	1680.44	1166.23	13.20
12	80.00	4.00	24.91	23.10	4.25	11.00	44.00	22.09	72.26	120.00	152.00	8055.56	1221.22	850.58	17.50
13	71.00	4.33	35.36	19.60	3.50	13.00	48.38	26.23	110.21	162.00	195.00	10129.63	1544.77	1065.12	9.80
14	40.00	2.83	20.68	18.60	3.00	9.00	34.33	17.22	36.15	96.00	130.00	8370.37	1276.48	885.88	13.70
15	90.00	4.00	29.12	15.50	3.50	15.00	47.50	26.27	126.60	120.00	154.00	9962.96	1514.37	1054.76	18.20
16	80.00	4.33	33.23	16.30	3.00	13.00	46.23	26.53	113.26	120.00	160.00	10444.44	1583.38	1091.74	8.60
17	90.00	4.17	24.88	16.00	3.75	12.00	46.91	25.66	97.71	96.00	134.00	9333.33	1423.33	1008.43	10.30
18	72.00	4.00	25.55	20.50	6.00	12.00	40.83	21.83	75.22	152.00	182.00	3907.41	593.93	416.64	11.50
19	80.00	4.33	28.54	12.40	5.25	16.00	44.31	25.81	110.07	134.00	173.00	11055.56	1676.02	1187.46	12.40
20	76.00	4.50	22.99	14.60	5.00	12.00	49.66	25.91	102.48	96.00	127.00	8166.67	1245.42	864.32	22.00
21	90.00	4.00	27.63	12.40	3.75	14.00	51.57	26.21	121.91	134.00	168.00	8111.11	1229.64	856.45	18.20
22	73.00	3.83	19.87	20.80	2.75	11.00	39.72	23.18	68.64	134.00	168.00	8240.74	1256.71	866.50	6.60
23	72.00	4.00	25.32	21.90	3.75	13.00	31.61	18.53	49.05	140.00	175.00	4388.89	667.11	467.98	18.40

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24	74.00	4.00	21.16	15.20	5.25	12.00	48.75	28.33	108.92	152.00	188.00	12092.59	1833.24	1298.85	16.90
25	80.00	4.33	29.70	15.90	4.00	11.00	48.36	25.54	90.17	120.00	155.00	14166.67	2160.42	1499.33	19.50
26	73.00	4.33	27.92	8.70	4.25	11.00	46.54	24.27	83.86	120.00	158.00	7240.74	1100.59	766.56	10.00
27	66.00	3.67	28.58	12.10	3.75	14.00	48.71	24.71	111.17	120.00	160.00	9592.59	1454.24	1002.70	14.60
28	70.00	4.17	27.10	16.60	3.00	11.00	48.36	25.90	90.33	152.00	184.00	6722.22	1025.14	711.45	11.30
29	67.00	3.83	26.25	14.30	3.00	12.00	44.41	22.25	79.12	120.00	152.00	6500.00	985.40	686.33	17.60
30	60.00	4.00	23.44	9.60	3.75	13.00	46.69	24.69	98.87	96.00	129.00	10518.52	1604.07	1106.01	13.30
31	85.00	3.67	25.56	8.60	3.50	12.00	41.00	21.58	72.18	108.00	145.00	11814.81	1795.85	1259.79	10.20
32	68.00	3.67	19.56	11.40	3.50	13.00	41.00	23.07	81.18	96.00	134.00	10592.59	1562.41	1106.97	11.90
33	40.00	3.83	18.79	6.60	3.50	13.00	43.53	23.23	88.79	134.00	166.00	7277.78	1088.03	755.09	15.60
34	40.00	3.67	22.67	15.10	3.00	9.00	42.33	22.55	104.57	120.00	154.00	9333.33	1414.93	985.50	12.30
35	40.00	4.50	18.51	8.70	2.75	12.00	47.66	24.00	90.51	120.00	154.00	10037.04	1530.65	1073.75	19.40
36	72.00	4.00	23.81	15.70	5.25	15.00	48.73	24.80	122.05	120.00	154.00	14166.67	2153.33	1525.64	22.50
37	85.00	3.83	24.47	13.50	4.25	9.00	47.77	24.44	70.61	120.00	163.00	7759.26	1160.01	805.05	9.40
38	64.00	3.50	23.43	10.00	2.50	11.00	39.00	19.72	55.89	140.00	155.00	9759.26	1479.50	1030.47	21.60
39	84.00	4.33	23.81	16.30	3.75	12.00	46.00	24.25	88.27	96.00	168.00	7740.74	1180.46	813.93	18.70
40	62.00	4.00	20.48	14.60	3.75	11.00	38.81	20.81	57.59	120.00	154.00	10555.56	1604.44	1136.75	4.60
41	57.00	4.00	23.54	18.60	3.75	12.00	44.33	24.75	85.81	130.00	160.00	9962.96	1510.39	1048.21	13.00
42	100.00	5.00	24.41	11.40	3.75	9.00	40.55	22.88	57.27	96.00	126.00	6888.89	1016.11	707.72	14.90
43	80.00	4.67	20.26	17.20	3.75	13.00	51.76	25.46	111.63	133.00	173.00	12833.33	1918.58	1322.86	17.80
44	80.00	4.83	26.53	13.40	5.00	12.00	46.08	25.33	91.11	120.00	162.00	10148.15	1538.46	1067.69	8.80
45	66.00	4.33	27.14	17.10	3.00	17.00	47.64	23.76	122.81	142.00	183.00	12611.11	1923.19	1339.50	4.20
46	85.00	4.00	25.90	15.10	4.75	15.00	44.13	24.93	108.32	96.00	137.00	14296.30	2173.04	1498.31	20.50
47	80.00	4.17	25.19	13.30	2.75	18.00	46.44	20.83	94.51	120.00	156.00	9000.00	1327.50	911.33	19.00
48	72.00	4.00	25.36	8.50	4.25	12.00	42.16	23.75	78.68	120.00	156.00	11592.59	1733.09	1215.76	13.50
49	77.00	4.00	23.13	10.40	4.50	12.00	44.91	22.33	80.00	120.00	157.00	9592.59	1454.24	1030.33	7.20
50	80.00	3.33	30.27	13.20	3.75	12.00	45.50	24.83	90.07	136.00	170.00	8333.33	1270.83	881.96	10.30

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51	54.00	4.83	18.19	11.70	2.50	15.00	37.73	19.93	72.90	120.00	160.00	6777.78	1030.22	717.55	15.80
52	59.00	4.00	27.25	12.50	2.75	13.00	48.61	25.30	106.86	136.00	166.00	11703.70	1726.30	1190.28	21.40
53	80.00	4.33	27.11	13.10	5.00	11.00	42.18	22.09	67.36	120.00	155.00	9462.96	1414.71	975.44	6.90
54	70.00	4.33	20.96	21.60	4.75	10.00	38.40	24.20	61.49	120.00	155.00	7203.70	1092.08	766.10	7.00
55	80.00	5.00	26.55	15.60	4.75	18.00	48.50	25.83	125.69	125.00	167.00	16703.70	2547.31	1804.77	13.60
56	66.00	3.67	24.88	12.80	3.75	14.00	44.85	23.71	98.14	120.00	155.00	8240.74	1256.71	881.58	15.20
57	74.00	3.17	21.88	7.90	4.00	15.00	44.40	25.26	109.63	144.00	182.00	12518.52	1902.81	1334.82	15.70
58	72.00	4.00	25.88	11.90	3.50	9.00	35.44	23.11	47.81	96.00	130.00	9222.22	1360.28	963.76	16.60
59	80.00	2.83	30.26	17.80	3.00	13.00	47.38	24.38	101.46	99.00	134.00	11111.11	1661.11	1152.81	4.20
60	63.00	3.17	27.57	18.40	2.00	11.00	46.36	26.09	87.95	120.00	163.00	10222.22	1549.69	1079.36	17.30
61	61.00	4.00	24.60	13.20	4.00	8.00	35.50	24.25	44.57	120.00	155.00	8333.33	1270.83	891.49	18.40
62	57.00	3.50	24.40	16.00	1.75	14.00	41.21	24.07	89.39	120.00	156.00	10611.11	1608.64	1139.72	10.90
63	29.00	3.50	18.80	14.20	2.50	12.00	43.33	24.58	83.49	120.00	165.00	10111.11	1541.94	1070.11	16.40
64	60.00	4.17	21.45	9.50	4.00	14.00	46.78	26.64	115.73	120.00	163.00	10666.67	1621.33	1137.37	9.40
65	80.00	4.17	24.53	16.70	4.25	11.00	47.27	27.72	92.83	108.00	144.00	11370.37	1677.13	1188.25	9.70
66	69.00	3.17	23.45	11.30	4.00	13.00	45.84	26.00	104.10	96.00	128.00	12240.74	1829.99	1270.01	5.50
67	75.00	4.00	16.87	16.40	3.00	12.00	43.75	26.50	89.88	115.00	145.00	8777.78	1330.71	926.84	18.50
68	34.00	3.33	17.94	17.10	2.75	8.00	41.50	24.12	53.34	120.00	155.00	6481.48	988.43	693.38	16.00
69	80.00	5.17	24.62	21.60	3.25	12.00	48.00	26.83	100.16	120.00	155.00	9351.85	1417.74	1004.47	12.40
70	100.00	5.67	35.11	15.60	3.00	13.00	51.46	28.69	122.81	96.00	128.00	11722.22	1787.64	1240.62	11.80
71	73.00	4.17	23.15	9.30	3.75	12.00	42.50	25.58	82.68	120.00	155.00	8370.37	1272.30	886.15	14.20
72	80.00	4.17	30.94	11.00	3.25	11.00	45.63	24.90	85.64	134.00	168.00	8000.00	1180.00	813.61	7.20
73	69.00	3.83	23.70	15.00	4.25	15.00	45.93	27.13	125.98	134.00	168.00	10111.11	1511.61	1070.98	6.60
74	70.00	4.17	24.22	17.40	2.75	14.00	36.14	23.71	78.52	120.00	155.00	10148.15	1538.46	1067.69	20.30
75	80.00	4.50	28.29	20.80	3.50	15.00	44.46	24.40	107.15	162.00	145.00	9425.93	1437.45	1001.19	15.80

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76	58.00	4.17	13.85	10.60	4.00	11.00	32.54	20.27	72.90	154.00	185.00	8907.41	1350.36	931.08	22.80
77	25.00	4.00	12.30	14.70	3.50	13.00	28.61	15.30	106.86	120.00	156.00	6518.52	994.07	689.89	12.70
78	72.00	4.00	25.76	12.60	4.00	10.00	31.70	19.60	67.36	120.00	155.00	5185.19	788.15	548.95	17.70
79	50.00	4.83	15.68	10.70	2.50	9.00	32.33	21.22	61.49	120.00	155.00	4833.33	712.92	491.56	22.30
80	46.00	3.83	18.46	9.00	2.75	10.00	44.00	24.30	125.69	96.00	134.00	7185.19	1074.19	740.65	18.70
81	40.00	4.33	16.81	7.30	4.25	10.00	40.90	24.30	98.14	108.00	140.00	7444.44	1128.58	791.70	18.90
82	55.00	4.50	21.18	9.60	3.75	12.00	45.08	24.33	109.63	120.00	155.00	10388.89	1584.31	1122.48	8.20
83	67.00	2.83	20.80	12.60	4.00	13.00	45.30	24.00	47.81	154.00	190.00	8129.63	1239.77	860.40	11.50
84	59.00	3.50	19.97	9.00	2.75	12.00	45.25	24.58	101.46	134.00	167.00	8833.33	1342.67	935.17	6.00
85	45.00	2.83	18.81	20.00	2.75	11.00	33.90	19.54	87.95	120.00	155.00	6833.33	1007.92	694.96	7.60
86	46.00	3.67	18.29	21.60	2.50	13.00	43.15	24.53	44.57	96.00	137.00	7129.63	1065.88	747.71	20.50
87	64.00	3.67	23.64	25.90	5.25	14.00	41.21	23.00	89.39	108.00	145.00	11259.26	1706.90	1209.34	22.60
88	65.00	3.33	29.44	24.10	20.25	11.00	44.63	23.09	83.49	120.00	154.00	8629.63	1316.02	913.32	14.80
89	80.00	3.50	33.88	17.30	6.25	16.00	39.88	24.56	115.73	96.00	135.00	12759.26	1907.51	1328.58	22.40
90	74.00	3.17	22.75	18.20	3.75	9.00	46.33	27.88	92.83	120.00	155.00	6370.37	965.75	665.88	18.20
91	80.00	3.50	33.44	10.60	5.75	14.00	47.00	25.35	104.10	120.00	155.00	11888.89	1813.06	1271.86	16.10
92	90.00	3.83	28.57	10.00	4.00	12.00	53.25	28.16	89.88	132.00	166.00	10574.07	1607.26	1138.74	13.80
93	72.00	3.50	24.37	13.50	4.00	12.00	45.16	25.66	53.34	132.00	161.00	9296.30	1389.80	964.52	19.50
94	71.00	3.50	26.91	14.80	3.50	11.00	47.27	24.54	100.16	134.00	172.00	10351.85	1569.34	1093.05	10.30
95	49.00	2.50	25.63	15.90	4.00	12.00	49.91	27.58	122.81	96.00	134.00	11000.00	1677.50	1156.64	19.40
96	69.00	3.67	24.90	14.10	4.00	11.00	44.45	26.00	82.68	152.00	185.00	10592.59	1610.07	1129.47	12.90
97	69.00	4.00	19.40	12.20	5.00	12.00	40.16	23.75	85.64	134.00	166.00	7555.56	1129.56	800.29	13.50
98	70.00	2.50	34.58	20.20	5.50	15.00	56.66	29.86	125.98	120.00	155.00	11944.44	1810.78	1256.68	19.90
99	57.00	3.83	16.26	18.70	4.00	12.00	45.16	25.50	78.52	120.00	156.00	8259.26	1259.54	877.27	15.70
100	67.00	3.50	27.33	17.70	4.25	7.00	46.71	25.57	107.15	120.00	155.00	4851.85	737.48	517.34	16.30

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101	80.00	4.17	25.75	9.30	2.75	5.00	39.00	27.40	34.33	120.00	155.00	8314.81	1243.06	880.71	9.70
102	80.00	3.50	24.94	12.50	4.00	11.00	42.81	27.18	85.26	120.00	155.00	7222.22	1094.89	759.85	14.20
103	80.00	3.50	21.80	15.90	4.00	12.00	34.16	22.00	59.80	154.00	186.00	7000.00	1067.50	743.51	5.00
104	80.00	4.17	27.40	16.70	3.00	8.00	30.37	21.25	34.82	96.00	133.00	6518.52	990.81	683.17	15.40
105	60.00	3.50	21.10	16.10	4.00	6.00	30.33	21.00	25.00	120.00	155.00	7222.22	1079.72	764.98	16.90
106	80.00	2.50	23.68	10.80	3.75	9.00	42.55	22.22	56.83	120.00	164.00	7814.81	1184.73	822.20	10.30
107	90.00	3.17	26.65	15.60	5.00	10.00	43.60	26.20	74.81	120.00	160.00	9203.70	1403.56	977.58	22.80
108	68.00	2.83	21.27	15.00	4.50	12.00	49.66	28.33	112.12	154.00	186.00	12907.41	1961.93	1352.75	13.20
109	80.00	4.50	29.39	16.50	5.00	12.00	55.41	30.58	131.44	108.00	144.00	12944.44	1935.19	1343.02	16.30
110	85.00	3.33	29.14	8.60	3.75	13.00	48.76	27.23	118.94	120.00	158.00	12203.70	1850.08	1288.58	12.80
111	90.00	3.17	35.64	12.20	4.50	12.00	48.91	30.00	114.53	120.00	157.00	9796.30	1493.94	1030.07	13.30
112	80.00	3.33	33.16	20.10	5.25	12.00	54.33	29.00	123.66	134.00	168.00	11629.63	1767.70	1240.04	14.20
113	71.00	3.50	22.53	16.70	4.25	11.00	53.90	29.63	113.23	120.00	155.00	9296.30	1324.72	929.29	4.70
114	65.00	2.67	25.54	21.80	3.50	14.00	47.00	23.78	100.59	154.00	188.00	7851.85	1158.15	820.55	18.90
115	63.00	3.50	21.98	15.60	4.00	11.00	42.45	24.27	76.90	120.00	156.00	9870.37	1475.62	1024.08	15.20
116	100.00	4.17	32.05	13.00	4.50	14.00	46.14	26.14	110.75	120.00	155.00	6166.67	934.87	651.13	14.50
117	90.00	2.83	27.11	9.90	5.00	13.00	52.30	25.30	110.91	154.00	194.00	6055.56	923.47	636.73	14.00
118	75.00	5.33	27.80	8.80	5.25	14.00	44.14	21.07	87.94	120.00	162.00	9388.89	1427.11	1011.11	18.60
119	64.00	4.00	30.55	15.20	2.75	10.00	49.10	28.20	92.80	120.00	168.00	10277.78	1515.97	1052.08	6.90
120	77.00	3.17	31.78	10.50	4.50	12.00	51.25	27.75	114.37	154.00	192.00	8407.41	1256.91	875.44	24.50
121	72.00	3.50	21.30	19.20	4.25	11.00	44.72	24.72	80.73	108.00	142.00	5500.00	833.80	574.91	6.40
122	70.00	3.50	20.83	7.80	3.75	8.00	49.00	27.25	70.81	120.00	158.00	9629.63	1468.52	1040.45	12.50
123	78.00	2.83	32.36	12.60	3.75	9.00	48.33	27.33	77.73	120.00	158.00	11185.19	1700.15	1192.65	10.20
124	80.00	3.17	27.26	9.50	5.25	12.00	58.83	28.08	122.89	154.00	188.00	9888.89	1409.17	998.39	12.30
125	80.00	2.83	29.10	9.90	4.50	10.00	57.27	26.45	107.23	154.00	174.00	12129.63	1843.70	1279.53	16.00

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126	70.00	4.00	33.16	18.30	4.75	14.00	52.50	28.14	132.33	120.00	154.00	9462.96	1414.71	985.35	18.00
127	80.00	3.00	30.56	11.50	5.00	11.00	44.09	25.81	82.94	120.00	157.00	11092.59	1681.64	1159.49	24.70
128	80.00	3.33	23.54	12.00	5.00	13.00	48.61	24.46	98.64	152.00	194.00	9333.33	1423.33	998.47	8.80
129	80.00	4.67	26.51	14.20	5.00	14.00	38.50	22.50	82.14	120.00	150.00	11222.22	1705.78	1208.54	17.50
130	80.00	4.33	29.32	16.00	5.25	15.00	49.13	26.86	132.24	134.00	162.00	11703.70	1726.30	1198.05	5.40
131	80.00	3.00	28.54	12.60	5.50	12.00	49.08	27.91	109.04	120.00	159.00	9870.37	1475.62	1027.77	14.60
132	72.00	3.00	20.74	12.00	4.50	12.00	35.33	22.25	61.08	108.00	139.00	12314.81	1866.93	1309.65	17.50
133	100.00	4.67	33.24	15.10	4.00	15.00	52.26	25.86	132.20	120.00	156.00	11814.81	1801.76	1276.55	12.90
134	80.00	3.67	30.77	14.50	5.25	15.00	51.66	29.46	149.49	120.00	155.00	12444.44	1886.58	1309.28	9.10
135	80.00	4.00	31.10	16.10	3.75	11.00	52.36	29.09	109.01	120.00	158.00	12685.19	1934.49	1342.54	15.00
136	80.00	4.17	25.84	14.30	5.00	11.00	52.18	28.63	106.80	134.00	172.00	7814.81	1187.85	827.34	14.50
137	68.00	3.67	20.69	9.20	3.25	10.00	37.50	23.10	56.60	120.00	155.00	5240.74	773.01	542.27	11.60
138	80.00	3.33	23.94	20.10	3.50	11.00	40.27	22.54	66.78	120.00	162.00	7944.44	1187.69	841.48	10.70
139	76.00	2.67	18.33	24.90	4.50	11.00	44.63	24.54	78.77	148.00	185.00	7740.74	1173.50	814.41	12.70
140	56.00	3.33	28.68	11.10	5.50	9.00	43.05	24.55	65.32	120.00	163.00	6314.81	963.01	670.74	16.80
141	80.00	2.67	25.26	10.60	4.25	10.00	34.30	23.20	51.43	120.00	166.00	8574.07	1299.83	896.23	13.60
142	79.00	3.00	24.80	9.20	5.25	10.00	41.80	21.80	59.64	108.00	144.00	12574.07	1917.55	1358.58	11.40
143	73.00	3.17	22.44	12.60	6.00	10.00	53.00	26.10	87.24	120.00	158.00	10685.19	1624.15	1127.16	16.60
144	69.00	2.50	22.35	9.70	4.25	12.00	50.75	27.83	111.15	120.00	162.00	10814.81	1595.19	1111.05	16.30
145	100.00	3.00	30.53	9.90	5.00	14.00	46.85	28.07	121.30	120.00	159.00	11370.37	1699.87	1172.06	22.60
146	80.00	3.00	27.29	13.80	3.50	7.00	57.85	30.00	77.09	134.00	177.00	6962.96	1055.59	732.58	19.50
147	80.00	3.00	24.43	13.30	2.75	9.00	44.77	29.55	81.14	108.00	145.00	7018.52	1070.32	745.48	14.00
148	80.00	3.67	22.18	11.00	5.00	10.00	49.00	26.70	84.86	120.00	165.00	11833.33	1793.93	1236.92	15.30
149	100.00	2.83	27.81	11.80	5.00	10.00	46.30	27.80	82.96	134.00	166.00	9425.93	1437.45	991.12	9.60
150	80.00	2.83	32.46	12.90	5.00	13.00	52.69	27.61	123.95	134.00	166.00	9425.93	1432.74	1005.07	13.20
Mean	**71.75**	**3.76**	**25.13**	**14.25**	**4.10**	**12.04**	**44.94**	**24.90**	**89.86**	**122.56**	**157.99**	**9532.84**	**1440.35**	**1005.36**	**14.15**

TB-100 × TB-102 (F_2 population)

Plant No./ Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
1	80.00	2.83	23.96	18.10	5.00	16.00	51.19	28.00	146.42	132.00	177.00	10555.56	1556.94	1092.20	12.30
2	68.00	3.17	27.74	12.70	5.25	13.00	49.08	28.62	118.52	126.00	166.00	10092.59	1508.84	1069.01	8.20
3	80.00	3.33	28.33	11.10	6.50	12.00	40.17	25.58	81.48	98.00	128.00	9870.37	1496.35	1038.47	7.50
4	80.00	2.83	26.20	23.00	3.25	10.00	45.40	28.00	83.96	132.00	172.00	7314.81	1115.51	776.95	11.10
5	51.00	3.00	20.96	20.90	6.75	9.00	44.44	24.67	65.16	132.00	177.00	8203.70	1246.96	874.74	20.80
6	80.00	3.33	23.32	16.50	4.25	12.00	48.42	26.33	102.68	136.00	172.00	10037.04	1521.61	1078.06	18.60
7	80.00	2.67	29.23	19.60	3.00	10.00	56.00	31.00	110.40	144.00	180.00	10111.11	1541.94	1070.11	16.90
8	70.00	2.50	25.20	10.20	6.50	8.00	39.75	24.25	49.22	132.00	187.00	8537.04	1297.63	903.80	12.20
9	60.00	3.33	30.48	29.20	3.00	12.00	50.00	27.00	106.41	132.00	172.00	10629.63	1611.45	1111.10	15.10
10	80.00	3.33	29.30	14.90	5.00	13.00	50.00	29.15	126.93	132.00	174.00	8592.59	1310.37	928.40	4.10
11	60.00	3.00	23.81	13.70	5.75	14.00	48.50	26.64	120.35	156.00	198.00	11462.96	1742.37	1209.21	14.30
12	76.00	3.00	25.57	15.00	2.75	11.00	49.91	29.45	107.04	132.00	174.00	8611.11	1305.44	909.24	19.90
13	80.00	3.50	27.26	14.00	4.50	13.00	44.15	24.23	91.48	117.00	153.00	10185.19	1553.24	1070.96	15.40
14	80.00	2.33	27.70	7.20	4.75	9.00	55.78	31.56	101.72	132.00	168.00	7074.07	1078.80	748.68	9.40
15	80.00	3.33	31.06	15.60	5.25	13.00	53.85	30.62	142.64	164.00	202.00	9722.22	1477.78	1029.27	10.00
16	52.00	3.33	24.45	11.80	4.75	9.00	60.56	32.22	111.99	132.00	168.00	10000.00	1516.00	1045.28	18.50
17	79.00	2.17	29.84	13.90	3.50	12.00	53.00	29.50	122.38	132.00	172.00	7500.00	1143.75	810.35	8.80
18	80.00	3.33	30.85	15.90	8.25	9.00	43.33	24.78	69.47	126.00	166.00	6851.85	1041.48	730.60	10.70
19	40.00	3.33	27.85	6.80	3.25	11.00	54.55	31.18	119.41	132.00	172.00	9462.96	1434.59	1016.40	6.30
20	80.00	3.00	22.91	20.30	4.25	15.00	49.93	29.73	144.92	136.00	176.00	9129.63	1392.27	966.23	13.70
21	80.00	3.50	21.80	16.10	4.50	11.00	53.91	27.91	105.94	132.00	175.00	9500.00	1440.20	1003.10	16.50
22	80.00	3.17	27.25	14.20	4.75	10.00	54.00	32.20	110.34	98.00	141.00	11370.37	1733.98	1195.58	10.90
23	85.00	3.33	26.63	9.90	3.75	11.00	54.91	30.91	120.68	132.00	175.00	9481.48	1441.19	1010.99	12.60
24	80.00	3.33	30.08	7.40	4.00	10.00	52.10	33.20	115.14	105.00	138.00	10592.59	1605.84	1137.74	21.20
25	54.00	3.17	21.20	23.10	3.50	7.00	52.14	29.86	69.10	132.00	165.00	5629.63	858.52	595.81	15.00

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26	80.00	2.50	27.71	12.40	5.50	11.00	55.00	30.91	120.24	126.00	159.00	7574.07	1151.26	801.85	16.70
27	80.00	2.17	22.55	9.60	3.00	12.00	52.58	27.50	114.63	132.00	175.00	11666.67	1768.67	1219.50	6.60
28	62.00	3.67	28.44	15.90	4.25	9.00	53.89	32.00	99.55	132.00	175.00	10518.52	1604.07	1113.23	14.40
29	76.00	3.17	21.71	10.10	4.50	12.00	51.17	29.00	115.44	150.00	193.00	6444.44	976.98	680.47	8.20
30	52.00	3.00	24.34	16.70	2.50	9.00	57.22	31.11	101.20	132.00	171.00	5129.63	782.27	539.37	8.40
31	79.00	2.33	28.71	14.30	3.25	16.00	42.35	25.24	108.28	156.00	194.00	6222.22	945.78	663.46	11.60
32	80.00	3.33	23.91	12.10	3.75	12.00	50.92	28.67	117.07	132.00	168.00	6740.74	994.26	704.43	9.10
33	74.00	3.33	31.20	15.50	4.75	13.00	59.08	38.23	192.49	132.00	174.00	7833.33	1171.08	812.73	14.90
34	50.00	2.67	21.85	19.80	4.50	14.00	39.09	25.36	71.62	115.00	149.00	10388.89	1574.96	1096.96	15.30
35	80.00	2.83	28.64	20.10	3.50	11.00	50.42	31.17	121.19	130.00	166.00	7851.85	1197.41	839.98	19.80
36	80.00	2.67	27.31	9.00	4.00	14.00	54.21	31.43	157.85	132.00	174.00	12037.04	1829.63	1296.29	14.00
37	78.00	2.83	22.41	17.70	3.00	10.00	56.00	31.00	111.93	136.00	170.00	8518.52	1273.52	883.82	16.60
38	72.00	2.67	26.35	18.10	3.00	11.00	37.36	19.82	56.79	132.00	168.00	9555.56	1448.62	1008.97	7.20
39	75.00	2.17	26.32	15.40	4.75	11.00	49.64	29.00	106.30	156.00	198.00	7907.41	1205.88	831.45	14.30
40	80.00	3.33	30.45	10.50	3.50	12.00	48.75	30.42	119.59	126.00	160.00	11185.19	1700.15	1204.55	7.50
41	80.00	2.67	29.91	18.50	3.50	12.00	49.17	29.08	113.39	98.00	134.00	6148.15	932.06	646.85	6.20
42	65.00	2.67	24.31	13.40	4.25	13.00	42.69	28.23	107.29	132.00	168.00	11518.52	1698.98	1183.34	9.00
43	71.00	3.00	29.59	37.40	3.75	10.00	55.00	30.80	111.29	144.00	180.00	7222.22	1079.72	744.47	12.40
44	80.00	2.67	27.68	12.90	4.25	11.00	57.82	36.64	152.18	132.00	175.00	8537.04	1294.21	898.19	16.70
45	69.00	2.33	25.07	14.60	3.50	11.00	52.64	27.45	107.84	160.00	203.00	9092.59	1386.62	965.78	17.50
46	80.00	2.33	27.16	17.30	5.00	12.00	51.33	29.92	120.05	136.00	179.00	9240.74	1404.59	968.47	12.00
47	63.00	2.00	27.30	23.30	3.75	9.00	54.44	34.78	109.01	132.00	168.00	6388.89	942.36	646.93	14.80
48	65.00	3.00	28.47	16.40	3.50	10.00	51.00	31.50	104.22	132.00	168.00	4370.37	653.37	458.34	11.70
49	80.00	2.50	26.90	19.90	4.25	10.00	43.40	23.40	69.93	150.00	186.00	7407.41	1122.96	795.62	13.00
50	70.00	3.00	18.24	9.00	3.25	13.00	50.08	28.31	119.48	98.00	145.00	9388.89	1431.81	993.67	5.00
51	68.00	2.00	20.86	9.00	4.25	12.00	50.33	25.75	100.77	132.00	176.00	5944.44	903.56	629.33	13.00

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52	80.00	2.67	24.93	12.00	3.25	10.00	50.00	32.10	108.82	132.00	172.00	5074.07	748.43	516.04	10.30
53	80.00	3.33	27.08	11.30	4.50	9.00	58.33	34.44	115.10	141.00	175.00	6907.41	1032.66	712.02	12.00
54	69.00	2.00	22.32	9.00	4.75	11.00	46.91	23.09	76.95	126.00	160.00	6592.59	999.44	701.11	8.10
55	75.00	3.33	23.08	9.60	3.00	10.00	49.90	28.80	96.03	132.00	164.00	5851.85	892.41	632.27	15.50
56	68.00	2.00	23.95	3.70	3.75	13.00	48.31	25.08	107.48	117.00	149.00	9462.96	1443.10	1012.34	16.30
57	80.00	2.00	20.89	10.90	2.75	10.00	52.00	24.40	80.96	156.00	198.00	5907.41	897.93	629.90	10.90
58	40.00	2.33	25.76	17.80	4.25	9.00	44.67	26.78	73.24	132.00	167.00	4814.81	710.19	503.17	11.20
59	68.00	2.33	24.03	14.10	4.00	11.00	42.73	21.73	66.20	126.00	164.00	5074.07	758.57	526.45	16.30
60	80.00	3.00	30.80	15.80	5.25	13.00	54.31	29.31	137.76	136.00	174.00	11018.52	1670.41	1163.44	6.00
61	80.00	2.33	25.19	21.30	4.75	9.00	51.67	32.33	98.79	132.00	167.00	5518.52	841.57	590.36	15.40
62	40.00	2.67	23.56	16.60	2.75	12.00	49.17	27.17	105.64	166.00	199.00	9833.33	1490.73	1056.18	6.30
63	80.00	3.00	21.48	10.80	3.75	13.00	43.62	25.69	99.25	166.00	190.00	6518.52	994.07	689.89	10.40
64	80.00	3.00	18.77	15.50	5.25	10.00	43.30	28.00	84.38	132.00	167.00	6444.44	979.56	687.16	12.50
65	53.00	2.67	21.85	11.40	3.00	8.00	52.25	32.25	87.08	98.00	133.00	4870.37	718.38	508.97	7.60
66	80.00	1.67	25.82	10.20	2.75	18.00	50.06	28.00	143.93	126.00	161.00	6740.74	1007.74	699.37	10.70
67	70.00	2.00	29.51	10.00	3.75	12.00	50.00	30.25	119.54	132.00	167.00	8981.48	1361.59	948.35	13.80
68	45.00	2.33	24.48	13.40	8.25	12.00	58.75	32.67	149.49	144.00	185.00	9611.11	1465.69	1028.18	18.50
69	80.00	2.67	32.47	12.60	3.50	10.00	56.80	35.40	131.98	163.00	204.00	6203.70	940.48	666.33	16.00
70	85.00	2.67	21.44	8.90	6.50	13.00	56.15	31.62	146.82	132.00	167.00	10240.74	1561.71	1083.83	16.60
71	66.00	2.33	28.91	13.10	3.75	14.00	49.79	25.71	118.80	126.00	162.00	8296.30	1261.04	878.31	10.70
72	80.00	3.00	21.11	8.70	3.50	14.00	45.21	23.93	99.33	156.00	192.00	4148.15	611.85	421.87	14.80
73	40.00	3.00	26.13	5.60	4.00	9.00	47.11	27.67	83.71	132.00	167.00	9351.85	1398.10	990.56	8.70
74	64.00	2.67	21.54	17.00	6.50	13.00	43.46	25.46	97.46	132.00	171.00	4592.59	696.24	483.19	12.90
75	80.00	2.67	24.13	16.90	4.25	8.00	54.00	30.25	82.26	156.00	195.00	9018.52	1375.32	957.91	21.80

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76	68.00	2.33	24.20	19.90	4.25	13.00	57.54	31.77	154.84	132.00	171.00	6907.41	1047.16	722.02	9.20
77	80.00	1.67	26.82	16.40	5.50	11.00	52.73	29.18	110.76	126.00	172.00	9574.07	1460.05	1013.27	7.90
78	80.00	2.00	26.10	15.60	4.50	12.00	54.67	28.17	121.44	136.00	180.00	9370.37	1424.30	992.02	16.30
79	80.00	2.67	21.75	9.90	4.00	7.00	48.57	29.29	63.13	132.00	174.00	3592.59	529.91	365.37	19.20
80	60.00	1.67	21.44	19.10	4.75	13.00	39.00	22.69	73.58	98.00	140.00	7259.26	1085.26	748.29	6.00
81	80.00	2.00	20.49	11.20	4.50	12.00	48.33	27.25	102.29	132.00	170.00	8592.59	1302.64	913.80	11.40
82	78.00	1.67	20.35	21.70	5.00	8.00	48.13	26.50	67.35	163.00	201.00	5722.22	872.64	618.26	7.20
83	80.00	2.00	21.07	9.70	5.25	14.00	47.00	25.43	112.32	117.00	155.00	8185.19	1248.24	866.28	17.30
84	80.00	1.67	26.06	20.30	4.25	15.00	49.47	26.60	135.36	132.00	165.00	6277.78	954.22	664.62	6.90
85	80.00	3.33	22.46	18.30	4.50	11.00	47.18	25.73	90.62	144.00	177.00	5222.22	770.28	531.11	9.50
86	68.00	1.67	22.21	22.50	4.25	11.00	56.11	30.11	95.56	144.00	172.00	7425.93	1110.18	778.79	12.40
87	80.00	2.67	17.97	17.00	4.25	12.00	49.83	28.83	111.10	132.00	177.00	7574.07	1148.23	813.52	13.70
88	80.00	2.67	24.01	19.60	5.25	9.00	38.78	21.33	54.76	132.00	172.00	2648.15	403.84	280.27	7.60
89	80.00	1.67	23.11	18.80	3.50	13.00	43.23	25.38	94.16	126.00	171.00	6833.33	1021.58	711.53	9.80
90	68.00	1.67	24.62	18.70	4.25	13.00	52.31	24.54	110.72	132.00	177.00	8851.85	1341.94	925.27	8.00
91	62.00	1.67	23.74	18.70	3.25	6.00	58.33	28.33	62.18	98.00	144.00	4888.89	745.56	523.01	4.30
92	80.00	2.00	30.81	11.30	3.50	11.00	53.18	27.45	90.89	132.00	178.00	7518.52	1142.81	809.68	14.60
93	40.00	1.67	18.93	31.60	3.00	13.00	49.38	27.69	115.52	136.00	182.00	5148.15	769.65	534.14	11.50
94	71.00	1.67	21.54	25.50	4.00	11.00	58.36	28.64	116.72	156.00	202.00	8148.15	1235.26	860.36	14.40
95	80.00	2.50	28.74	19.70	3.50	10.00	54.00	29.20	100.63	132.00	169.00	8629.63	1316.02	907.39	13.20
96	70.00	2.67	23.15	12.30	5.50	10.00	45.50	26.70	79.63	156.00	193.00	3870.37	588.30	412.69	10.60
97	80.00	2.33	31.92	18.60	5.25	10.00	58.36	28.64	116.72	98.00	135.00	7925.93	1184.93	839.52	20.40
98	65.00	2.33	25.91	13.90	2.75	11.00	54.00	29.20	100.63	132.00	170.00	9074.07	1375.63	954.69	13.00
99	80.00	3.33	26.52	17.60	3.75	8.00	45.50	26.70	79.63	132.00	162.00	5907.41	900.88	627.46	19.00
100	78.00	2.00	22.60	14.70	7.00	6.00	61.67	29.17	68.53	136.00	177.00	5759.26	875.41	614.10	5.20

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101	40.00	1.67	28.07	25.20	4.50	8.00	54.63	25.50	72.56	98.00	139.00	7148.15	1068.65	757.14	9.00
102	62.00	1.83	21.92	19.70	5.00	13.00	47.69	25.38	104.02	126.00	167.00	8129.63	1232.45	855.32	10.20
103	80.00	2.67	29.13	42.30	3.00	13.00	57.92	29.77	143.97	144.00	185.00	8333.33	1270.83	885.14	13.50
104	80.00	2.67	25.17	23.90	3.25	13.00	56.25	27.50	120.36	132.00	167.00	5407.41	821.93	566.72	9.10
105	54.00	2.33	19.46	11.30	2.50	6.00	62.00	27.60	57.49	168.00	213.00	7759.26	1160.01	821.87	15.30
106	65.00	2.33	20.94	17.30	3.00	11.00	56.50	26.00	100.76	132.00	162.00	5388.89	816.96	566.97	20.50
107	45.00	1.67	23.86	22.20	3.75	12.00	49.73	26.64	100.00	117.00	147.00	9240.74	1409.21	981.52	8.20
108	68.00	2.00	23.13	10.70	3.50	13.00	56.50	34.50	151.86	126.00	156.00	6425.93	976.74	673.46	6.60
109	79.00	1.50	24.01	13.80	3.75	9.00	61.88	28.75	94.65	132.00	167.00	7518.52	1124.02	780.07	14.40
110	66.00	3.00	26.56	30.10	4.00	11.00	59.80	29.30	120.52	132.00	167.00	10444.44	1583.38	1102.82	9.80
111	68.00	1.67	23.04	25.70	5.25	15.00	54.29	26.86	113.09	132.00	167.00	11611.11	1770.69	1220.89	14.20
112	70.00	2.50	25.26	11.40	3.25	14.00	54.54	27.38	132.08	132.00	172.00	8870.37	1348.30	945.83	13.50
113	55.00	2.50	27.43	9.20	5.50	12.00	56.00	29.09	119.73	132.00	168.00	8185.19	1166.39	818.22	8.00
114	80.00	2.67	25.67	21.10	6.00	11.00	62.00	28.00	124.36	153.00	188.00	9481.48	1398.52	990.85	11.40
115	68.00	1.67	20.10	11.00	3.50	9.00	56.25	28.75	82.82	132.00	172.00	4796.30	717.05	497.63	6.80
116	59.00	2.67	25.67	41.10	4.75	9.00	60.00	27.25	95.49	98.00	133.00	5277.78	800.11	557.28	13.50
117	80.00	1.67	28.93	18.00	5.00	11.00	53.30	28.80	106.72	126.00	167.00	10500.00	1601.25	1104.06	18.30
118	68.00	3.00	23.75	8.60	4.25	10.00	60.00	31.67	118.97	132.00	173.00	5944.44	903.56	640.17	11.40
119	68.00	2.00	23.65	17.30	2.75	12.00	50.27	28.82	108.46	144.00	185.00	8574.07	1264.68	877.69	21.70
120	51.00	2.17	24.12	14.60	4.50	12.00	47.91	26.36	89.34	136.00	182.00	6351.85	949.60	661.40	7.00
121	56.00	2.00	21.88	12.40	6.00	10.00	57.78	29.67	101.25	132.00	178.00	8314.81	1260.53	869.13	11.50
122	68.00	3.17	25.12	9.70	4.50	12.00	53.64	27.91	112.32	117.00	163.00	10203.70	1556.06	1102.47	6.40
123	68.00	3.17	23.18	17.50	4.75	13.00	51.75	27.42	113.06	98.00	144.00	10851.85	1649.48	1157.11	16.90
124	60.00	1.67	24.80	16.10	4.75	13.00	52.08	28.33	116.30	132.00	180.00	9833.33	1401.25	992.79	13.00
125	52.00	1.67	27.56	19.30	6.25	11.00	58.00	27.00	110.40	153.00	186.00	7814.81	1187.85	824.37	15.20

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126	80.00	2.00	23.46	15.60	4.50	10.00	58.89	29.00	102.98	132.00	165.00	8018.52	1198.77	834.94	6.90
127	68.00	1.67	20.64	21.50	4.75	12.00	47.73	27.45	94.13	126.00	159.00	10333.33	1566.53	1080.12	12.40
128	74.00	1.67	24.65	22.20	5.00	5.00	60.00	27.50	50.44	132.00	167.00	8444.44	1287.78	903.38	7.30
129	69.00	2.17	25.06	17.30	4.50	11.00	53.30	27.90	105.42	136.00	171.00	7740.74	1176.59	833.62	12.80
130	65.00	1.33	21.33	13.20	4.75	11.00	45.80	25.50	81.30	132.00	173.00	8555.56	1261.94	875.79	11.70
131	54.00	3.83	25.88	20.50	4.25	13.00	45.83	25.08	94.10	132.00	173.00	11407.41	1705.41	1187.82	8.30
132	68.00	2.17	27.80	38.30	5.00	13.00	55.42	30.67	133.49	126.00	166.00	6055.56	918.02	643.99	16.00
133	70.00	2.50	25.05	23.00	6.00	13.00	40.33	23.08	77.82	132.00	172.00	10425.93	1589.95	1126.48	19.00
134	80.00	3.33	25.14	11.50	6.75	7.00	60.50	33.67	81.06	94.00	136.00	11111.11	1684.44	1169.00	15.60
135	80.00	1.67	25.15	20.50	5.25	11.00	57.50	29.50	124.36	98.00	143.00	5111.11	779.44	540.93	17.80
136	64.00	1.67	23.82	15.10	6.25	7.00	53.33	27.50	63.96	132.00	177.00	8314.81	1263.85	880.27	13.70
137	68.00	3.33	27.53	26.00	6.00	11.00	56.50	28.60	111.29	156.00	201.00	6222.22	917.78	643.82	8.40
138	66.00	3.67	20.96	29.90	4.25	8.00	57.86	30.71	91.69	126.00	171.00	8203.70	1226.45	868.94	16.90
139	69.00	3.00	25.57	23.60	4.75	10.00	58.89	28.89	98.18	117.00	152.00	9129.63	1384.05	960.53	15.60
140	80.00	1.33	10.72	21.70	4.00	11.00	47.70	28.40	90.77	126.00	161.00	9425.93	1437.45	1001.19	8.30
141	80.00	1.67	26.97	23.90	5.50	10.00	56.67	30.11	107.23	153.00	188.00	6907.41	1047.16	722.02	12.20
142	51.00	2.67	22.31	20.20	4.25	10.00	42.78	24.00	68.23	144.00	179.00	7018.52	1070.32	758.32	5.70
143	80.00	2.67	30.09	23.20	5.00	10.00	50.22	29.56	92.23	132.00	170.00	6166.67	937.33	650.51	9.60
144	56.00	2.67	27.80	33.90	4.25	7.00	51.33	26.83	56.83	98.00	136.00	8740.74	1289.26	897.97	10.80
145	80.00	3.00	28.59	23.00	5.00	10.00	55.89	31.67	111.14	126.00	164.00	7370.37	1101.87	759.74	21.20
146	60.00	2.67	27.99	14.00	4.25	13.00	48.75	26.75	100.92	132.00	177.00	9203.70	1395.28	968.33	16.20
147	55.00	2.33	29.98	22.40	4.75	14.00	43.00	23.54	95.55	132.00	177.00	6833.33	1042.08	725.81	14.40
148	80.00	2.67	28.50	24.20	4.25	9.00	44.63	25.63	65.06	150.00	195.00	6500.00	985.40	679.43	17.00
149	63.00	3.00	26.10	24.70	4.00	9.00	50.50	27.25	74.86	156.00	201.00	9129.63	1392.27	959.97	10.20
150	80.00	3.67	26.14	15.30	3.75	10.00	56.67	29.00	104.57	126.00	158.00	9129.63	1387.70	973.47	18.40
Mean	**70.43**	**2.54**	**25.11**	**16.95**	**4.38**	**11.06**	**51.54**	**28.35**	**103.34**	**131.99**	**170.80**	**7968.27**	**1204.31**	**840.42**	**12.46**