GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN RUSTICA TOBACCO (*Nicotiana rustica* L.)

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RATHOD BHAVIKSINH BHARATSINH
B.Sc. (Hons.) Agriculture

DEPARTMENT OF GENETICS AND PLANT BREEDING
CHIMANBHAI PATEL COLLEGE OF AGRICULTURE
SARDARKRUSHINAGAR DANTIWADA AGRICULTURAL UNIVERSITY
SARDARKRUSHINAGAR-385 506

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ABSTRACT

GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN RUSTICA TOBACCO (*Nicotiana rustica* L.)

Name of Student	Major Advisor
RATHOD BHAVIKSINH B.	Dr. D. R. CHAUDHARI

DEPARTMENT OF GENETICS AND PLANT BREEDING
CHIMANBHAI PATEL COLLEGE OF AGRICULTURE
SARDARKRUSHINAGAR DANTIWADA AGRICULTURAL UNIVERSITY
SARDARKRUSHINAGAR-385 506

ABSTRACT

Tobacco is an important non-edible commercial crop in India. Due to economic significance of cured leaves, the correlated response of cured leaves with other traits is of vital importance in tobacco breeding programmes. The present investigation entitled, "Genetic variability, correlation and path analysis in rustica tobacco (*Nicotiana rustica* L.)" was carried out at Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol during *rabi* 2019-20. The experimental material consisted of thirty-five genotypes which were evaluated in Randomized Block Design with four replications. The genotypes were evaluated for 11 characters *viz.,* cured leaf yield (g/plant), days to flowering, days to maturity, plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), leaf thickness (mg/cm^2), nicotine content (%), reducing sugar content (%) and chloride content (%) to study the extent of genetic variability, correlation and path analysis.

The analysis of variance revealed that mean sum of squares due to genotypes was found significant for all the eleven characters indicating that the genotypes under study were genetically diverse. The estimates of genotypic and phenotypic coefficient of variation were moderate for cured leaf yield, days to flowering, number of leaves per plant, leaf width, nicotine content and reducing sugar content indicating that sufficient variability present in the experimental material for these traits. The estimates of genotypic and phenotypic variance revealed that genotypic variance contributed larger in phenotypic variance for cured leaf yield, days to flowering, days to maturity, plant height, number of leaves per plant, leaf thickness, nicotine content and chloride content, which indicated less influence of environmental factors on the expression of the traits.

High heritability coupled with high genetic advance as per cent of mean was observed for cured leaf yield, number of leaves per plant, leaf width, leaf thickness, nicotine content, reducing sugar content and chloride content, which indicated that these characters are governed by additive genetic variance. Hence, selection may be made in desired direction based on phenotypic performance.

For improving cured leaf yield, high performing genotypes *viz.,* DCT-4, LR-55, LR-60, AR-44, AR-93, VR-36, LR-64 and LR-69 based on *per se* performance

were identified as elite genotypes. Nicotine content was high in genotypes *viz.,* SR-32, AR-56, VR-1, VR-8, C-21, Sel.15-1-1 and AR-49. However, their potentiality should be confirmed by testing them over space and time. These genotypes could be used in hybridization programme and from the segregating generations promising progenies could be selected for higher cured leaf yield through its component characters.

Correlation studies revealed that cured leaf yield per plant had positive and significant association with plant height, number of leaves per plant, leaf length, leaf width at both genotypic and phenotypic levels. Hence, these characters should be given due consideration while selecting for higher yield. Cured leaf yield was significantly and positively associated with days to flowering and days to maturity suggested that late flowering and maturing genotypes would be higher yielder, but such association may be prove to be constrain in breeding of high yielding early varieties. The estimated value of genotypic and phenotypic correlations revealed comparatively higher degree of genotypic correlation coefficient than their phenotypic counterpart for most of the characters, which indicated strong and inherent association between two characters. Significant positive correlation of number of leaves per plant, leaf length, leaf width and plant height with cured leaf yield suggested that number of leaves per plant and plant height would be good index for isolating high yielding varieties.

Path coefficients analysis based on genotypic correlation revealed that number of leaves per plant showed highest positive direct effect followed by leaf width, days to flowering, plant height, reducing sugar content and leaf length. Hence, these traits may be directly attributed for the improvement of cured leaf yield and important in the selection of better genotypes in rustica tobacco. To improve cured leaf yield, proper attention should therefore be paid to these traits at the time of selection; since they had strong, direct and positive effects on cured leaf yield, they should be directly selected.

Based on the results obtained, it would be reasonable to suggest that a breeder engaged in the improvements of cured leaf yield in rustica tobacco should place emphasis on number of leaves per plant, leaf length, leaf width, days to flowering and plant height. Selection for these traits will therefore directly become helpful in increasing the cured leaf yield in rustica tobacco.

SARDARKRUSHINAGAR DANTIWADA AGRICULTURAL UNIVERSITY
CHIMANBHAI PATEL COLLEGE OF AGRICULTURE
SARDARKRUSHINAGAR-385 506

CERTIFICATE – I

Date : 12/11/2020

This is to certify that the thesis entitled, **"GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN RUSTICA TOBACCO (*Nicotiana rustica* L.)"** submitted for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **GENETICS AND PLANT BREEDING** is a record of bonafide research work carried out by **RATHOD BHAVIKSINH BHARATSINH** under my guidance and supervision and that no part of this thesis has been submitted for any other degree, diploma, associateship, fellowship or other similar titles. The assistance and help received during the course of investigation have been fully acknowledged.

(D. R. CHAUDHARI)
Major Advisor

(J. M. PATEL)
Minor Advisor

(R. M. PATEL)
Advisor

(K. N. PRAJAPATI)
Advisor

SARDARKRUSHINAGAR DANTIWADA AGRICULTURAL UNIVERSITY
CHIMANBHAI PATEL COLLEGE OF AGRICULTURE
SARDARKRUSHINAGAR-385 506

CERTIFICATE – II

Date : 12/11/2020

This is to certify that, **RATHOD BHAVIKSINH BHARATSINH,** Department of Genetics and Plant Breeding, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar has made all corrections/modifications in the thesis entitled, **"GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN RUSTICA TOBACCO (*Nicotiana rustica* L.)"** as suggested by the External Examiner and the Advisory Committee in the oral examination held on **05th NOVEMBER, 2020.**

(D. R. CHAUDHARI)
Major Advisor and
Assistant Research Scientist
Agricultural Research Station
S. D. Agricultural University
Ladol-384 540

(S. D. SOLANKI)
Professor and Head
Department of Genetics and
Plant Breeding
C. P. College of Agriculture
S. D. Agricultural University
Sardarkrushinagar-385 506

(R. K. PATEL)
Principal and Dean,
C. P. College of Agriculture,
S. D. Agricultural University,
Sardarkrushinagar-385 506.

APPROVED (Seal and Date)

(R. N. SINGH)
Director of Research and
Dean, Post-Graduate Studies,
S. D. Agricultural University,
Sardarkrushinagar-385 506.

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Bhavik

Place : Sardarkrushinagar
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(RATHOD BHAVIK B.)

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ABBREVIATIONS USED

%	:	Per cent
>	:	Greater than
<	:	Less than
∑	:	Sigma
2n	:	Somatic chromosome number
°C	:	Degree Celsius
C.D.	:	Critical Difference
C.V.	:	Coefficient of variance
cm	:	Centimetre
d.f.	:	Degrees of freedom
e.g.	:	Example
et al.	:	and other
etc.	:	Etcetera
g	:	Grams
G	:	Genotypic level
GA	:	Genetic Advance
GAM	:	Genetic Advance as per cent of Mean
GCV	:	Genotypic Coefficient of Variation
H	:	Heritability
$h^2_{(b)}$	:	Heritability (Broad Sense)
ha	:	Hectare
i.e.	:	That is
KOH	:	Potassium hydroxide
m	:	Metre
P	:	Phenotypic level
PCV	:	Phenotypic Coefficient of Variation
r_g	:	Genotypic Correlation
r_p	:	Phenotypic Correlation
S.Em.±	:	Standard error of mean
Sr. No.	:	Serial number
via	:	Through
viz.,	:	Namely

INTRODUCTION

I. INTRODUCTION

Tobacco is one of the important cash crops and bio-factory for molecular farmings, is considered native of Americas and its cultivation was thought to have begun as early as 6000 B.C. It is believed that wilted and dried leaf blades were rolled to make cigars. Columbus noted Cuban natives smoking cigars when he discovered America. In 1560, Jean Nicot, the French Ambassador to Portugal, brought tobacco to England and France. It is reported that Nicot gifted tobacco to the Queen of France to cure headache. From his name Nicot, the botanical name of the plant *Nicotiana* and the word nicotine (principle alkaloid of tobacco) have been derived. The genus *Nicotiana* belonging to *Solanaceae* family is represented by about 60 species of which, *Nicotiana tabacum* and *Nicotiana rustica* are cultivated extensively. It is a *Solanaceous* crop and belongs to the genus *Nicotiana*. Out of 66 species of *Nicotiana*, 45 of them are being maintained in India. Out of these, only two species *viz., tabacum* and *rustica* are under cultivation. *Nicotiana rustica* have chromosome number 2n = 4x = 48 and it is natural allotetraploid arised by hybridization of wild progenitor *Nicotiana paniculata* and *Nicotiana undulata*. The *Nicotiana rustica* varieties known as *Vilayati* and *Calcutti* tobacco, which are characterised by short plant stature with puckered leaf and yellow flowers.

The inflorescence is usually a compact 'Thyrse' represented by a thickened central axis, short branches and monopodial-sympodial development of peripheral flowers. The leaves of *Nicotiana rustica* are usually petiolate and of regular ovate or cordate shape with a dark green, shiny surface. In rustica tobacco the leaves are thicker, dark green and have uneven surface. Calyx is cylindrical, pubescent, membranous and narrow with pointed sepals with longer odd sepals. Corolla is greenish yellow 1.2 to 1.5 cm long, pubescent with tube proper 3 mm long and 2 mm wide. Capsule is elliptic, oval and dusky brown.

The major tobacco producing countries in the world are China, Brazil, India, Indonesia, Malavi, Tanzania, U.S.A. and Turkey. Due to high nicotine content than *Nicotiana tabacum*, it is in demand in European countries, probably to prepare high nicotine sheets. In India, tobacco is grown on 0.467 M ha of area accounting

for 0.32 per cent of the total arable land of country with 799.96 M kg production with productivity of 1711 kg/ha. India stands third in tobacco production (800 Million kg) in the worldwide. China and Brazil occupying the first and second place in tobacco production. Tobacco production concentrated in the states of Andhra Pradesh, Karnataka, Gujarat, Bihar, Uttar Pradesh, West Bengal and Tamil Nadu.

Tobacco, a commodity which earns combined tax revenue including central excise, state taxes (VAT, entry tax *etc.*), more than ₹29,000 crores and foreign exchange ₹6449 crores annually besides providing employment directly or indirectly to 45.7 millions of people.

Rustica tobacco is unlike *Nicotiana tabacum*, it is short day and low temperature loving plant best suited for winter cultivation in Gujarat and northern states of India. Major production of rustica varieties in the country is confined to the tobacco growing areas of North India. Snuff, chewing and hookah tobacco are mostly produced in West Bengal, Gujarat, Orissa, Uttar Pradesh, Karnataka, Tamil Nadu and Bihar. In Gujarat, bidi tobacco, chewing (*lal* and *kala chopadia*), hookah (*Gadaku*) and rustica tobacco are cultivated. In which, rustica tobacco occupy an area of 1.14 lakh ha with the production of 2,40,100 tonnes and productivity was 2102 kg/ha (Anonymous, 2019-20).

Tobacco is an important commercial commodity in the world trade since the beginning of the 17th century. It enters the foreign trade of all the countries either in the form of raw tobacco or as manufactured tobacco products. Tobacco is an agricultural product processed from the fresh leaves of plants of the genus *Nicotiana*. Tobacco smoking is the practice where tobacco is burned and the vapor either tasted or inhaled. Tobacco is reported to contain one of the most important alkaloid called nicotine. It is consumed by the people of all countries of the world and also used as an organic pesticide. Its narcotic qualities convert the fashion users to habitual consumers. Pure nicotine (99.90 %) can be used in pharma sector as nicotinamide and nicotine sulphate. It also contains solanesol, which can be used for making anti-cancer drugs. Furthermore, tobacco seed oil can be used as a deodourised product for making paint, soaps and detergents and can also be used for edible purpose. The largest quantities of tobacco are used for smoking, chewing and snuff. The major thrust area of rustica tobacco research is

to improve the productivity and quality in context to demand at national and international market (Krishnamurthy, 2007).

In any crop improvement programme, existence of variability and selection of genotypes with due selection pressure on yield component characters is of prime importance. Moreover, assessment of genetic variability in the base population is the first step in any breeding programme. Thus, the knowledge of existing genetic variability and estimation of heritability for economic yield and its components in a population is of great significance in determining the influence of environment for the expression of the characters and the extent to which improvement would be possible after selection. Therefore, in order to assess the extent amount of genetic variation present in breeding material the knowledge of genetic parameters such as genotypic coefficient of variation, heritability and expected genetic advance is require in genetic improvement in crop. Various biometrical techniques are extensively used for the estimation of relative magnitude of the different components of genetic variation, out of which techniques developed by Hayman (1958); Jinks and Jonse (1958) and Mather (1949) require less number of families and are comprehensive, easy and equally informative.

Yield is the complex quantitative character controlled by a large number of component characters and their interaction. It is not only influenced by a number of related characters, which are governed by polygenes, but also influenced to a great extent by environment. Thus, study of correlation of these characters provide basis for further selection.

Further, the yield is dependent on many component characters and the total correlation is insufficient to explain the true association among the characters. So, in order to have clearer picture of yield components for effective selection programme, it would be desirable to consider the relative magnitude of various characters. Therefore, path coefficient analysis helps for sorting out the total correlation into direct and indirect effects and useful in selecting high yielding accessions. Keeping this in view, the present investigation is an attempt to collect information on :

(1) To study the variability present among the genotypes with respect to cured leaf yield and its components

(2) To study the extent of phenotypic and genotypic correlations between yield and different attributes

(3) To study path coefficient for assessing the relative contribution of each of yield components towards yield

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

A thorough understanding of the extent of variation, genetic architecture of the plant and heritability of characters among the genotypes would help in developing sound plant improvement programmes. Genetic variability is the gift of nature and its fruitful utilization in any crop species calls for systematic collection, evaluation, description and grouping based on economic descriptors.

In the present investigation an attempt has been made to study genetic variability, correlation and path analysis in rustica tobacco (*Nicotiana rustica* L.). A brief review of available literature pertaining to the investigation has been presented in this chapter.

2.1 Variability parameters

2.2 Correlation studies

2.3 Path coefficient analysis

2.1 Variability parameters

The genetic improvements in any crop depended upon the extent, nature and magnitude of genetic variability present in the material and the extent to which it is heritable. Genotypic coefficient of variation, heritability and genetic advance are the genetic parameters which manifesting the variability.

Kim and Hwayng (1981) studied F_1 and F_2 generation of aromatic tobacco varieties and found high genotypic coefficient of variation (GCV) and phenotypic coefficient variation (PCV) for cured leaf yield, days to flowering, number of leaves per plant and nicotine content. They observed high heritability for nicotine content and number of leaves per plant and low heritability for cured leaf yield and days to flowering.

Ibrahim and Avratovscukova (1982) studied five varieties of tobacco and reported significant differences among five varieties for all the six characters. The high genotypic coefficient of variation (GCV) was observed for green leaf yield and plant height and the low value of GCV was observed for number of leaves, days to flowering and leaf length. High heritability estimates combined with high expected genetic advance were observed for green leaf yield and plant height.

Nersesyan (1982) studied different varieties of tobacco and found high heritability for number of leaves per plant.

Markaryan and Gyulkhasyn (1984) reported high heritability for number of leaves per plant while studying different tobacco varieties.

Smalcelj and Vasilj (1984) studied variability parameters and chemical characteristics *viz.,* plant height, internode length, number of leaves, days to flowering, leaf length, leaf width, leaf area, leaf thickness, leaf weight, nicotine content, protein content, ash content in tobacco and observed that reducing sugar and chloride content had high genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance.

Sasikumar *et al.* (1985) studied F_2 population of bidi tobacco and found high heritability for cured leaf yield.

Amarnath (1987) studied nine quantitative characters in 40 chewing tobacco genotypes. He reported that cured leaf yield had high genotypic coefficient of variation (GCV), while it was medium for plant height, leaf breath and leaf length and low for days to maturity. Heritability estimates were medium for cured leaf yield and leaf breath and low for leaf length, plant height and days to maturity. The estimates of genetic advance were high for cured leaf yield, leaf breadth and plant height. Whereas, it was medium for leaf length and low for days to maturity.

Dobhal (1987) studied genetic variability, heritability and genetic advance for eight characters in 25 genotypes of cigar wrapper tobacco. High genotypic coefficient of variation, heritability and genetic advance were recorded for cured leaf yield, whereas medium genotypic coefficient of variation, high heritability and high genetic advance were noticed for plant height, leaf breath and number of leaves. Leaf length and days to flowering showed low genotypic coefficient of variation, high heritability and medium genetic advance.

Patel and Patel (1987) found significant variation in all the characters studied suggesting that genetic variability was present in 100 bidi tobacco germplasm.

Dobhal and Rao (1988) evaluated 55 genotypes of hookah and chewing tobacco and revealed that high genotypic coefficient of variation was observed for cured leaf yield. The characters, number of leaves per plant, leaf thickness, plant height and days to flowering showed medium genotypic coefficient variation, whereas leaf

breadth showed low genotypic coefficient of variation. High heritability coupled with high genetic advance was obtained for cured leaf yield, leaf thickness, plant height and days to flowering. Number of leaves per plant and leaf length showed medium heritability and medium genetic advance, whereas leaf breadth showed low heritability and low genetic advance.

Dobhal (1989) carried out diallel analysis for nicotine content and leaf thickness in hookah and chewing tobacco and observed that nicotine content had high genotypic and phenotypic coefficient of variation and high heritability along with high genetic advance.

Dobhal and Monga (1989) assessed 121 lines of hookah and chewing tobacco. They reported that nicotine content showed high genetic coefficient of variation, whereas cured leaf yield, leaf thickness and days to flowering showed medium genotypic coefficient of variation. Low heritability values were obtained for cured leaf yield, while leaf thickness, days to flowering and nicotine content showed medium heritability values. High genetic advance was found for nicotine content, whereas cured leaf yield, leaf thickness, days to flowering expressed medium genetic advance.

Patel (1997) studied progenies of two crosses GT5 × A119 and GT7 × A145 developed through North Carolina Design I and reported that significant differences among the progenies for days to flower, cured leaf yield, nicotine content, reducing sugars and total nitrogen in both the crosses. Moderate to high GCV and PCV were observed for leaf thickness, spangles score, cured leaf yield, leaf curl incidence, nicotine content and reducing sugar. Days to flower, leaf thickness, cured leaf yield estimated moderate heritability with high genetic advance.

Datta (2002) studied 17 bidi tobacco genotypes under irrigated and rainfed condition. Under both the ecosystems, cured leaf yield, number of leaves, leaf breadth and plant height depicted medium genotypic coefficient of variation, while leaf length, leaf thickness, days to flowering and days to maturity showed low genotypic coefficient of variation. The results also indicated that nicotine content and reducing sugar content had medium and low genotypic coefficient of variation under irrigated condition, while both had low and medium genotypic coefficient of variation under rainfed condition, respectively. Cured leaf yield and plant height expressed high heritability along with high genetic advance under both

irrigated and rainfed conditions. Nicotine content, leaf thickness and reducing sugar content expressed low heritability along with low genetic advance under irrigated condition and high heritability along with low genetic advance under rainfed condition. Number of leaves had high heritability coupled with low genetic advance; whereas, leaf length and leaf breath had medium heritability coupled with low genetic advance. Further, days to flowering had high heritability and medium genetic advance in rainfed condition. Days to maturity, on the other hand showed medium heritability and low genetic advance under irrigated condition and high heritability and medium genetic advance under rainfed conditions.

Lalithadevi *et al.* (2002) evaluated 32 varieties of tobacco and reported that the characters number of leaves, leaf length, leaf breadth, plant height and days to flowering showed high heritability and high genetic advance. They also found high heritability and low genetic advance for cured leaf yield.

Patel and Makwana (2002) evaluated 121 genotypes of chewing tobacco for 8 characters and found that days to flowering had high heritability, cured leaf yield, number of leaves, leaf length, leaf breadth and plant height had medium heritability, while the leaf thickness and days to maturity had low heritability. They found high genetic advance for cured leaf yield, leaf thickness, plant height and days to flowering; medium genetic advance for number of leaves and leaf length and low genetic advance for days to maturity.

Patel and Kingaonkar (2005) evaluated 40 genotypes of bidi tobacco. They reported that plant height and cued leaf yield possessed high genetic coefficient of variation; leaf length, leaf breadth, days to flowering and reducing sugar content depicted medium genotypic coefficient of variation, while leaf thickness, days to maturity and nicotine content showed low genotypic coefficient of variation. Further, cured leaf yield, number of leaves, leaf length, leaf breadth, plant height, days to flowering and reducing sugar content showed high heritability coupled with high genetic advance. Leaf thickness and days to maturity showed high heritability with low genetic advance, while nicotine content depicted medium heritability with high genetic advance.

Patel *et al.* (2007) conducted experiment with 31 diverse genotypes of tobacco. The analysis of variance showed highly significant difference among genotypes of all characters indicating inherent variability in the material taken up for study. A wide range of variation was observed for all traits except oil content.

The estimate of phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the characters studied. PCV includes variability due to genotype and environment. Characters like days to flowering, plant height, individual capsule weight and oil content showed low genotypic coefficient of variation. The characters like days to flowering, individual capsule weight and plant height had recorded high heritability and moderate genetic advance. So, there is scope for improvement through straight selection.

Bhumarannavar (2009) evaluated 191 germplasm lines of bidi tobacco for six quantitative traits and found high values of GCV and PCV for plant height, internodal length and leaf yield per plant. The traits like number of leaves per plant and leaf width showed moderate GCV and PCV values. The characters plant height, internodal length, number of leaves per plant, leaf width and leaf yield per plant showed high heritability. The genetic advance was found to be high for plant height, internodal length, number of leaves per plant, leaf length and leaf yield. High heritability coupled with high genetic advance were noticed for plant height, internodal length, number of leaves per plant and leaf yield per plant.

Nama (2011) investigated 42 genotypes of tobacco in randomized complete block design with three replications. The study revealed that high genotypic coefficient of variation for cured leaf yield, number of leaves, plant height and reducing sugar content, whereas leaf length, leaf breath and days to flowering possessed low genotypic coefficient of variation. Nicotine content, on the other hand, showed medium genotypic coefficient of variation. The characters cured leaf yield, number of leaves, plant height, nicotine content and reducing sugar content had high heritability followed by high genetic advance. Leaf length and leaf width possessed medium heritability among with low genetic advance, whereas days to flowering showed high heritability coupled with medium genetic advance.

Patel *et al.* (2011) observed wide range of variability among 40 tobacco genotypes. The genetic variance contributed major proportion to total variance for number of leaves, days to flowering, days to maturity, leaf length, leaf width and plant height indicating that these characters are not influenced by environmental effect. High heritability coupled with high genetic advance as

percent of mean was observed for number of leaves, days to flowering and plant height suggesting additive gene action in the expression of these trait and improvement in this character through straight selection. High estimate of heritability coupled with lower value of genetic advance as per cent of mean were recorded for days to maturity, leaf length and leaf width revealed major role of non-additive gene action inheritance of these traits.

Katba (2012) studied 40 genotypes of rustica tobacco. He found high genotypic coefficient of variation for cured leaf yield and days to flowering, whereas low genotypic coefficient of variation for plant height, number of leaves, days to maturity, leaf length, leaf width, leaf thickness, nicotine content, reducing sugar content and chloride content, on the other hand, showed medium genotypic coefficient of variation. High heritability coupled with high genetic advance were observed for cured leaf yield, days to flowering, number of leaves per plant, plant height, leaf length, leaf width, leaf thickness, reducing sugar content and chloride content, whereas days to maturity and nicotine content showed high heritability followed by medium genetic advance.

Basirnia *et al.* (2014) evaluated accumulation rates of chloride in the leaves of 100 oriental and semi-oriental tobacco genotypes. Analysis of variance revealed significant differences among the tobacco genotypes for chloride concentration indicating that chloride concentration is genetically controlled in the genotypes tested. The Chloride concentration of 100 genotypes ranged from 0.38 to 2.68 per cent.

Parajuli *et al*. (2015) conducted an experiment with forty genotypes of rustica tobacco in randomized complete block design with three replications. The analysis of variance revealed significant differences among genotypes for following characters *viz.,* cured leaf yield, days to flowering, number of leaves per plant, plant height, leaf length, leaf width, leaf thickness, days to maturity, nicotine content, chloride content and reducing sugar content indicating the presence of great deal of variability for different traits. The genetic variance contributed major proportion of total variance for all the characters under study suggesting that these characters were largely under genetic control. The mean sum of squares revealed highly significant differences among genotypes for all the characters, which indicated the presence of considerable variability among the

genotypes for various characters. Cured leaf yield showed wide range of variability (83.10 to 175.00 g/plant).

Shah *et al.* (2015) conducted an experiment comprising four tobacco parental cultivars and their 12 F_2 populations was conducted in a randomized complete block (RCB) design with three replications to quality traits. The characters studied include number of leaves per plant, number of cured leaves per kg, nicotine content and reducing sugar. Analysis of variance showed highly significant differences among all the genotypes for all the characters. Spt-G-28 was superior among the parental cultivars for quality characters. KHG-21 × KHG-22 and KHG-22 × KHG-24 were better among the F_2 populations for nicotine content. KHG-22 × KHG-21 and Spt-G-28 × KHG-22 revealed enhanced performance for number of leaves per plant among F_2 populations.

Shah *et al.* (2016) conducted an experiment comprising four tobacco parental cultivars and their 12 F_2 populations was conducted in a randomized complete block (RCB) design with three replications. The characters studied include days to flowering, plant height, leaf area, number of leaves per plant, weight of green leaves per m^2, number of green leaves per kg, number of cured leaves per kg, grade index, yield per ha, nicotine content and reducing sugar. Analysis of variance showed highly significant differences among all the genotypes for all the characters.

Sunil and Mohan (2015) conducted experiment with nine genotypes of chewing tobacco and observed high heritability coupled with high genetic advance as percent of mean observed for characters such as capsule per plant, plant height, leaves per plant and leaf breadth while high heritability along with moderate genetic advance observed for days to maturity and leaf length. The phenotypic coefficient of variance and genotypic coefficient of variance were highest for seed yield per plant, capsule per plant, capsule weight per plant and moderate GCV and PCV observed for leaves per plant, leaf length and plant height. Days to flowering, days to maturity and oil content recorded low GCV and PCV.

Sunil *et al.* (2016) studied fifty-nine genotypes of chewing tobacco in a randomized complete block design with three replications. Analysis of variance revealed the existence of significant differences among genotypes for all characters studied. The magnitude of PCV and GCV was moderate to high for plant height, days to 50 per cent flowering, leaves per plant, leaf breadth,

individual capsule weight, leaf area, internodal length, capsules per plant, chlorophyll content, specific leaf weight, number of branches, capsule weight per plant, seed yield per plant and oil yield per plant. The results showed wide range of variability for all the characters except for oil content.

Ahmed *et al*. (2017) studied heritability in one hundred recombinant inbred lines (RIL) derived from four F_4 populations of Flue Cured Virginia tobacco. The characters *viz.,* days to flowering, plant height, leaves per plant, internodal length, leaf area, green leaves weight per plot, number of green leaves per kg, cured leaves weight per plot, number of cured leaves per kg, grade index, nicotine, reducing sugars were studied. Significant differences were observed among RIL for days to flowering, plant height, cured leaves weight $plot^{-1}$, nicotine and reducing sugar were reported. Heritability in broad sense was generally low for all the traits except nicotine and reducing sugar.

Ganachari *et al.* (2018) studied thirty F_1 populations and their six parents (Bhavya, FCV-Special, Sahyadri, Kanchan, Tobios-6 and FCH-222). Where, Kanchan is used as a Standard check. These materials were used for genetic analysis of leaf yield and its component traits in FCV tobacco. The analysis of variance indicated significant amount of variability among genotypes for sixteen quantitative characters studied *viz.,* days to 50 per cent flowering, days to maturity, plant height, chlorophyll content, stem girth, internodal distance, specific leaf weight, leaf length, leaf width, leaf area per plant, green leaf yield, cured leaf yield, top grade equivalent except for the characters like number of leaves per plant, reducing sugar and nicotine content.

Porkabiri *et al.* (2019) evaluated 25 genotypes of tobacco using simple lattice design. The following eight traits were measured and evaluated : plant height (PH), leaf length (LL), leaf width (LW), leaf number per plant (LN), stem girth (SG), leaf area (LA), dry leaf yield (DLW) and fresh leaf yield (FLW). The genotype by trait biplot for tobacco dataset explained 73 per cent of the total variation of the standardized data.

2.2 Correlation studies

The concept of correlation was first put forward by Galton (1889) and later elaborated by Fisher (1918) and Wright (1921). It is an index of proportion of causes common in the genesis of two variables to the total. The correlation coefficient analysis measures the mutual relationship between various characters

and it determines the component traits on which selection can be relied upon to effect the improvement. There are three types of correlations *viz.,* phenotypic, genotypic and environmental correlations. Phenotypic correlation is the observable correlation between two variables and includes both genotypic and environmental effects. Genotypic correlation on the other hand, is the inherent association between two variables may be due to pleiotropic action of genes or linkage.

Knowledge of magnitude and direction of association among different characters is of paramount important to a plant breeder, as characters genetically related to each other tend to move in the same direction under selection.

Kim and Hwang (1981) studied F_1 and F_2 generations of aromatic tobacco. The cured leaf yield had positive genotypic correlation with plant height. They also found positive genotypic correlation between days to flowering and number of leaves.

Pandeya *et al*. (1983) studied FCV tobacco in 5 × 5 diallel fashion. He reported that the cured leaf yield exhibited positive association with number of leaves, leaf length, lead width, plant height and days to flowering.

Gaines *et al*. (1983) studied FCV tobacco genotypes and revealed that cured leaf yield showed positive genotypic correlation with nicotine content.

Patel *et al*. (1985) evaluated 100 bidi tobacco genotypes and observed positive genotypic as well as phenotypic correlation of cured leaf yield with number of leaves per plant, leaf length, leaf width and plant height. The number of leaves per plant showed negative genotypic and phenotypic correlation with leaf length and leaf width and positive genotypic and phenotypic correlation with plant height.

Sixteen tobacco varieties were studied by Tsai (1985) and results revealed that cured leaf yield had positive genotypic correlation with number of leaves per plant, leaf length, leaf width, and days to maturity.

Amarnath and Murthy (1988) studied 38 genotypes of chewing tobacco and observed that cured leaf yield had positive correlation with leaf length, leaf width and days to maturity at both at genotypic and phenotypic level. The plant height exhibited negative genotypic as well as phenotypic correlation with cured leaf yield. They also found positive genotypic as well as phenotypic correlation between days to flowering and number of leaves.

While evaluating 55 genotypes of hookah and chewing tobacco, Dobhal and Rao (1988) reported that cured leaf yield depicted positive phenotypic correlation with number of leaves per plant, leaf length, leaf width, plant height and days to flowering. The number of leaves exhibited positive phenotypic correlation with leaf length, number of leaves per plant, plant height and days to flowering and plant height. The positive phenotypic correlation was also noticed between leaf width and days to flowering and plant height and days to flowering.

Cho and Jin (1989) assessed different tobacco genotypes and observed positive genotypic correlation of cured leaf yield with leaf length, leaf width, plant height and days to flowering. They also found positive genotypic correlation of days to flowering with number of leaves.

Dobhal and Monga (1989) evaluated 121 hookah and chewing tobacco accessions and found that days to flowering had positive association, while leaf thickness had negative association with cured leaf yield. The leaf thickness showed negative genotypic correlation with days to flowering and nicotine content.

Dobhal *et al.* (1989) studied genetic divergence in hookah and chewing tobacco (*Nicotiana rustica* L.) and revealed that nicotine and chloride content were negatively associated with cured leaf yield, whereas reducing sugar showed positive correlation with cured leaf yield.

Patel (1989) studied F_1, M_1, M_2 and M_3 generations of bidi tobacco and revealed that cured leaf yield was positively correlated with number of leaves, leaf length, leaf width and plant height and days to flowering. The leaf length showed positive genotypic as well as phenotypic correlation with leaf length, leaf width, plant height and days to flowering. The leaf length showed positive genotypic as well as phenotypic correlation with leaf yield and plant height. The positive genotypic as well as phenotypic correlations were found between leaf width and plant height.

In their study of 72 strains of hookah tobacco, Chaubey *et al.* (1990) reported positive genotypic as well as phenotypic correlation of cured leaf yield with number of leaves had positive genotypic as well as phenotypic correlation with leaf length, plant height and days to flowering, while negative genotypic correlation with leaf width. Further, leaf length showed positive genotypic as well as phenotypic association with days to flowering and plant height, while leaf width

exhibited negative association with plant height. Plant height expressed positive genotypic and phenotypic association with days flowering.

Chung *et al*. (1992) found positive genotypic correlation between cured leaf yield and reducing sugar content.

Kara and Esendal (1996) assessed six genotypes of Turkish tobacco and their 15 half diallel crosses. They found that leaf width had positive correlation with cured leaf yield. There was negative correlation with cured leaf yield. There was negative phenotypic correlation between number of leaves per plant and leaf length. The leaf length showed positive phenotypic correlation with leaf width.

Butorae (1999) studied Burley tobacco genotypes and reported positive genotypic correlation of cured leaf yield with number of leaves per plant, leaf length, leaf width, leaf thickness and plant height.

In their study of different FCV tobacco genotypes, Lakshmish and Shivanna (1999) found that the number of leaves per plant, plant height and reducing sugar content had positive genotypic correlation with cured leaf yield.

Datta (2002) evaluated 17 bidi tobacco genotypes under irrigated and rainfed conditions. Under irrigated condition, cured leaf yield showed positive genotypic as well as phenotypic correlation with number of leaves, leaf length, leaf width, plant height and days to flowering. Under rainfed condition, cured leaf yield showed positive genotypic as well as phenotypic correlation with number of leaves, plant height and days to flowering.

Lalithadevi *et al.* (2002) carried out correlations studies on 32 varieties of tobacco. They observed that cured leaf yield was positively correlated with number of leaves, leaf length, leaf width and plant height at genotypic level.

Patel and Makwana (2002) studied 121 genotypes of chewing tobacco and reported that cured leaf yield had positive association with number of leaves, leaf length, leaf width, plant height, days to flowering and days to maturity, while it showed negative correlation with leaf thickness both at genotypic and phenotypic levels.

Forty genotypes of bidi tobacco were evaluated by Patel and Kingaonkar (2005). They found positive genotypic as well as phenotypic correlation of cured leaf yield with number of leaves, leaf length, leaf width, plant height, days to flowering and days to maturity.

Bhumarannavar (2009) studied 191 germplasm lines of bidi tobacco for six quantitative traits. There was positive correlation of cured leaf yield with plant height, intermodal length, number of leaves, leaf length and leaf width.

Maleki *et al.* (2011) assessed 100 tobacco genotypes and reported that dry leaf yield was positively and significantly correlated with fresh leaf yield, plant height, number of leaves, leaf width, leaf length, stem girth and days to 50 per cent flowering.

Nama (2011) studied 42 genotypes of rustica tobacco and found that number of leaves per plant, leaf length, days to flowering and nicotine content were positively correlated with cured leaf yield, whereas reducing sugar content, leaf thickness and leaf width expressed negative correlation with cured leaf yield.

Patel *et al.* (2011) observed that significant positive genotypic and phenotypic correlations were found for cured leaf yield with number of leaves, days to flowering, days to maturity, leaf length, leaf width and plant height. Among the character, days to flowering with number of leaves, days to maturity with number of leaves, plant height with number of leaves, days to flowering, days to maturity, leaf length and leaf width, while leaf length with number of leaves, days to flowering and days to maturity, leaf width with days to flowering, days to maturity and leaf length, number of leaves with days to maturity showed significant positive correlation at both genotypic and phenotypic levels while, with days to flowering, leaf length and leaf width it showed significant negative correlation at both genotypic and phenotypic levels.

Bayat *et al.* (2014) studied ninety one oriental and semi oriental tobacco genotypes separately under normal and stress condition dry leaf yield per plant showed significant and positive correlation between biomass and fresh leaf weight under normal and abiotic stress condition. Flowering date and plant height showed minimum correlation under both condition.

Ramchandra *et al.* (2014) studied 14 cultivars and 48 F_1 hybrid and observed plant height, number of leaves per plant, leaf length and leaf breath were highly significant and positively correlated with leaf yield at both genotypic and phenotypic level. While, leaf thickness showed negative correlation with cured leaf yield.

Parajuli *et al*. (2015) studied correlation which revealed that cured leaf yield showed positive and significant association with days to flowering and days to

maturity at both genotypic and phenotypic levels, which indicated that selection for late maturing genotypes would likely to increase cured leaf yield. Other characters showed positive and significant associations with cured leaf yield were number of leaves per plant, plant height, leaf length and leaf width. Hence, these characters should be given due weightage while selecting for increasing cured leaf yield. On the other hand, leaf thickness and reducing sugar content were negatively and significantly correlated with cured leaf yield. The estimated value of genotypic and phenotypic correlations revealed comparatively higher degree of genotypic correlation coefficient than their phenotypic counterpart for most of the characters, which indicated strong and inherent association between two characters.

Shah *et al.* (2016) observed four tobacco parental cultivars and 12 F_2 populations. Leaf yield showed significant positive phenotypic and genotypic correlations with leaf area, number of leaves per plant and green leaf weight.

Ahmed *et al.* (2017) studied Correlation analysis which revealed significantly positive associations of yield with plant height (r_p = 0.078), however, non-significant association was detected at genotypic level.

Katba *et al.* (2018) studied 40 genotypes of tobacco (*Nicotiana rustica* L.). The estimates of correlation coefficient revealed that cured leaf yield was positively correlated at both genotypic and phenotypic levels with days to flowering, number of leaves per plant, plant height, days to maturity, leaf length and leaf width, while it was negatively correlated with leaf thickness and reducing sugar content.

Netravati *et al.* (2018) conducted experiment in randomized block design (RBD) with three replications. The materials for the study consisted of two F_2 populations (TB-70 × TB-102 and TB-100 × TB-102) of FCV tobacco. In each F_2 population, seventy-five plants were selected at random for recording the observations on eight different quantitative characters. Correlation coefficient analysis revealed that cured leaf yield was positively and significantly correlated with most of the studied traits in both F_2 populations. The characters such as days to flower and plant height had weak association in both F_2 populations.

2.3 Path coefficient analysis

Path coefficient analysis is simply a standardized partial regression coefficient, which splits the genotypic correlation coefficient into direct and indirect effects.

It reveals whether the association of the characters with yield is due to their direct effect on yield or is a consequence of their indirect effect via other component characters.

Path analysis was initially suggested by Wright (1921) and it was applied for the first time in plant breeding by Dewey and Lu (1959).

Patel *et al.* (1981) reported that leaf thickness and plant height were principle attributes influencing cured leaf yield as indicated by their high positive direct effect on cured leaf yield. On the other hand, leaf number had weak positive direct effect on cured leaf yield.

Patel *et al.* (1985) studied various morphological traits in 100 bidi tobacco genotypes and found that number of leaves per plant, leaf length and leaf width high positive direct effect on cured leaf yield.

Amarnath and Murthy (1988) evaluated 88 genotypes of chewing tobacco. Path coefficient analysis revealed that leaf length and days to maturity had high positive direct effect on cured leaf yield, while plant height had negative direct effect on cured leaf yield.

Dobhal and Rao (1989) assessed 55 genotypes of hookah and chewing tobacco and reported that leaf length, leaf width and curable leaf number were strongest forces influencing cured leaf yield.

Patel *et al.* (1989) evaluated chemical quality parameters of bidi tobacco and found that nicotine content and reducing sugar content exhibited positive direct effect, whereas chloride content had negative direct effect on cured leaf yield.

Chaubey *et al.* (1990) evaluated 72 strains of hookah tobacco and reported that maximum weightage may be given to the late flowering and dwarf plant height, while formulating selection for cured leaf yield.

Kara and Esendal (1996) studied various Turkey tobacco genotypes and observed positive direct effect of number of leaves on cured leaf yield.

Lakshmish and Shivanna (1999) carried out path coefficient analysis in 48 FCV tobacco genotypes. They reported that plant height had low positive direct effect, while number of the leaves had high negative direct effect on cured leaf yield.

Datta (2002) studied 17 bidi tobacco genotypes under irrigated and rainfed conditions. Under irrigated conditions, days to flowering had the highest

positive direct effect on cured leaf yield followed by number of leaves, while plant height had the highest positive direct effect on cured leaf yield followed by days to maturity and leaf length under rainfed condition.

Patel and Makwana (2002) studied different genotypes of rustica tobacco and revealed that leaf width and days to maturity had high positive direct effects, while the leaf thickness, plant height and days to flowering had moderate positive direct effect on cured leaf yield.

Patel and Kinganokar (2005) carried out path analysis for 10 characters in tobacco. The results indicated that the number of leaves, leaf length and leaf breadth were the major yield contributing characters those exerted considerable positive direct effect on cured leaf yield. Plant height, days to flowering and days to maturity showed low positive direct effect on cured leaf yield.

Bhumarannavar (2009) studied the contribution of different traits towards the leaf yield per plant in 191 germplasm lines of bidi tobacco. He found that plant height, number of leaves, leaf length and leaf width influenced leaf yield directly and predominantly.

Maleki *et al.* (2011) studied sequential path analysis in 100 tobacco genotypes and reported that dry leaf yield were identified as first order traits, whereas stem girth and leaf length presented maximum direct effects in second and third orders, respectively.

Nama (2011) studied 42 rustica tobacco genotypes and reported that days to flowering, leaf length and number of leaves per plant showed remarkable positive direct effect on cured leaf yield.

Patel *et al.* (2011) studied 40 tobacco genotypes for the path coefficient analysis. The results of the path analysis revealed that number of leaves per plant, days to maturity and plant height had moderate to high direct effect, while number of leaves, days to flowering, days to maturity, leaf length and leaf width had moderate indirect effect *via* plant height.

Bayat *et al.* (2014) conducted experiment in normal and abiotic stress condition by using 91 tobacco genotypes. They observed that biomass and aerial dry weight without leaves had direct effect on leaf yield per plant.

Ramchandra *et al.* (2014) conducted experiment consisted 14 cultivars and 48 F_1 hybrids. Path analysis revealed that direct contribution of number of leaves, leaf breadth and total fresh weight were of higher magnitude of leaf yield.

However, indirect positive contributions of plant height and leaf length were appreciable to enhance yield.

Parajuli *et al.* (2015) conducted path analysis of 40 diverse genotypes of rustica tobacco (*Nicotiana rustica* L.). The overall path coefficient analysis based on genotypic correlations revealed that leaf length (0.451), plant height (0.229) and days to flowering (0.178) in leaf width and numbers of leaves per plant were major characters having positive direct effects and significant association with cured leaf yield.

Katba *et al.* (2018) studied 40 genotypes of tobacco (*Nicotiana rustica* L.) for path analysis. Path analysis based on genotypic correlation showed that number of leaves per plant, plant height and leaf length are important characters that exerted considerable direct effect on cured leaf yield revealing scope for considering these characters in selection programme for bringing out desired improvement in tobacco yield.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 Location and climatic condition

The present investigation entitled, "Genetic variability, correlation and path analysis in rustica tobacco (*Nicotiana rustica* L.)" was conducted in *rabi* 2019-20 at Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol. The center lying between 230° 38' to 230° 41' North latitude and 720° 41' to 720° 44' East longitude. The soil of the station is sandy to sandy-loam, low in organic matter, poor in soil fertility and water holding capacity. The weather condition during crop season is favorable for the crop. The meteorological data for the cropping season is given in Appendix-I. The details of the material used, methods adopted and statistical analysis followed during the investigation are described as below.

3.2 Experimental materials

The experimental material for the present investigation consisted of 35 diverse genotypes of rustica tobacco (*Nicotiana rustica* L.), were obtained from the germplasm maintained at Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol. The details of genotypes used in present investigation are presented in table 3.1.

Table 3.1 : List of genotypes used in present study

Sr. No.	Genotypes	Sr. No.	Genotypes
1	Black queen	19	AR-47
2	C-21	20	Sel.15-1-1
3	Cocker-1	21	SR-32
4	GC-1	22	DWFC
5	Jharipura	23	AR-49
6	Maharka	24	AR-50
7	S-7	25	AR-56
8	S-12	26	AR-60
9	SK-140	27	VR-36
10	SK-141-1	28	AR-77
11	SK-200	29	AR-93
12	SK-400	30	LR-55
13	AR-30	31	LR-60
14	AR-44	32	LR-64
15	VR-1	33	LR-69
16	VR-2	34	GCT-3
17	VR-8	35	DCT-4
18	VR-12		

(Source : Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol, District : Mehsana).

3.3 Experimental details

3.3.1 Experimental design

The present experiment was conducted in a Randomized Block Design (RBD) with four replications. Each plot consist of a double row of ten plants with inter and intra row spacing being 60 cm and 45 cm.

3.3.2 Cultural operations

The application of fertilizer in the experimental plot was done at the rate of 200 kg per hectare in form of ammonium sulphate, Urea and Castor cake. The post transplanting operations like interculturing, sweeding, insecticidal spray and desuckering were done in accordance with the recommended practices. The topping was done at bald sucker stage along with top leaves.

3.4 Characters studied

The characters studied in the present investigation along with the techniques used are described below.

The observations on cured leaf yield and its components were recorded from five randomly selected tagged plants for each genotype in each replication and the average value per plant was computed. The plant height as well as leaf measurement was recorded at maturity. The observation on days to flowering and days to maturity was recorded per plot basis. The procedure adopted for each recording each observation is given below.

3.4.1 Days to flowering

It was recorded by counting days from transplanting to the opening of first flower in 50 per cent plants.

3.4.2 Days to maturity

Days to maturity was recorded by counting days from transplanting to the appearance of spangles on 50 per cent leaves of the plant.

3.4.3 Plant height (cm)

Plant height was measured at harvest from ground level to the point at which the plant was topped.

3.4.4 Number of leaves per plant

It was recorded by counting the leaves from the base of plant to the bald sucker point after topping.

3.4.5 Leaf length (cm)

Leaf length was measured from leaf base to leaf tip of three leaves from top to bottom of the plant and mean value was computed.

3.4.6 Leaf width (cm)

Leaf width was measured in the region of maximum expansion of each of three leaves used for measurement of leaf length and mean value was computed.

3.4.7 Leaf thickness (mg/cm^2)

Leaf thickness was calculated by dividing the dry weight of leaves by their total leaf area.

3.4.8 Nicotine content (%)

Nicotine content was estimated by using auto analyzer; model AA III (Harvey *et al.,* 1969).

3.4.9 Reducing sugar content (%)

The reducing sugar content was estimated by using auto analyzer; model AA III (Harvey *et al.,* 1969).

3.4.10 Chloride content (%)

The chloride estimation was done by titrimetric method using N/35.5 normal $AgNo_3$ with help of galvanometer (Murthy *et al.,* 1962).

3.4.11 Cured leaf yield (g/plant)

Cured leaf yield of individual plant was recorded after sun curing of leaves. The cured leaf yield involved the yield of lamina (bhuka), mid-rib (rago), leaf bits (geran) and sand leaves (galia).

3.5 Statistical analysis

The mean values of five randomly selected observational plants for thirty-five different genotypes were used for statistical analysis. The following statistical parameters were worked out for presentation of the data on different quantitative attributes.

3.5.1 Analysis of variance

The data recorded for all the characters were subjected to analysis of variance with the formula suggested by Panse and Sukhatme (1978). The statistical model used for analysis of the present investigation is described below.

$$Y_{ij} = \mu + a_i + b_j + e_{ij}$$

Where,

Y_{ij} = Yield of j^{th} genotype in i^{th} replication,

μ = General mean,

a_i = Effect of i^{th} replication,

b_j = Effect of j^{th} genotype, and

e_{ij} = Uncontrolled variation associated with i^{th} replication and j^{th} genotype.

For all the characters under study, the mean values of five randomly selected plants were used for statistical analysis. The data recorded for different characters were subjected to analysis of variance. Different components of variance *viz.,* phenotypic, genotypic and environmental variances were estimated. Different parameters of genetic variability were computed by standard statistical procedures. The phenotypic and genotypic correlations were also estimated. The genotypic correlations were subjected to path coefficient analysis. The analysis of variance was done as suggested by Panse and Sukhatme (1978).

Table 3.2 : Analysis of variance for experimental design

Source of variation	d.f.	MSS	Expected mean square
Replications	(r-1)	MS_r	$\sigma^2_e + t\,\sigma^2_r$
Genotypes	(t-1)	MS_t	$\sigma^2_e + r\,\sigma^2_g$
Error	(r-1) (t-1)	MS_e	σ^2_e
Total	(rt-1)	-	-

Where,

r = Number of replications,

g = Number of genotypes,

σ^2_e = Variances due to error,

σ^2_r = Variances due to replication,

σ^2_g = Variances due to genotypes,

MS_r = Mean sum of square for replication,

MS_t = Mean sum of square for genotypes, and

MS_e = Mean sum of square for error.

The standard error for differences between treatments mean was calculated from ANOVA table.

$$S.Em.\pm = \sqrt{\frac{\sigma^2_e}{r}}$$

Where,

S.Em. = Standard error of mean,

σ^2_e = Error mean square, and

r = Number of replications.

The critical difference to compare the mean values of various genotypes was calculated by using the following formula.

$$C.D. = \sqrt{2} \times S.Em. \times t_{0.05} \text{ at error d.f.}$$

Where,

C.D. = Critical difference

S.Em. = Error Mean Square,

r = Number of replication, and

t = Table 't' value at error d.f.

The Coefficient of Variation (C.V. %) was calculated by using the following formula : $x = \frac{-b \pm \sqrt{MSe}}{2a}$

$$C.V.\% = \frac{\sqrt{MSe}}{\overline{X}} \times 100$$

Where,

C.V. = Coefficient of variation,

MSe = Mean sum of square of error, and

$\overline{X}$ = General mean.

3.5.2 Genetic variability parameters

[i] Mean ($\overline{X}$)

It is computed by dividing the sum of all observations in a sample by their number.

$$\overline{X} = \frac{\Sigma X_{ij}}{n}$$

Where,

$\overline{X}$ = General mean,

X_{ij} = Any observation in i^{th} replication and j^{th} genotype, and

n = Number of observations.

[ii] Range

It is the difference between maximum value and minimum value in a particular character. The genotypic, phenotypic and environmental components were estimated as explained by Johnson *et al.* (1955).

Range = Maximum value - Minimum value

[iii] Genotypic variance (σ^2_g)

The genotypic variance is contributed by genetic cause or the occurrence of difference among individuals due to differences in their genetic make-up. Following formula was used.

$$\text{Genotypic variances } (\sigma^2_g) = \frac{\text{Genotypic M S} - \text{Error M S}}{\text{Number of replications (r)}}$$

[iv] Environmental variance(σ^2_e)

Following formula was used.

Environmental variances (σ^2_e) = Mean Square of Error (MSe)

[v] Phenotypic variance (σ^2_p)

It is the sum of the variances contributed by genetically causes and environmental factors and is calculated as under.

Phenotypic variance (σ^2_p) = Error variance (σ^2_e) + Genotypic variance (σ^2_g)

[vi] Coefficient of variation

The coefficient of phenotypic and genotypic variations was calculated by the formula suggested by Burton (1952).

(a) Phenotypic Coefficient of Variation (PCV)

The phenotypic coefficient of variation, which measures the magnitude of phenotypic variation present in a particular character, was estimated as per the formula suggested by Burton (1952).

$$\text{PCV\%} = \frac{\sqrt{\sigma^2 p}}{\text{Mean } (\bar{X})} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance, and

$\overline{X}$ = Mean of a character.

(b) Genotypic Coefficient of Variation (GCV)

The genotypic coefficient of variation, which measures the magnitude of genetic variation present in a particular character, was estimated as per the formula suggested by Burton (1952).

$$GCV\% = \frac{\sqrt{\sigma^2 g}}{\text{Mean } (\overline{X})} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance, and

$\overline{X}$ = Mean of a character.

GCV and PCV were categorized as low, moderate and high by following Shivasubramanian and Menon (1973). It is as follows :

0-10 %	=	Low
10-20 %	=	Moderate
20 % and above	=	High

[vii] Heritability (Broad Sense) h^2 (bs)

It is the proportion of phenotypic variability that is due to genetic reasons. It was calculated by using the formula proposed by Allard (1960).

$$h^2(b)\% = \frac{\text{Genotypic variance } (\sigma^2 g)}{\text{Phenotypic variance } (\sigma^2 p)} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance, and

$\sigma^2 p$ = Phenotypic variance.

Heritability percentage was categorized as demonstrated by Robinson *et al.* (1949). It is as follows :

0-30 %	=	Low
30-60 %	=	Moderate
60 % and above	=	High

[viii] Expected Genetic Advance (GA)

Expected genetic advance represents the shift in a population towards superior side under some selection pressure after single generation of selection. It could be calculated by using the methodology suggested by Allard (1960) at 5 per cent selection intensity using the constant 'k' as 2.06.

$$G.A. = h^2 (b) \times k \times \sigma_p$$

Where,

G.A. = Genetic Advance,

h^2(bs) = Heritability (Broad sense),

K = Selection intensity at 5 per cent = 2.06, and

σ_p = Phenotypic standard deviation.

[ix] Genetic advance expressed as per cent of mean (Genetic gain)

The expected genetic advance as expressed in per cent of mean was calculated by the method suggested by Johnson *et al.* (1955).

$$\text{Genetic gain \%} = \frac{\text{Expected genetic advance (G.A.)}}{\text{Mean } (\overline{X})} \times 100$$

The genetic advance as per cent mean was categorized as suggested by Johnson *et al.* (1955). It is as follows :

0-10 %	=	Low
10-20 %	=	Moderate
20 % and above	=	High

3.5.3 Correlation coefficient

Correlation coefficients measure the relationship between two or more series of variables. The genotypic correlation coefficient provides a measure of genotypic association between different characters, while phenotypic correlation includes both genotypic as well as environmental influences.

For this purpose, analysis of covariance for all possible pairs of eleven characters was carried out using the procedure of Panse and Sukhatme (1998).

Table 3.3 : Analysis of variance for correlation coefficient

Source	d.f.	Mean square of products (M.S.)	Expectation of mean square of products
Replications	(r-1)	MSP_1	$Cov_exy + gCov_rxy$
Genotypes	(g-1)	MSP_2	$Cov_exy + rCov_gxy$
Error	(r-1) (g-1)	MSP_3	Cov_exy
Total	(rg-1)	-	-

Where,

r	=	Number of replications,
g	=	Number of genotypes,
Cov_exy	=	Environmental component of covariance,
Cov_rxy	=	Replication component of covariance,
Cov_gxy	=	Genotypes components of covariance,
MSP_1	=	Mean square products for replication,
MSP_2	=	Mean square products for genotypes, and
MSP_3	=	Mean square product for error.

The components of covariance were estimated by equating the observed mean sum of products with their expectations as shown below.

$$Cov_g xy = \frac{(MSP2-MSP3)}{r}$$

$$Cov_e xy = MSP_3$$

$$Cov_p xy = Cov_g xy + Cov_e xy$$

Where,

$Cov_g xy$ = Genotypic components of covariance,

$Cov_e xy$ = Environmental components of covariance, and

$Cov_p xy$ = Phenotypic components of covariance.

The genotypic (r_g) and phenotypic (r_p) correlation coefficient were calculated as under by adopting the procedure explained by Al-Jibouri *et al.* (1958).

(a) Genotypic correlation coefficient :

$$r_g(XY) = \frac{Cov_g\ (XY)}{\sqrt{\sigma_g^2(X)} \times \sqrt{\sigma_g^2(Y)}}$$

(b) Phenotypic correlation coefficient :

$$r_p(XY) = \frac{Cov_p\ (XY)}{\sqrt{\sigma_p^2(X)} \times \sqrt{\sigma_p^2(Y)}}$$

Where,

$r_g(xy)$ and $r_p(xy)$ are genotypic and phenotypic correlation coefficient for a pair of trait x and y, respectively.

$Cov_g(xy)$ and $Cov_p(xy)$ are genotypic and phenotypic covariance for a pair of characters x and y, respectively.

The phenotypic correlation was tested using the method suggested by Fisher and Yates (1963).

3.5.4 Path coefficient analysis

The cause and effect, interrelationship between two variables cannot be estimated from simple correlation coefficient analysis. Path coefficient is a standardized partial regression coefficient and measures the direct and indirect influence of one variable upon another thereby permitting the separation of correlation coefficient into the component of direct and indirect effects Therefore, the path coefficient analysis was carried-out according to the method suggested by Wright (1921) and used by Dewey and Lu (1959). Genotypic correlation coefficients of eleven variables with cured leaf yield per plant were used to estimate the path coefficients for the direct effects of various independent characters on cured leaf yield per plant.

The path coefficients were obtained by solving a set of simultaneous equations as below.

$$r_{ny} = P_{ny} + r_{n2} \cdot P_{2y} + r_{n3} \cdot P_{3y} + r_{n4} \cdot P_{4y} + \ldots\ldots + r_{nx} \cdot P_{xy}$$

Where,

r_{ny} = Represents correlation coefficient between one component character and seed yield per plant,

P_{ny} = Represents the path coefficient between the character and seed yield per plant, and

$r_{n2}, r_{n3} \ldots r_{nx}$ = Represents correlation coefficient between that character and other yield component in turn.

The following correlation matrix was formed,

Matrix-A **Matrix-B** **Matrix-C**

$$\begin{pmatrix} r_1y \\ r_2y \\ r_3y \\ : \\ : \\ : \\ r_ny \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12}.....r_{1n} \\ r_{21} & r_{22}.....r_{2n} \\ r_{31} & r_{31}.....r_{3n} \\ : & : & : \\ : & : & : \\ : & : & : \\ r_{n1} & r_{n2} & r_{nn} \end{pmatrix} \times \begin{pmatrix} p_1y \\ p_2y \\ p_3y \\ : \\ : \\ : \\ p_ny \end{pmatrix}$$

Or $A = B \times C$

Where,

$r_{11} \ldots r_{nn}$

r_{12}, r_{21} and so on = Correlation between two component characters, and

r_{1y}, r_{2y} and so on = Correlation between component characters and seed yield per plant.

The technique given by Goulden (1962) was followed for inversion of the 'B' matrix using partitioning method of matrix inversion.

Path coefficients (P_{ij}) were obtained as follows.

$$P_{ij} = (B^{-1}) \times (A)$$

Where,

(B^{-1}) is the inverse of mutual correlation matrix of character.

The indirect effects for a particular character through other characters were obtained by multiplication of direct path and particular correlation coefficient between those two characters, respectively.

$$\text{Indirect effect} = r_{ij} \times P_{ij}$$

Where,

i = 1, 2, 3, ...,....,..,., n

j = 1, 2, 3, ...,..,..,..., n

P_{ij} = $P_1y \times P_2y \times P_3y \times ..... \times P_ny$

The residual factor *i.e.,* variation in yield unaccounted for by these associations was calculated with the following formula.

$$\text{Residual factor (R)} = \sqrt{1 - R^2}$$

Where,

R^2 = $(P_{1y} r_{1y} + P_{2y} r_{2y} + \ldots\ldots\ldots + P_{ny.} r_{ny})$,

$P_{1y}, P_{2y}, \ldots\ldots, P_{ny}$ = Direct path values, and

r_{1y}, r_{2y}, r_{ny} = Correlation coefficient.

The path coefficient value was categorized as suggested by (Lenka and Mishra, 1973).

0.00 to 0.09	=	Negligible
0.10 to 0.19	=	Low
0.20 to 0.29	=	Moderate
0.30 to 0.99	=	High
More than 1.00	=	Very high

RESULTS AND DISCUSSION

IV. RESULTS AND DISCUSSION

The results of present investigation entitled, "Genetic variability, correlation and path analysis in rustica tobacco (*Nicotiana rustica* L.)" is discussed as per the following sub-heads.

4.1 Analysis of variance

4.2 Variance components and variability parameters

4.3 Estimation of correlation coefficients

4.4 Path coefficient analysis

4.1 Analysis of variance

The analysis of variance was carried out for all the eleven characters considered for the study. The analysis of variance depicting mean squares for different characters studied are presented in Table 4.1.

Table 4.1 : Analysis of variance for different characters in rustica tobacco

Sr. No.	Characters	Mean Sum of Squares		
		Replications	Genotypes	Error
		d.f. = 3	d.f. = 34	d.f. = 102
1	Days to flowering	49.75	369.07**	7.90
2	Days to maturity	15.35	168.36**	5.20
3	Plant height	10.80	262.78**	15.84
4	Number of leaves per plant	1.28	05.76**	0.65
5	Leaf length	6.07	13.99**	3.34
6	Leaf width	14.97	13.02**	3.35
7	Leaf thickness	0.52	10.47**	0.48
8	Nicotine content	0.06	3.81**	0.06
9	Reducing sugar content	0.08	1.16**	0.03
10	Chloride content	0.01	0.21**	0.01
11	Cured leaf yield per plant	20.05	2644.95**	175.10

** Indicates significant at 0.01 level of probability.

The result revealed highly significant differences among the rustica tobacco genotypes for eleven characters *viz.,* cured leaf yield, days to flowering, days to maturity, plant height, number of leaves per plant, leaf length, leaf width, leaf thickness, nicotine content, reducing sugar content, chloride content. This indicated the presence of considerable genetic variability among the genotypes for various characters.

4.2 Variance components and variability parameters

Analysis of variance (ANOVA) may not reveal the absolute variability and this could be accessed through standardizing the phenotypic and genotypic variances by obtaining coefficient of variability.

The genetics of metric character is centered on the study of its variation. The amount of variation is measured and expressed as the variance. The mean values of 35 genotypes of rustica tobacco for 11 characters along with the Standard Error of Mean (S.Em.), Critical Difference (C.D.) and Coefficient of Variation (C.V. %) are given in Appendix-II.

Further, it is essential to separate the environmental influence from the total variability. This indicates the accuracy with which a genotype can be identified by its phenotypic performance.

The ratio of genotypic variance to the phenotypic variance is known as broad sense heritability. It is generally expressed in per cent. Thus, heritability is the heritable portion of phenotypic variance. It is a good index of the transmission of characters from parents to their offspring (Falconer, 1989). Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. Heritability and genetic advance were considered as important selection parameters. The estimation of heritability together with the genetic advance is more useful to predict the gain according to selection than the estimation of heritability alone. The estimate of genotypic (σ^2_g) and phenotypic (σ^2_p) variances of each character as well as other genetic components *viz.,* heritability in broad sense (h^2b), genetic coefficient of variance (GCV %), phenotypic coefficient of variance (PCV %) and genetic advance as per cent of mean (GA % of mean) are narrated in Table 4.2.

4.2.1 Mean performance

4.2.1.1 Days to flowering

The range of days to flowering was varied from 57.50 to 94.25 days with general mean of 71.75 days. The genotype C-21 reported earliness in flowering (57.50 days) followed by SK-141-1 (57.75 days) and GC-1 (59.50 days). The genotype DCT-4 (94.25 days) took maximum days for flowering.

4.2.1.2 Days to maturity

The character ranged from 107.50 to 134.75 days with general mean of 121.91 days was recorded. The genotype C-21 was earliest in maturity (107.50 days) followed by SK-141-1 (109.25 days) and GC-1 (113.75 days). The late maturing genotypes were DCT-4 (134.75 days) followed by GCT-3 (133.25 days).

4.2.1.3 Plant height

The range of plant height was varied from 41.10 to 71.67 cm with general mean of 56.87 cm. The genotype AR-93 (71.67 cm) registered with the highest plant height followed by C-21 (70.53 cm) and LR-55 (71.27 cm). The genotype SK-141-1 (41.10 cm) registered the lowest plant height.

4.2.1.4 Number of leaves per plant

The range of variability for number of leaves per plant from8.75 to 13.25 with general mean of 10.31 recorded. The genotype DCT-4 (13.25) registered the highest number of leaves per plant followed by LR-55 (13.15), GCT-3 (12.74) and AR-93 (12.40). The genotype AR-56 (8.75) registered the lowest number of leaves per plant followed by S-12 (9.05) and AR-77 (9.05).

4.2.1.5 Leaf length

The character ranged from 33.10 to 39.87 cm with general mean of 36.52 cm. The genotype LR-69 was the longest for leaf length (39.87 cm) followed by LR-55 (38.70 cm). The genotype DWFC (33.10) recorded minimum for leaf length.

4.2.1.6 Leaf width

Higher values for leaf width as it is associated with cured leaf yield. The character ranged from 33.28 to 40.35 cm with general mean of 36.69 cm. The genotype AR-56 significantly superior for leaf width (40.35 cm) followed by AR-44 (39.88 cm). The genotype VR-8 (33.28) recorded minimum leaf width.

4.2.1.7 Leaf thickness

The significant differences were observed in the study of leaf thickness ranged from 9.05 to 15.60 mg/cm^2 with general mean of 10.97 mg/cm^2. The genotype AR-30 significantly superior for leaf thickness (15.60 mg/cm^2) followed by Black queen (15.08 mg/cm^2). The genotype LR-60 (9.05 g/cm^2) registered lowest leaf thickness.

4.2.1.8 Nicotine content

The range of variability was observed in this trait varied from 3.33 to 6.57 per cent with general mean of 4.90 per cent. Among all genotypes, the highest nicotine per cent recorded in genotypes SR-32 (6.57 %) followed by AR-56 (6.44 %). The lowest nicotine per cent recorded by LR-69 (3.33 %) followed by genotype LR-64 (3.48 %).

4.2.1.9 Reducing sugar content

The range of variability was recorded for reducing sugar content from 3.17 to 5.62 per cent with a general mean of 4.11 per cent. The genotype LR-64 (5.62 %) registered the highest reducing sugar content followed by Black queen (5.14 %) and Sel.15-1-1 (5.00 %). The genotype SK-140 (3.17 %) registered the lowest reducing sugar content.

4.2.1.10 Chloride content

The range of variability for chloride content from 0.61 to 1.42 per cent with general mean of 1.03 per cent was recorded. The genotype AR-60 (1.42 %) registered as the highest chloride content followed by AR-30 (1.38 %). The genotypes LR-69 (0.61 %) registered the lowest chloride content followed by Cocker-1 (0.62 %).

4.2.1.11 Cured leaf yield per plant

Significant differences among genotypes were observed for cured leaf yield, which ranged from 112.80 to 234.70 g/plant. The genotype DCT-4 recorded significantly the higher cured leaf yield (234.70 g/plant) followed by LR-55, LR-60 and AR-44. The lowest cured leaf yield (112.80 g/plant) recorded by the genotype AR-56. The general mean of cured leaf yield per plant was 165.44 g/plant.

4.2.2 Variance components

4.2.2.1 Days to flowering

The results revealed that genotypic variance (90.29) contributed a major portion to phenotypic variance (98.19) in expression of the character, thus indicating less influence of the environment on the expression of this character (Table 4.2). Similar findings were reported by Dobhal (1987), Patel and Patel (1987), Dobhal and Rao (1988), Dobhal and Monga (1989), Datta (2002), Patel and Makwana (2002), Patel and Kingaonkar (2005) and Nama (2011).

Table 4.2 : The estimates of genotypic and phenotypic variances and variability parameters for different characters in rustica tobacco

Sr. No.	Characters	Genotypic variance (σ^2_g)	Phenotypic variance (σ^2_p)	GCV (%)	PCV (%)	h^2_b (%)	GA (% of mean)
1	Days to flowering	90.29	98.19	10.95	13.47	66.12	18.34
2	Days to maturity	40.79	45.99	4.46	6.70	44.36	6.13
3	Plant height	61.74	77.57	5.24	5.56	88.70	10.16
4	Number of leaves per plant	01.28	1.93	13.81	15.48	79.58	25.38
5	Leaf length	2.66	6.00	4.24	6.54	41.96	5.66
6	Leaf width	2.42	5.77	14.40	15.72	83.87	27.17
7	Leaf thickness	2.50	2.98	19.76	20.35	94.29	39.52
8	Nicotine content	0.94	1.00	12.90	13.59	90.08	25.21
9	Reducing sugar content	0.28	0.31	22.46	22.95	95.79	45.28
10	Chloride content	0.05	0.06	15.02	17.02	77.91	27.31
11	Cured leaf yield per plant	617.46	792.56	13.26	13.83	91.96	26.19

4.2.2.2 Days to maturity

The results revealed that genotypic variance (40.79) contributed major portion to phenotypic variance (45.99) in expression of the character, this indicating a low influence of the environment on the expression of this character. This findings were relevant with Dobhal (1987), Patel and Patel (1987), Dobhal and Rao (1988), Dobhal and Monga (1989), Datta (2002), Patel and Makwana (2002), Patel and Kingaonkar (2005) and Nama (2011).

4.2.2.3 Plant height

The magnitude of genotypic variance (61.74) and phenotypic variance (77.57) exhibited less difference between them which suggested that there was less influence of the environment on this trait. Dobhal (1987), Patel and Patel (1987), Dobhal and Rao (1988), Dobhal and Monga (1989), Datta (2002), Patel and Makwana (2002), Patel and Kingaonkar (2005) and Nama (2011) was detected similar results for this trait.

4.2.2.4 Number of leaves per plant

The results revealed that genotypic variance (1.28) contributed a major portion to phenotypic variance (1.93) in expression of the character, indicating less influence of the environment on the expression of this character. This findings were agreement with Dobhal (1987), Patel and Patel (1987), Dobhal and Rao (1988), Dobhal and Monga (1989), Datta (2002) and Patel and Kingaonkar (2005).

4.2.2.5 Leaf length

The results revealed that genotypic variance (2.66) contributed less portion to phenotypic variance (6.00) in expression of the character, this indicating a high influence of the environment on the expression of this character. Dobhal and Rao (1988), Patel (1997), Datta (2002) and Nama (2011) were identical result for this trait.

4.2.2.6 Leaf width

The results revealed that genotypic variance (2.42) contributed less portion to phenotypic variance (5.77) in expression of the character, this indicating a high influence of the environment on the expression of this character. Earlier identical reports were found by Dobhal and Rao (1988), Patel (1997), Datta (2002) and Nama (2011).

4.2.2.7 Leaf thickness

The results revealed that genotypic variance (2.50) contributed a major portion to phenotypic variance (2.98) in expression of the character, this indicating less influence of the environment on the expression of this character. This results were in accordance with Dobhal and Rao (1988) and Patel and Kingaonkar (2005).

4.2.2.8 Nicotine content

The results revealed that genotypic variance (0.94) contributed a major portion to phenotypic variance (1.00) in expression of the character, this indicating less influence of the environment on the expression of this character. Dobhal and Rao (1988), Patel (1997) and Patel and Kingaonkar (2005) was detected similar results for this trait.

4.2.2.9 Reducing sugar content

The magnitude of genotypic variance (0.28) and phenotypic variance (0.31) exhibited low differences between them which suggested that there was a low influence of the environment on this trait. This findings were in agreement with Patel (1997), Datta (2002), Patel and Kingaonkar (2005) and Nama (2011).

4.2.2.10 Chloride content

The magnitude of genotypic variance (0.05) and phenotypic variance (0.06) were exhibited no difference between them which suggested that there was less influence of the environment on this trait. These findings were relevant with Katba (2012).

4.2.2.11 Cured leaf yield per plant

The magnitude of genotypic variance (617.46) and phenotypic variance (792.56) exhibited low difference between them which suggested that there was low influence of environment on this trait. The genotypic variance contributed more proportion to the total variance suggesting the phenotypic variance mainly due to genotypic variance. These findings were corresponding with work done by Nama (2011), Patel *et al*. (2011), Katba (2012), Barsinia *et al*. (2014), Parajuli *et al.* (2015), Shah *et al.* (2016) and Ahmed *et al.* (2017).

4.2.3 Genotypic and phenotypic coefficients of variation

4.2.3.1 Days to flowering

The estimates of GCV (10.95 %) and PCV (13.47 %) were moderate indicating the presence of moderate variability in the population for days to flowering. Similar findings reported by Dobhal (1987), Patel and Patel (1987), Dobhal and Rao (1988), Dobhal and Monga (1989), Datta (2002) and Patel and Kingaonkar (2005).

4.2.3.2 Days to maturity

The estimates of GCV (4.46 %) and PCV (6.70 %) were low indicating the presence of less variability in the population for days to maturity. Datta (2002) and Patel and Kingaonkar (2005) were identical results for the same trait.

4.2.3.3 Plant height

The estimates of GCV (5.24 %) and PCV (5.56 %) were low indicating the presence of low variability in the population for plant height. These findings were relevant with Dobhal and Rao (1988) and Datta (2002).

4.2.3.4 Number of leaves per plant

The estimates of GCV (13.81 %) and PCV (15.48 %) were moderate indicating the presence of moderate variability in the population for number of leaves per plant. Dobhal and Rao (1988), Datta (2002) and Patel and Kingaonkar (2005) were corresponding with work.

4.2.3.5 Leaf length

The estimates of GCV (4.24 %) and PCV (6.54 %) were low indicating the presence of poor variability in the population for leaf length. These findings were agreement with Patel (1997), Datta (2002) and Nama (2011).

4.2.3.6 Leaf width

The estimates of GCV (14.40 %) and PCV (15.72 %) were moderate indicating the presence of medium variability in the population for leaf width. Earlier, similar results were found by Datta (2002), Patel and Kingaonkar (2005), Bhumarannavar (2009) and Katba (2012).

4.2.3.7 Leaf thickness

The estimate of GCV (19.76 %) was moderate and PCV (20.35 %) were high indicating the presence of medium to high variability in the population for leaf thickness. Similar findings were reported by Dobhal and Rao (1988) and Patel (1997).

4.2.3.8 Nicotine content

The estimates of GCV (12.90 %) and PCV (13.59 %) were moderate indicating the presence of moderate variability in the population for nicotine content. Patel (1997), Datta (2002) and Parajuli *et al.* (2015) were identical results for this trait.

4.2.3.9 Reducing sugar content

The estimates of GCV (22.46 %) and PCV (22.95 %) were high indicating presence of high variability in the population for reducing sugar content. Patel and Kingaonkar (2005) and Nama (2011) were accordance with findings.

4.2.3.10 Chloride content

The estimates of GCV (15.02 %) and PCV (17.02 %) were indicating the presence of moderate variability in the population chloride content. These findings were relevant with Katba (2012) and Parajuli *et al.* (2015).

4.2.3.11 Cured leaf yield per plant

The estimates of GCV (13.26 %) and PCV (13.83 %) were moderate indicating presence of sufficient variability in the population for cured leaf yield. Similar findings were reported by Patel (1997) and Datta (2002).

4.2.4 Genetic advance as per cent of mean and heritability

4.2.4.1 Days to flowering

The genetic advance as per cent of mean was comparatively moderate (18.34 %) coupled with high heritability (66.12 %), indicating that most likely the heritability is due to additive gene effects and selection may be effective. Dobhal (1987), Dobhal and Monga (1989), Datta (2002) and Nama (2011) were similar results with the present findings.

4.2.4.2 Days to maturity

The genetic advance as per cent of mean was low (6.13 %) coupled with moderate heritability (44.36 %), indicates non-additive gene action and selection for such trait may not be rewarding. Hence, for the improvement of this character, population improvement approach would be more remunerative. Amarnath (1987) and Datta (2002) were corresponding with work.

4.2.4.3 Plant height

The genetic advance as per cent of mean was moderate (10.16 %) coupled with high heritability (88.70 %) indicating that most likely the heritability is due to additive gene effects and selection may be effective. These results were discordant with Katba (2012) and Parajuli *et al.* (2015).

4.2.4.4 Number of leaves per plant

The genetic advance as per cent of mean was high (25.38 %) coupled with high heritability (79.58 %), which indicates that most likely the heritability is influenced by less environmental effects and additive gene effects, thus selection for this trait is effective. Dobhal (1987), Patel and Kingaonkar (2005), Nama (2011) and Katba (2012) were reported identical results for this trait.

4.2.4.5 Leaf length

The genetic advance as per cent of mean was comparatively low (5.66 %) coupled with moderate heritability (41.96 %), that indicates non-additive gene action and selection for such trait may not be rewarding. Similar findings were reported by Datta (2002) and Nama (2011).

4.2.4.6 Leaf width

The genetic advance as per cent of mean was comparatively high (27.17 %) coupled with high heritability (83.87 %), that indicates additive gene action and selection for such trait is rewarding. Amarnath (1987), Dobhal (1987) and Katba (2012) were accordance with findings.

4.2.4.7 Leaf thickness

The genetic advance as per cent of mean was comparatively high (39.52 %) coupled with high heritability (94.29 %), indicating that the predominance of additive gene action in the expression of the character and independence of phenotypic expression reflect the genotypic ability to transmit the genes to their offspring, hence selection may be effective. Dobhal and Rao, (1988) and Katba (2012) were relevant with these findings.

4.2.4.8 Nicotine content

The per cent of mean genetic advance was high (25.21 %) coupled with high heritability (90.08 %) was recorded which indicated the possibility of improving and fixing this character through selection. High heritability coupled with high genetic advance suggested that additive gene action was found in such character. High heritability coupled with high genetic advance was corresponding with the work of Nama (2011) and Parajuli *et al.* (2015).

4.2.4.9 Reducing sugar content

The genetic advance as per cent of mean was high (45.28 %) coupled with high heritability (95.79 %), reveals the additive gene action. For inheritance of the characters, thereby there would be scope of improvement of this character by selection. Similar finding were observed by Smalcelj and Vasilj (1984), Katba (2012) and Parajuli *et al.* (2015).

4.2.4.10 Chloride content

The genetic advance as per cent of mean was high (27.31 %) coupled with high heritability (77.91 %), suggested that character is governed by additive gene action and high heritability exhibited due to low environmental effect. So selection may be effective. Katba (2012) and Parajuli *et al.* (2015) reported high heritability with high genetic advance for this trait.

4.2.4.11 Cured leaf yield per plant

The genetic advance as per cent of mean was high (26.19 %) coupled with high heritability (91.96 %) was also recorded for this trait indicating presence of additive genes and selection is beneficial. These findings were accordance with Patel and Kingaonkar (2005), Nama (2011), Patel *et al*. (2011), Katba (2012) and Parajuli *et al.* (2015).

The estimate of genotypic and phenotypic variance revealed that in all the characters showed significant variation among the genotypes studied. In respect to

cured leaf yield, the genotypes *viz.,* DCT-4, LR-55, LR-60, AR-44, AR-93, VR-36, LR-64 and LR-69 had high *per se* performance and found to be promising. The estimates of genotypic and phenotypic variance revealed that genotypic variance contributed larger in phenotypic variance for cured leaf yield, days to flowering, days to maturity, plant height, number of leaves per plant, leaf thickness, nicotine content, reducing sugar content and chloride content, which indicated less influence of environmental factors on the expression of the characters. The estimates of genotypic and phenotypic coefficient of variation were moderate for cured leaf yield, days to flowering, number of leaves per plant, leaf width, nicotine content and chloride content. While, for plant height, days to maturity, leaf length GCV and PCV estimates were found to be low and for reducing sugar content GCV and PCV found to be high. The narrow difference between GCV and PCV estimates indicate that little influence of environment in expression of these characters.

The estimate of heritability was high for all the characters except days to maturity and leaf length. The high heritability coupled with high genetic advance as per cent of mean was observed for cured leaf yield, number of leaves per plant, leaf width, leaf thickness, nicotine content, reducing sugar content and chloride content, which indicated that these characters are governed by additive genetic variance. Hence, selection may be made in desired direction based on phenotypic performance. While, characters days to maturity and leaf length showed moderate heritability coupled with low genetic advance as percent of mean, which indicated that, it was largely governed by non-additive gene action and hence, would not be improved by simple selection.

4.3 Estimation of correlation coefficients

Crop improvement programmes largely depend on the availability of sufficient variability and association among different characters which are the prerequisite for executing an effective selection programme. Cured leaf yield, being a complex quantitative trait, is dependent on several component characters. Therefore, knowledge of the association of different components together with their relative contributions has immense value in selection. The correlation coefficients were estimated for all the combinations of eleven characters under study at genotypic (r_g) and phenotypic (r_p) levels.

The correlation coefficient analysis was used to determine the type and magnitude of association between all possible pairs among the characters under study. The association between characters that can be directly observed is phenotypic correlation and it includes the actual correlation excludes the environmental effect and is used in strengthening the interpretation based on phenotypic correlation. The estimated values of genotypic and phenotypic correlations are presented in Table 4.3.

4.3.1 Days to flowering

Days to flowering was highly significant and positively correlated with days to maturity (r_g = 0.952, r_p= 0.881), plant height (r_g = 0.324, r_p = 0.297), number of leaves per plant (r_g = 0.823, r_p = 0.659), leaf length (r_g = 0.430 r_p = 0.289), leaf width (r_g = 0.170, r_p = 0.062) and cured leaf yield (r_g = 0.735, r_p = 0.652) at genotypic and phenotypic levels. It had also highly significant and negatively correlated with leaf thickness (r_g = -0.577, r_p = -0.506) at both genotypic and phenotypic levels. On the other hand, it was significant and negatively associated with chloride content (r_g = -0.216, r_p = -0.209) at both the genotypic and phenotypic levels. While, non-significant and negatively correlated with nicotine content (r_p = -0.165, r_p = -0.150) at both genotypic and phenotypic level and non-significant and positive associated with reducing sugar content (r_g = 0.036, r_p = 0.031). Lalithadevi *et al.* (2002), Patel and Kingaonkar (2005), Nama (2011), Parajuli *et al.* (2015) and Katba *et al.* (2018) were corresponding with work.

4.3.2 Days to maturity

This trait showed highly significant and positively correlated with plant height (r_g = 0.319, r_p = 0.269), number of leaves per plant (r_g = 0.739, r_p = 0.551), leaf length (r_g = 0.451, r_p = 0.292) and cured leaf yield (r_g = 0.668, r_p = 0.572) at both genotypic and phenotypic levels. It showed non-significant and positively correlated with reducing sugar content (r_g = 0.114, r_p = 0.104) at both genotypic and phenotypic levels. It had highly significant and negatively correlated with leaf thickness (r_g = -0.630, r_p= -0.534), chloride content (r_g = -0.249, r_p = -0.232) at both genotypic and phenotypic levels. It had non-significant and negatively correlated with leaf width (r_g = -0.023, r_p = -0.028) and nicotine content (r_g = -0.069, r_p = -0.060) at genotypic and phenotypic level. Identical results for this trait reported by Patel *et al.* (2011), Parajuli *et al.* (2015) and Katba *et al.* (2018).

4.3.3 Plant height

Plant height had highly significant and positively associated with number of leaves per plant (r_g = 0.462, r_p = 0.424), cured leaf yield (r_g = 0.295, r_p = 0.206) at both genotypic and phenotypic levels and leaf length (r_g = 0.244) at genotypic level and non-significant and positively correlated at phenotypic level (r_p = 0.161). While, it had positive and significantly associated with reducing sugar content (r_g = 0.174, r_p = 0.176). It had highly significant and negatively associated with leaf width (r_g = -0.374, r_p = -0.223) and chloride content (r_g = -0.355, r_p = -0.303) at both genotypic and phenotypic levels. It had non-significant and positive association with nicotine content (r_g = 0.030, r_p = 0.024) at both genotypic and phenotypic levels. It had a non-significant and negative association with leaf thickness (r_g = -0.038, r_p = -0.066) at both genotypic and phenotypic levels. These findings were accordance with Bhumarannavar (2009), Maleki *et al.* (2011), Patel *et al.* (2011), Ramchandra *et al.* (2014) and Katba *et al.* (2018).

4.3.4 Number of leaves per plant

Number of leaves per plant had highly significant and positively associated with leaf length (r_g = 0.226, r_p = 0.135), leaf width (r_g = 0.599, r_p = 0.353) and cured leaf yield per plant (r_g = 0.715, r_p = 0.515) at both genotypic and phenotypic levels. It had highly significant and negatively associated with leaf thickness (r_g = -0.335, r_p = -0.259) at both genotypic and phenotypic levels. It showed significant and negatively associated with nicotine content (r_g = -0.214, r_p = -0.178) at both genotypic and phenotypic levels. It had also non-significant and negatively associated with chloride content (r_g = -0.128, r_p = -0.091) at both genotypic and phenotypic levels. While, it had non-significant and positive correlation with reducing sugar content (r_g = 0.138, r_p = 0.130). Similar findings were reported by Maleki *et al.* (2011), Nama (2011), Parajuli *et al.* (2015) and Katba *et al.* (2018).

4.3.5 Leaf length

Leaf length exhibited highly significant and positively associated with leaf width (r_g = 0.434, r_p = 0.376), reducing sugar content (r_g = 0.282, r_p = 0.218) and cured leaf yield (r_g = 0.676, r_p = 0.489), at both genotypic and phenotypic levels. It had non-significant and positively associated with nicotine content (r_g = 0.005, r_p = 0.017) at both genotypic and phenotypic levels. It had highly significant and negatively correlated with leaf thickness

Table 4.3 : Genotypic and Phenotypic correlations between different characters of rustica tobacco

Characters		Days to flowering	Days to maturity	Plant height	Number of leaves per plant	Leaf length	Leaf width	Leaf thickness	Nicotine content	Reducing sugar content	Chloride content	Cured leaf yield per plant
Days to flowering	r_g		0.952**	0.324**	0.823**	0.430**	0.170**	-0.577**	-0.165	0.036	-0.216*	0.735**
	r_p		0.881**	0.297**	0.659**	0.289**	0.062**	-0.506**	-0.150	0.031	-0.209*	0.652**
Days to maturity	r_g			0.319**	0.739**	0.451**	-0.023	-0.630**	-0.069	0.114	-0.249**	0.668**
	r_p			0.269**	0.551**	0.292**	-0.028	-0.534**	-0.060	0.104	-0.232**	0.572**
Plant height	r_g				0.462**	0.244**	-0.374**	-0.038	0.030	0.174*	-0.355**	0.295**
	r_p				0.424**	0.161	-0.233**	-0.066	0.024	0.176*	-0.303**	0.206**
Number of leaves per plant	r_g					0.266**	0.599**	-0.355**	-0.214*	0.138	-0.128	0.715**
	r_p					0.135**	0.353**	-0.259**	-0.178*	0.130	-0.091	0.515**
Leaf length	r_g						0.434**	-0.254**	0.005	0.282**	-0.033	0.676**
	r_p						0.376**	-0.212**	0.017	0.218**	-0.015	0.489**
Leaf width	r_g							-0.058	0.246**	-0.152	0.168*	0.039**
	r_p							-0.050	0.150**	-0.137	0.082*	0.062**
Leaf thickness	r_g								0.112	-0.023	0.366**	-0.280**
	r_p								0.107	-0.025	0.318**	-0.227**
Nicotine content	r_g									-0.197*	0.060	-0.277**
	r_p									-0.173*	0.050	-0.179*
Reducing sugar content	r_g										-0.125	0.078
	r_p										-0.110	0.070
Chloride content	r_g											-0.016
	r_p											-0.043

(r_g = -0.254, r_p = -0.212) and non-significant and negatively correlated with chloride content (r_g = -0.033, r_p = -0.015) at genotypic and phenotypic level. Bhumarannavar (2009), Maleki *et al*. (2011), Nama (2011), Patel *et al.* (2011), Ramchandra *et al*. (2014) and Katba *et al.* (2018) was detected similar results for this trait.

4.3.6 Leaf width

Leaf width exhibited highly significant and positively associated with cured leaf yield (r_g = 0.039, r_p = 0.062) and nicotine content (r_g = 0.246, r_p = 0.150) at both genotypic and phenotypic levels. It had significant and positively associated with chloride content (r_g = 0.168, r_p = 0.082) at both genotypic and phenotypic levels. It had non-significant and negatively correlated with leaf thickness (r_g = -0.058, r_p= -0.050) and reducing sugar content (r_g = -0.152, r_p = -0.137) at genotypic and phenotypic level. Bhumarannavar (2009), Maleki *et al*. (2011), Nama (2011), Patel *et al*. (2011), Ramchandra *et al*. (2014), Parajuli *et al.* (2015) and Katba *et al.* (2018) were relevant with this findings.

4.3.7 Leaf thickness

Leaf thickness exhibited highly significant and negatively associated with cured leaf yield (r_g = -0.375, r_p = -0.280) at both genotypic and phenotypic levels. It had highly significant and positively correlated with chloride content (r_g = 0.366, r_p = 0.318) at both genotypic and phenotypic levels. It had non-significant and negatively correlated with reducing sugar content (r_g = -0.023, r_p = -0.025) and non-significant and positively correlated with nicotine content (r_g = 0.112, r_p = 0.107) at genotypic and phenotypic level. Earlier identical results were obtained by Bhumarannavar (2009), Nama (2011), Patel *et al*. (2011), Ramchandra *et al*. (2014), Parajuli *et al.* (2015) and Katba *et al.* (2018).

4.3.8 Nicotine content

Nicotine content exhibited highly significant and negatively correlated with cured leaf yield at genotypic and phenotypic level (r_g = -0.227) and significant and negatively correlated at phenotypic level (r_p = -0.179) whereas, significant and negatively correlated with reducing sugar content (r_g = -0.197, r_p = -0.173) at both genotypic and phenotypic levels. It had positive and non-significantly correlated with chloride content (r_g = 0.060, r_p = 0.050). Similar findings were reported by Dobhal and Monga (1989) and Parajuli *et al*. (2015).

4.3.9 Reducing sugar content

Reducing sugar content exhibited non-significant and positively correlated with cured leaf yield (r_g = 0.078, r_p = 0.070) at genotypic and phenotypic level and non-significant and negatively correlated with reducing sugar content at both genotypic and phenotypic levels (r_g = -0.125, r_p = -0.110). Datta (2002), Parajuli *et al*. (2015) and Katba *et al*. (2018) were accordance with these findings.

4.3.10 Chloride content

Chloride content exhibited non-significant and negatively correlated with cured leaf yield at both genotypic and phenotypic levels (r_g = -0016, r_p = -0.043). Contradict results for this trait obtained by Parajuli *et al*. (2015) and Katba *et al*. (2018).

4.3.11 Cured leaf yield per plant

The highly significant and positive correlation was found for cured leaf yield with days to flowering (r_g = 0.735, r_p = 0.652), days to maturity (r_g = 0.668, r_p = 0.572), plant height (r_g = 0.295, r_p = 0.206), number of leaves per plant (r_g = 0.715, r_p = 0.515), leaf length (r_g = 0.676, r_p = 0.489) and leaf width (r_g = 0.039, r_p= 0.062) at both genotypic as well as phenotypic level. The significant to highly significant and negative correlation for cured leaf yield observed with leaf thickness (r_g = -0.375, r_p = -0.280) and nicotine content (r_g = -0.227, r_p = -0.179). While, non-significant and negative correlation observed with chloride content (r_g = -0.016, r_p = -0.043) at both genotypic as well as phenotypic level and non-significant and positive correlation (r_g = 0.078, r_p = 0.070) at both genotypic as well as phenotypic level was found with reducing sugar content. This findings were agreement with Dobhal and Monga (1989), Datta (2002), Patel and Makwana (2002), Lalithadevi *et al.* (2002), Patel and Kingaonkar (2005), Nama (2011), Maleki *et al.* (2011), Patel *et al.* (2011), Ramchandra *et al.* (2014), Parajuli *et al.* (2015), Shah *et al.* (2016), Ahmed *et al.* (2017), Katba *et al.* (2018) and Netravati *et al.* (2018).

Cured leaf yield was significant and positively associated with days to flowering and days to maturity suggested that late flowering and maturing genotypes would be higher yielder but such association may be prove to be constrain in breeding high yielding early varieties.

Significant positive correlation of number of leaves per plant, leaf length, leaf width and plant height with cured leaf yield suggested that number of leaves per plant and plant height would be good index for isolating high yielding varieties.

Correlation studies revealed that cured leaf yield per plant had positive and significant association with plant height, number of leaves per plant, leaf length, leaf width at both genotypic and phenotypic levels. Hence, these characters should be given due consideration, while, selecting for increasing yield. Days to flowering and days to maturity showed positive and significant correlation which indicated that selecting early maturing genotypes would likely to decrease cured leaf yield. On the other hand, leaf thickness, nicotine content and chloride content was negatively associated with cured leaf yield per plant. The estimated value of genotypic and phenotypic correlations revealed comparatively higher degree of genotypic correlation coefficient than their phenotypic counterpart for most of the characters, which indicated strong and inherent association between two characters.

4.4 Path coefficient analysis

Genotypic and phenotypic correlation coefficients between cured leaf yield per plant and its component characters were partitioned in their direct and indirect effects. Since, the mutual relationship of component characters might vary both in magnitude and direction it may tend to vitiate the association of cured leaf yield with attributes. It is necessary to partition the genetic correlation into indirect and indirect effects of each other. This will provide more precise information for the selection of traits, which may contribute more towards cured leaf yield. The estimates of direct and indirect effects of various traits on cured leaf yield per plant are presented in Table 4.4 and Fig. 1.

4.4.1 Days to flowering *vs.* Cured leaf yield per plant

Days to flowering was highly significant and positively correlated with cured leaf yield per plant (r_g = 0.735). The direct effect of days to flowering was positive and high (0.642). The indirect effect of this trait on cured leaf yield per plant was positive and negligible *via* plant height (0.034), leaf length (0.003), nicotine content (0.013), reducing sugar content (0.004) and chloride content (0.020). While, its indirect effects *via* leaf thickness (0.120) was positive and low. The indirect effect *via* number of leaves per plant (1.572) was positive and very high. While, the indirect

effect *via* leaf width (-0.213) was negative and moderate. The indirect effect *via* days to maturity (-1.460) was negative and very high. This findings were agreement with Datta (2002), Patel and Makwana (2002), Patel and Kingaonkar (2005), Nama (2011) and Parajuli *et al*. (2015).

4.4.2 Days to maturity *vs.* cured leaf yield per plant

The days to maturity had highly significant and positively correlated with cured yield per plant (r_g = 0.668), however its direct effect was negative and very high (-1.534). The indirect effects of days to maturity through plant height (0.034), leaf length (0.003), nicotine content (0.006), reducing sugar content (0.012) and chloride content (0.023) was positive and negligible. While, positive and low indirect effects through leaf thickness (0.131). The indirect effect *via* days to flowering was positive and high (0.611). While, the indirect effect *via* number of leaves per plant was positive and very high (1.411). The indirect effect *via* leaf width was negative and negligible (-0.029). Datta (2002), Patel and Makwana (2002), Patel and Kingaonkar (2005), Parajuli *et al*. (2015) and Katba *et al.* (2018) were identical results for this trait.

4.4.3 Plant height *vs.* Cured leaf yield per plant

Plant height had highly significant and positively correlated with cured leaf yield per plant (r_g = 0.295). The direct effect of plant height was positive and low (0.106). The indirect effect of this trait on cured leaf yield per plant was positive and negligible *via* leaf length (0.002), leaf thickness (0.008), and reducing sugar content (0.018) and chloride content (0.033). While, its indirect effects *via* days to flowering (0.208) was positive and moderate. The indirect effect *via* number of leaves per plant (0.882) was positive and high. The indirect effect *via* nicotine content (-0.003) was negative and negligible. While, its indirect effects *via* days to maturity (-0.489) and leaf width (-0.470) were negative and high. These findings were accordance with Patel and Makwana (2002), Patel and Kingaonkar (2005), Parajuli *et al*. (2015) and Katba *et al.* (2018).

4.4.4 Number of leaves per plant *vs.* Cured leaf yield per plant

Number of leaves per plant had highly significant and positively correlated with cured leaf yield per plant (r_g = 0.715), however its direct effect was positive and very high (1.910). The indirect effect of this trait on cured leaf yield per plant was positive and high *via* days to flowering (0.528). The indirect effects of number of

leaves per plant *via* plant height (0.049), leaf length (0.001), leaf thickness (0.070), nicotine content (0.017), reducing sugar content (0.015) and chloride content (0.012) were positive and negligible. The indirect effect *via* leaf width was negative and high (-0.753). The indirect effect *via* days to maturity was negative and very high (-1.133). Datta (2002), Patel and Kingaonkar (2005), Nama (2011), Parajuli *et al.* (2015) and Katba *et al.* (2018) were corresponding with this work.

4.4.5 Leaf length *vs.* Cured leaf yield per plant

Leaf length had highly significant and positively correlated with cured leaf yield per plant (r_g = 0.676). The direct effect of leaf length was positive and negligible (0.006). The indirect effect of this trait on cured leaf yield per plant was positive and negligible *via* plant height (0.026), leaf thickness (0.053), reducing sugar content (0.030), and chloride content (0.003). The indirect effect *via* days to flowering (0.276) was positive and moderate. While, the indirect effect *via* number of leaves per plant (0.431), leaf width (0.545) was positive and high. The indirect effect of leaf length on cured leaf yield per plant *via* nicotine content was negative and negligible (-0.001). While, the indirect effect *via* days to maturity was negative and high (-0.692). Datta (2002), Patel and Makwana (2002), Patel and Kingaonkar (2005), Parajuli *et al*. (2015) and Katba *et al.* (2018) were identical results for this trait.

4.4.6 Leaf width *vs.* Cured leaf yield per plant

Leaf width had highly significant and positively correlated with cured leaf yield per plant (r_g = 0.039). The direct effect of leaf width was positive and very high (1.256). The indirect effect of this trait on cured leaf yield per plant was positive and negligible *via* days to maturity (0.035), leaf length (0.003) and leaf thickness (0.012). The indirect effect *via* plant height (-0.040), nicotine content (-0.020), reducing sugar content (-0.016) and chloride content (-0.016) was negative and negligible. While, the indirect effect *via* days to flowering was negative and low (-0.109). The indirect effect of leaf width on cured leaf yield per plant *via* number of leaves per plant was negative and very high (-1.145). Earlier identical results were reported by Patel and Makwana (2002), Patel and Kingaonkar (2005), Nama (2011), Parajuli *et al*. (2015) and Katba *et al.* (2018).

Table 4.4 : Path coefficient analysis showing direct and indirect effect of different characters on cured leaf yield in rustica tobacco

Characters	Days to flowering	Days to maturity	Plant height	Number of leaves per plant	Leaf length	Leaf width	Leaf thickness	Nicotine content	Reducing sugar content	Chloride content	Genotypic correlation with cured leaf yield
Days to flowering	**0.642**	-1.460	0.034	1.572	0.003	-0.213	0.120	0.013	0.004	0.020	0.735**
Days to maturity	0.611	**-1.534**	0.034	1.411	0.003	-0.029	0.131	0.006	0.012	0.023	0.668**
Plant height	0.208	-0.489	**0.106**	0.882	0.002	-0.470	0.008	-0.003	0.018	0.033	0.295**
Number of leaves per plant	0.528	-1.133	0.049	**1.910**	0.001	-0.753	0.070	0.017	0.015	0.012	0.715**
Leaf length	0.276	-0.692	0.026	0.431	**0.006**	0.545	0.053	-0.001	0.030	0.003	0.676**
Leaf width	-0.109	0.035	-0.040	-1.145	0.003	**1.256**	0.012	-0.020	-0.016	-0.016	0.039**
Leaf thickness	-0.370	0.966	-0.004	-0.639	-0.002	-0.073	**-0.208**	-0.009	-0.003	-0.034	-0.375**
Nicotine content	-0.106	0.106	0.003	-0.408	0.001	0.309	-0.023	**-0.081**	-0.021	-0.006	-0.227**
Reducing sugar content	0.023	-0.175	0.018	0.263	0.002	0.191	0.005	0.016	**0.105**	0.012	0.078
Chloride content	-0.139	0.382	-0.038	-0.245	-0.001	0.211	-0.076	-0.005	-0.013	**-0.093**	-0.016

4.4.7 Leaf thickness *vs.* Cured leaf yield per plant

Leaf thickness had highly significant and negatively correlated with cured leaf yield per plant (r_g = -0.375). The direct effect of leaf thickness was negative and moderate (-0.208). The indirect effect of this trait on cured leaf yield per plant was positive and high *via* days to maturity (0.966). The indirect effect *via* plant height (-0.004), leaf length (-0.002), leaf width (-0.073), nicotine content (-0.009), reducing sugar content (-0.003) and chloride content (-0.034) was negative and negligible. While, the indirect effect *via* days to flowering (-0.370) and number of leaves per plant was negative and high (-0.639). Similar findings were observed by Patel and Makwana (2002), Nama (2011), Parajuli *et al*. (2015) and Katba *et al.* (2018).

4.4.8 Nicotine content *vs.* Cured leaf yield per plant

Nicotine content exhibited highly significant and negatively correlated with cured leaf yield at genotypic level (r_g = -0.227). The direct effect of nicotine content was negative and negligible (-0.081). The indirect effect of this trait on cured leaf yield per plant was positive and negligible *via* plant height (0.003) and leaf length (0.001). The indirect effect *via* leaf width was positive and high (0.309). The indirect effect *via* days to maturity (0.106) was positive and low. The indirect effect of nicotine content on cured leaf yield per plant *via* leaf thickness (-0.023), reducing sugar content (-0.021) and chloride content (-0.006) was negative and negligible. While, the indirect effect *via* days to flowering was negative and low (-0.106). While, the indirect effect of nicotine content *via* number of leaves per plant was negative and high (-0.408). Similar findings were recorded by Parajuli *et al*. (2015) and Katba *et al.* (2018).

4.4.9 Reducing sugar content *vs.* Cured leaf yield per plant

Reducing sugar content exhibited non-significant and positively correlated with cured leaf yield at genotypic level (r_g = 0.078). The direct effect of reducing sugar content was positive and low (0.105). The indirect effect of this trait on cured leaf yield per plant was positive and negligible *via* days to flowering (0.023), plant height (0.018), leaf length (0.002), leaf thickness (0.005), nicotine content (0.016) and chloride content (0.012). The indirect effect *via* number of leaves per plant was positive and moderate (0.263). The indirect effect *via* days to maturity (-0.175) and

leaf width (-0.191) was negative and low. Katba *et al.* (2018) recorded identical result for this trait.

4.4.10 Chloride content *vs.* Cured leaf yield per plant

Chloride content exhibited non-significant and negatively correlated with cured leaf yield at genotypic level (r_g = -0.016). The direct effect of chloride content was negative and negligible (-0.093). The indirect effect of this trait on cured leaf yield per plant was positive and moderate *via* leaf width (0.211). The indirect effect *via* days to maturity was positive and high (0.382). The indirect effect of chloride content on cured leaf yield per plant *via* plant height (-0.038), leaf length (-0.001), leaf thickness (-0.076), nicotine content (-0.005) and reducing sugar content (-0.013) was negative and negligible. While, the indirect effect *via* days to flowering was negative and low (-0.139). The indirect effect of chloride content *via* number of leaves per plant was negative and moderate (-0.245). These findings were agreement with Parajuli *et al*. (2015) and Katba *et al.* (2018).

The overall path analysis based on genotypic correlation revealed that number of leaves per plant showed highest positive direct effect followed by leaf width, days to flowering, plant height, reducing sugar content and leaf length. Hence, these traits may be directly attributed for the improvement of cured leaf yield and important in the selection of better genotypes in rustica tobacco. To improve cured leaf yield, proper attention should therefore be paid to these traits at the time of selection; since they had strong, direct and positive effects on cured leaf yield, they should be directly selected. Remaining characters showed either negative or negligible direct effects on cured leaf yield.

SUMMARY AND CONCLUSIONS

V. SUMMARY AND CONCLUSIONS

The present investigation work on "Genetic variability, correlation and path analysis in rustica tobacco (*Nicotiana rustica* L.)" was conducted at Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol during *rabi* season of 2019-20 with the following objectives.

(1) To study the variability present among the genotypes with respect to cured leaf yield and its components

(2) To study the extent of phenotypic and genotypic correlations between yield and different attributes

(3) To study path coefficient for assessing the relative contribution of each of yield components towards yield

- The analysis of variance revealed that mean sum of squares due to genotypes was found significant for all the eleven characters indicating that the genotypes under study were genetically diverse.
- The estimate of genotypic and phenotypic variance revealed that in all the characters showed significant variation among the genotypes studied. In respect to cured leaf yield, genotypes *viz.,* DCT-4, LR-55, LR-60, AR-44, AR-93, VR-36, LR-64 and LR-69 had high *per se* performance and found to be promising.
- The estimates of genotypic and phenotypic variance revealed that genotypic variance contributed larger in phenotypic variance for cured leaf yield, days to flowering, days to maturity, plant height, number of leaves per plant, leaf thickness, nicotine content, reducing sugar content and chloride content, which indicated less influence of environmental factors on the expression of the characters.
- The estimates of genotypic and phenotypic coefficient of variation were moderate for cured leaf yield, days to flowering, number of leaves per plant, leaf width, nicotine content and chloride content indicating that sufficient variability present in the experimental material for these traits. While for plant height, days to maturity and leaf length GCV and PCV estimates were found to be low and for reducing sugar content GCV and PCV found to be high.

The narrow difference between GCV and PCV estimates indicated that little influence of environment in expression of these characters.

- The estimates of heritability was high for all the characters except days to maturity and leaf length. The high heritability coupled with high genetic advance as per cent of mean was observed for cured leaf yield, number of leaves per plant, leaf width, leaf thickness, nicotine content, reducing sugar content and chloride content, which indicated that these characters are governed by additive genetic variance. Hence, selection may be made in desired direction based on phenotypic performance. While, days to maturity and leaf length showed moderate heritability coupled with low genetic advance as per cent of mean, which indicated that, it was largely governed by non-additive gene action and hence, would not be improved by simple selection.
- Correlation studies revealed that cured leaf yield per plant had positive and significant association with plant height, number of leaves per plant, leaf length, leaf width at both genotypic and phenotypic levels. Hence, these characters should be given due consideration while selecting for higher yield.
- Days to flowering and day to maturity showed positive and significant correlation which indicated that selecting early maturing genotypes would likely to decrease cured leaf yield. On the other hand, leaf thickness, nicotine content and chloride content was negatively associated with cured leaf yield per plant.
- The estimated value of genotypic and phenotypic correlations revealed comparatively higher degree of genotypic correlation coefficient than their phenotypic counterpart for most of the characters, which indicated strong and inherent association between two characters.
- Cured leaf yield was significantly positive associated with days to flowering and days to maturity suggested that late flowering and maturing genotypes would be higher yielder but such association may be prove to be constrain in breeding high yielding early varieties.
- Significant positive correlation of number of leaves per plant, leaf length, leaf width and plant height with cured leaf yield suggested that number of leaves per plant and plant height would be good index for isolating high yielding varieties**.**

- Path coefficients analysis based on genotypic correlation revealed that number of leaves per plant showed highest positive direct effect followed by leaf width, days to flowering, plant height, reducing sugar content and leaf length. Hence, these traits may be directly attributed for the improvement of cured leaf yield and important in the selection of better genotypes in rustica tobacco. To improve cured leaf yield, proper attention should therefore be paid to these traits at the time of selection; since they had strong, direct and positive effects on cured leaf yield, they should be directly selected. Remaining characters showed either negative or negligible direct effects on cured leaf yield.

Based on the results obtained, it would be reasonable to suggest that a breeder engaged in the improvement of cured leaf yield in rustica tobacco should place emphasis on the traits *viz.,* number of leaves per plant, leaf length, leaf width, days to flowering and plant height. Selection for these traits will therefore, directly become helpful in increasing the cured leaf yield in rustica tobacco.

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* Original not seen.

APPENDICES

APPENDICES

Appendix-I : Meteorological data recorded at Ladol (North Gujarat) during the period of experiment (November-2019 to March-2020)

Months and Year	Standard weeks	Temperature (^{o}C)		Relative Humidity (%)	
		Maximum	Minimum	Morning	Evening
November-2019	45	31.2	19.8	82.5	90.8
	46	31.7	17.7	82.7	86.2
	47	31.0	16.0	79.0	87.1
	48	29.5	16.7	83.5	90.2
December-2019	49	28.2	14.6	81.1	87.5
	50	26.2	10.7	77.4	82.5
	51	27.0	11.8	76.7	85.8
	52	25.0	8.8	70.0	84.0
January-2020	1	24.2	9.2	78.5	87.1
	2	23.7	9.5	77.0	82.8
	3	19.8	6.7	73.4	84.0
	4	26.9	9.8	70.8	84.1
	5	25.0	8.2	71.5	81.4
February-2020	6	25.9	7.9	68.7	80.0
	7	31.7	11.7	69.7	77.7
	8	32.0	13.0	67.0	79.0
	9	32.6	13.5	73.1	77.1
March-2020	10	29.4	13.3	74.7	79.5
	11	32.0	12.2	69.7	77.4
	12	35.7	18.1	73.0	76.2
	13	34.3	17.7	74.1	76.5

(Source : Agricultural Research Station, Sardarkrushinagar Dantiwada Agricultural University, Ladol, District : Mehsana).

Appendix-II : Mean value genotypes for different characters in rustica tobacco

Sr. No.	Genotype	Days to flowering	Days to maturity	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Leaf thickness (mg/cm^2)	Nicotine content (%)	Reducing sugar content (%)	Chloride content (%)	Cured leaf yield (g/plant)
1	Black queen	63.25	117.70	62.13	9.80	33.55	34.15	15.08	3.70	5.14	0.80	136.75
2	C-21	**57.50**	**107.50**	70.53	9.70	35.80	34.93	13.08	6.19	4.00	0.79	134.50
3	Cocker-1	72.50	120.25	59.03	10.05	35.88	35.85	9.76	5.70	4.30	0.62	174.55
4	GC-1	59.50	113.75	54.88	9.15	36.38	38.15	11.25	5.71	4.65	1.11	149.65
5	Jharipura	63.00	117.50	54.85	9.55	37.63	39.73	11.45	5.56	3.43	1.35	157.25
6	Maharka	67.25	121.00	54.77	11.05	35.20	33.90	10.09	5.05	4.67	1.25	155.65
7	S-7	68.50	117.00	48.93	9.85	36.73	36.18	12.04	4.76	3.82	0.90	159.20
8	S-12	67.75	119.50	53.35	9.05	35.73	36.38	13.27	5.33	3.97	1.24	144.75
9	SK-140	62.75	114.25	47.65	9.50	33.45	37.98	10.79	3.95	**3.17**	1.00	130.50
10	SK-141-1	57.75	109.25	**41.10**	9.10	34.28	37.15	13.67	3.72	3.51	1.30	132.75
11	SK-200	71.25	121.75	54.93	9.55	38.40	38.63	10.93	5.72	3.80	1.10	153.15
12	SK-400	70.00	123.75	68.35	9.75	38.98	37.98	9.18	4.66	4.39	0.91	159.60
13	AR-30	63.50	115.50	60.30	9.95	38.70	38.05	**15.60**	5.74	3.90	1.38	175.55
14	AR-44	71.00	123.25	53.35	9.55	39.45	39.88	9.95	5.18	4.27	0.78	200.40
15	VR-1	71.75	126.50	60.10	10.50	36.10	36.98	10.70	6.29	4.06	1.00	174.75
16	VR-2	60.75	114.25	48.47	9.30	33.98	36.20	10.09	3.59	4.45	1.15	147.75
17	VR-8	71.75	124.00	69.20	11.75	34.80	**33.28**	10.89	6.21	3.69	0.74	153.05
18	VR-12	77.50	121.00	47.23	11.05	35.48	34.23	9.79	4.55	3.86	1.10	167.05
19	AR-47	73.00	124.25	43.13	10.20	34.43	37.63	9.10	4.62	3.30	0.88	166.75
20	Sel.15-1-1	75.50	126.50	46.33	10.36	38.45	38.00	10.49	6.06	5.00	1.14	148.75
21	SR-32	69.25	120.75	51.55	9.65	36.95	36.28	11.24	**6.57**	4.47	1.31	160.00
22	DWFC	61.75	117.50	64.55	10.40	**33.10**	33.43	12.01	4.25	4.19	1.08	132.50
23	AR-49	75.25	126.00	54.88	9.95	34.72	38.23	10.21	5.95	3.69	0.99	176.75
24	AR-50	76.50	125.50	53.20	10.16	36.95	36.63	9.23	5.32	4.02	0.93	157.50
25	AR-56	71.50	124.50	56.12	**8.75**	34.88	**40.35**	11.16	6.44	3.82	0.88	**112.80**
26	AR-60	67.50	120.25	51.62	9.45	36.72	36.65	11.20	4.88	4.00	**1.42**	170.50

Appendix-II Continue...

Appendix-II Continue...

Sr. No.	Genotype	Days to flowering	Days to maturity	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Leaf thickness (mg/cm^2)	Nicotine content (%)	Reducing sugar content (%)	Chloride content (%)	Cured leaf yield (g/plant)
27	VR-36	67.75	117.75	56.77	9.85	37.45	36.05	11.74	3.89	3.63	1.30	190.05
28	AR-77	77.25	126.25	60.58	9.05	38.23	38.10	10.39	4.11	3.55	0.90	176.50
29	AR-93	87.25	132.25	**71.67**	12.40	37.88	36.40	9.23	3.84	4.33	0.81	198.00
30	LR-55	87.75	130.00	71.27	13.15	38.70	35.35	9.67	4.84	3.88	0.67	212.50
31	LR-60	91.75	131.75	68.82	11.75	38.20	36.35	**9.05**	3.88	4.37	1.30	201.75
32	LR-64	69.50	120.25	59.95	10.85	38.70	38.30	11.40	3.48	**5.62**	1.07	187.50
33	LR-69	76.25	127.75	50.88	10.71	**39.87**	36.93	9.45	**3.33**	4.94	**0.61**	183.85
34	GCT-3	92.00	133.25	63.75	12.74	35.83	34.00	9.34	3.68	4.35	0.80	173.10
35	DCT-4	**94.25**	**134.75**	56.33	**13.25**	36.70	36.08	11.61	4.91	3.81	1.31	**234.70**
General mean		71.75	121.91	56.87	10.31	36.52	36.69	10.97	4.90	4.11	1.03	165.44
Minimum		57.50	107.50	41.10	8.75	33.10	33.28	9.05	3.33	3.17	0.61	112.80
Maximum		94.25	134.75	71.67	13.25	39.87	40.35	15.60	6.57	5.62	1.42	234.70
S. Em.±		1.51	1.14	1.99	0.37	0.92	0.95	0.35	0.12	0.09	0.02	6.59
C.D. @ 5 %		4.25	3.21	5.59	1.03	2.59	2.66	0.97	0.33	0.25	0.07	18.50
C.V. %		4.22	1.88	7.01	7.09	5.06	5.16	6.31	4.87	4.27	4.71	7.97

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering reference service in a library or documentation centre.

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