Correlation and path analysis in tea [*Camellia sinensis* (L). O. Kuntze]

Thesis

SUBMITTED TO THE

G. B. PANT UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, PANTNAGAR – 263 145, U. S. NAGAR UTTARAKHAND, INDIA

By

JITENDRA BHASKAR

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science in Agriculture

(Genetics and Plant Breeding)

June, 2007

Dedicated to

My

Beloved Parents

And

Late Grandmother

ACKNOWLEDGEMENT

I sincerely bow to the almighty for showering blessings and love over me and for giving me the opportunity to write this manuscript.

I heartily owe indebtness to Dr.D.Roy Professor, Department of Genetics and Plant Breeding and chairman of my advisory committee for his sincere guidance, proper rectification, support whenever needed and fatherly affection during my research work and preparation of manuscript.

I am immensely grateful and indebted to the members of my advisory committee, Dr. B. C. Saini, Professor, Department of soil science and Dr. V. K. Khanna, Professor, Department of Genetics and Plant breeding for their valuable suggestions and guidance during the course of study.

I express my sincere thanks to Dr. D.P. Singh, Professor and Head, Department of Genetics and Plant Breeding; Dean, Post Graduate Studies; Dean, College of Agriculture; Director of Research and Associate Director, Crop Research Centre for providing necessary facilities during the investigation.

I extend my regards to Dr. S.K. Tiwari, Dr. R. S. Rawat, Dr. P.K. Shrotia, Dr. Sumer Pal Singh, Dr. R.K. Pawar, Dr. N.K. Singh, Dr. J.S. Jaiswal, Dr. H.N. Singh, Dr. R.R. Devadi, Dr. Neelum Bhardwaj, Dr. R.S. Bist, Mr. S.C. Tewari, System Programmer and all the other staff members and office staff for their inspiration, encouragement, advice and help during the entire course of study.

My special thanks goes to Dr Manoj sir, Pradeep Sirari sir, Ambusha sir, Sailendra sir, Sundar, for helping me to do my thesis.

I am highly indebted to my adorable Late Dadi and Baba without their affections and sacrifice; I could not reach to this stage.

I owe my every success to my parents Shri. R.D. Bhaskar and Smt. Kamla Bhaskar whose boundless love, constant inspiration, patients, sacrifices, technical guidance and emotional support lifted my spirits through their constant encouragement and they are just after the God who brought me, where I am today.

I am extremely grateful to my elder brothers Bharat Bhushan and Jayprakash, my bhabhi Gunjan, my sisters Reena and Dolly, my Jijaji, Sri. Surendra Kumar for their valuable suggestions and help during the course of study and investigation as a guardian.

I can never forget Khushi Honey, Money, Sunney and Udhayan for their precious love to me.

I am especially thankful to my remembering seniors, Sattu sir, Pawan sir, Rahul sir, J.P. sir, D.J. sir, Nandu sir, Avinav sir, Rajneesh sir, Harpreet sir, Anuradha mam, Tanu mam, and Preety mam.

I wish to record my cordial thanks to all of my friends especially Priyanka, Pooja, Prabhat, Vipin, Rakesh, Sunil, Narayan, Rajeev, Indiver, Udhay, Proloy, Ashish, Gitika, Neerja, Tripathi, Mamta, Reena & Swapnil and all of my cricket players are also a source of my success.

My seniors cum friends, Ankit, Abhisek, Hariom, Roshan, Naresh, Kamal, Rishika, Hema, Sunita and Jaya has supported me a huge, mentally as well as physically to do my M.Sc. and to be a man in future.

I must mention the help and cooperation extended by my juniors dhanraj, devjoite, promood, Deepak, sudheer, navneet, motilal, latif, gopal singh, hokum, seema sati, prati, priyanka, seema, nandita, pooja, depti, piyusha and sangeeta.

Lastly thanks to all the official staffs of Genetics and Plant Breeding Department and the members of tea breeding who loved and helped me.

Pantnagar **(Jitendra Bhaskar)** ***June, 2007***
Author

Dr. D. Roy
Professor

Department of Genetics and Plant Breeding,
College of Agriculture,
G. B. Pant Uni.of Agric.and Tech., Pantnagar
Pantnagar- 263145 District- Udham Singh Nagar
Uttarakhand , INDIA

CERTIFICATE

This is to certify that the thesis entitled **"Correlation and path analysis in Tea [*Camellia sinensis* (L).O. Kuntze]"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** with major in **Genetics and Plant Breeding** and minor in **Molecular Biology and Biotechnology** of the College of Post Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar is a record of *bona-fide* research carried out by **Mr. Jitendra Bhaskar, Id. No. 27940,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation and source of literature have been duly acknowledged.

(D. Roy)
Chairman
Advisory Committee

Pantnagar
June 2007

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Jitendra Bhaskar, Id. No. 27940**, a candidate for the degree of **Master of Science in Agriculture** with major in **Genetics and Plant Breeding** and minor in **Molecular Biology and Biotechnology** agree that the thesis entitled **"Correlation and path analysis in Tea [*Camellia sinensis* (L).O. Kuntze]",** may be submitted in partial fulfillment of the requirements for the degree.

(D. Roy)
Chairman
Advisory Committee

(B.C. Saini)
Member

(V. K. Khanna)
Member

CONTENTS

Sl.No.	CHAPTER	Page No.
1.	INTRODUCTION	….
2.	REVIEW OF LITERATURE	….
3.	MATERIALS AND METHODS	….
4.	EXPERIMENTAL RESULTS	….
5.	DISCUSSION	….
6.	SUMMARY	….
	BIBLIOGRAPHY	….
	VITA	….

LIST OF TABLES

Tables	Description
1.1	Indian tea production, consumption and trade
1.2	India's share in World Tea Area
4.1	Analysis of variance
4.2	Tables of mean
4.3	General mean, variance, PCV, GCV, ECV, heritability (broad sense), and genetic advance of different traits
4.4	Comparison of means
4.5	Comparison of variances
4.6	Phenotypic, genotypic and environmental correlation coefficients between different pairs of traits
4.7	Direct and indirect effects of different traits on number of plucking points

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Description
ANOVA	: analysis of variance
g	: gram
ha	: hectare
i.e.,	: that is
kg	: Kilogram
m kg	: million kilogram
m	: meter
mm	: millimeter
cm	: centimeter
No.	: number
PCV	: phenotypic coefficient of variation
GCV	: genotypic Coefficient of Variation
ECV	: environmental coefficient of variation
H_b	: broad sense heritability
GA	: genetic advance
^{o}	: degree
/	: per
ns	: non significant
*	: significant
**	: highly significant

CHAPTER 1 INTRODUCTION

Next to water, tea is the more popular non-alcoholic beverage in the world. Indian tea industry produces about 840 m kg of tea from about 0.5 m ha of land. North India produces 75% of the total tea produced in India. The industry has annual turn over of Rs 6000 crores and provides employment to 1.2 million people of which 50% are women. It also earns valuable foreign exchange of Rs 2000 crores from export. Indian tea industry contributes Rs 1100 crores annually to Indian economy as taxes and duties.

Tea occupies an important place in our social and cultural life and is offered as a gesture of hospitality and goodwill at Indian home. India has the unique distinction of being the largest producer as well as the consumer of tea. India's position in this regard is not only unique but also unparalleled. Indian tea industry faces a challenging task of producing more than 1000 million kg of quality tea.

Tea (*Camellia sinesis* (L). O. Kuntze) is a highly heterozygous and outbreeding crop, exhibiting great diversity of form and

shape. Tea plant is broadly classified as Assam, China and Cambodia type. The scientific nomenclature is as follows:

- The China plant : *Camellia sinensis* (L).
- The Assam plant : *Camellia assamica* (Maston).
- The Cambodia plant : *Camellia assamica* sub sp. *lasiocalyx* (Planch. M.S.)

Tea [*Camellia sinensis* (L). O. Kuntze], also known as queen of beverage crops, belongs to family Camelliaceae. It is a diploid species with 2n = 2x = 30 and is native of China in South East Asia. Morphologically, tea is an evergreen shrub or tree. Leaves are simple, alternate and serrate. Flower is bisexual, with superior ovary and is cross pollinated. Fruit is a capsule.

Production of tea, after stagnating between 1997-98 and 2004-05 at around 830- 850 million kg, increased by over 12 percent in 2005-06 **(Table 1.1).** The current year also looks promising as the April-October output is estimated to be 8.2 per cent higher than in the comparable period in 2005-06. With nine major tea producing States in India **:** Assam, West Bengal, Tripura, Arunachal Pradesh, Nagaland, Himachal Pradesh, TamilNadu, Kerala and Karnataka, India is the largest producer

Table 1.1: Indian tea production, consumption and trade

(Qty: million kgs, Value: Rs crore)

Year	Production	Exports		Imports		Domestic consumption &
	Quantity	Quantity	Value	Quantity	Value	Quantity
1997-98	835.6	211.3	2003.2	2.6	17.8	597
1998-99	855.2	205.9	2191.8	8.9	64.7	615
1999-00	836.8	188.9	1796.3	10.4	62.0	633
2000-01	848.4	203.6	1889.8	15.2	95.5	653
2001-02	847.4	190.0	1695.8	16.8	86.7	673
2002-03	846.0	184.4	1665.0	22.5	105.3	693
2003-04	850.5	183.1	1637.0	11.1	67.0	714
2004-05	830.7	205.8	1924.7	32.5	145.0	735
2005-06	930.9	181.1	1631.6	16.40	99.26	757
2006-07 (April-Oct.)@	722.5	114.3	1048.5	13.75	70.84	NA

@ Estimated NA not available & relates to calendar year.

Source: Ministry of Commerce and Industry

and consumer of tea in the world. With consumption of tea in quantity terms growing more or less steadily at about 3 percent per year, net exports (exports less imports) of tea has declined over the years.

The estimated area to be taken up for replantation /rejuvenation is expected to be 85,044 hectares comprising replantation of 68,154 hectares and 16,890 hectares of rejuvenation. This is expected to improve yield levels **[Economic survey: 2006-07].**

On production front, all the tea growing countries are far behind India, but in terms of productivity India ranks second. The tea industry has played an important role in the Indian economy by providing employment to the rural workers and earning foreign exchange for the country. India's place and share under area is given in **Table 1.2.**

Tea is grown in many countries around the world from 43^0 N to 27^0 S latitude in a wide range of soil types. The altitude ranges from sea level to about 2300 m above mean sea level, and annual rainfall from 900 to 8000 mm. Since tea grows well in strongly acidic soils that are porous and well drained, the physical and chemical characteristics of the tea soils are of paramount

Table 1.2: Indian share in World Tea Area during 1961-2002

(In thousand hectares)

Year	World		India		India
	Absolute area	Increase / decrease	Absolute area	Increase / decrease	share as % of world
1961	964	--	331		34.33
1971	1386	(+)422	357	(+) 26	25.75
1981	2358	(+)972	384	(+) 27	16.28
1991	2569	(+)211	420	(+) 36	16.35
1997	2572	(+) 3	434	(+) 14	16.87
1998	2597	(+) 25	474	(+) 40	18.25
1999	2692	(+) 95	490	(+) 16	18.20
2000	2668	(-) 24	507	(+) 17	19.00
2001	2735	(+) 67	510	(+) 3	18.65
2002	2756	(+) 21	511	(+) 1	18.54

Source: Tea Statistics, Tea Board, Kolkata, various Issues.

importance. The texture of tea soils varies from sandy loam to clay and the predominantly non- expanding type.

Uttarakhand has the necessary climate for tea and has tea garden in Dehradun, Kausani, Berinag, and Bhowali. It had processing units in different places. But production was not good and different processing units were shut down because of no research support. Now, considering the soil condition of hills and farmer's wealth different research experiments are conducted since the past few years for tea cultivation.

In Uttarakhand, about 370 hectares of tea plantation have been established on farmer's fields and another 9000 ha land has been identified for future tea plantation. Tea is grown as a rainfed crop and soil and climatic factors may limit tea production under high altitude conditions. The soils of tea growing regions are acidic in nature with pH varying from 3.7 and 6.0. Tea plantation will bring about socio-economic development in the Uttarakhand hills through income and employment generation and utilization of uncultivated land.

Tea plantations at Kausani include genotypes like T-78, AV-2, and UPASI-9, BSS-449, Kangrajat and some other old bushes are also found in the farmer's field. So there is a considerable

variation present among the genotypes. Tea plantation at Kausani was undertaken by Tea Development Project of Uttarakhand Govt. in 1996. Tea plantations consist of heterogeneous populations and the bushes exhibit variation for growth habit, leaf form, pubescence, pigmentation, and foliar characteristics. The bushes of such populations also differ markedly for crop yield and quality characteristics which can be exploited through selection **(Grice, 1963; Barua, 1965)**.

Improvement of yield mainly depends on the nature and extent of genetic variability in the available germplasm which is a prerequisite for starting any breeding programme. The available information on such aspects in tea is meager **(Barua, 1989; Wilson, 1992)**.

Keeping above points in view, the present investigation was undertaken with the following objectives:

1) To understand the nature and magnitude of variation present among the tea germplasm of Uttarakhand.
2) To characterize the different clones.

Chapter 2 REVIEW OF LITERATURE

The literature relevant to present study is briefly reviewed under the following heads:

2.1 Taxonomy and Cytology of tea

2.2 Germination and storage of tea seeds

2.3 Vegetative propagation and plucking

2.4 Genetic variability

2.5 Correlation analysis and path analysis

2.6 Polyploidy in tea

2.7 Pollination in tea

2.8 Chemical composition in tea

2.1 Taxonomy and Cytology of tea

Bruce (1823) discovered local type of tea plant in Assam. The possibility of its commercial cultivation had to wait till 1834 when Lord Willium Bentinck appointed a Tea committee.

The early improvement of Tea (*Camellia sinensis* (L).O. Kuntze) in India dates back to 1835 when tea seeds and plants

were introduced from China by **G. J. Gordon** who started tea garden in Assam, the Himalayas and the Nilgiris.

Linnaeus (1752) was the first to typify the Tea plant as *Thea sinensis*. Originally, the genus *Thea* existed separately from the genus *Camellia*, but the tea plant is now days classified as *Camellia sinensis* on account of the close resemblance between the species included in the two genera.

Sealy (1937) noted that correct name of the tea plant should be *Camellia sinensis* (L).O. Kuntze.

Wight (1962) and **Barua (1965)** described China and Assam kind of tea according to a specific rank and retained the name *Camellia sinensis* (L) for the China type and *Camellia assamica* (masters) for the Assamica type tea plants. The typical China variety is a shrub with more or less virgate stem arising near the ground; It is 1.0 to 3.0 m high and has relatively small, hard, dark green, 3-6 centimeter long leaves with a dull (matt) surface. The typical Assamica type variety is small, 10-15 meter high, many-branched tree, sometimes with a trunk one third its height, with supple light green, 15-20 centimeter long, leaves with a glossy surface.

Kingdom Ward (1950) described a third form of tea referred to as the 'Cambodia race' and termed 'Southern form of tea' by **Roberts *et al.* (1958)** could be equated to **Planchon's** *Thea lansiocalex* and has been named *Camellia assamica ssp. lasiocalex* (Planch-MS). It was treated as a subspecies of *Camellia assamica* because of its close relation to this species.

Barua, (1965) gave a specific rank to a forth form known as 'Wilson's Camellia' at Tocklai which has been described as *Camellia irrawadiensis.*

Sealy (1948) described another kind of tea allied to *C. irrawadiensis* as 'forest's Camellia' named as *Camellia taliensis.*

Cytology

Normal form of tea is diploid with 2n = 30 chromosome. Numerous studies have been carried out by **Harada, (1957)** and **Simura, (1952)**, especially in Japan, on the breeding and utilization of polyploidy varieties of tea. Natural triploids have been found among Japanese 'varieties' as well as among the large leaved China tea called '**macrophylla**'. Tetraploids have obtained from the progenies of the triploid plants and by treating the

growing points of the diploid seedlings with colchicines (0.2 – 0.5 % for 3 to 5 days under light and dark condition).

Toyao (1965) found that the viability of the pollen and fertility of triploids are usually poor. Tetraploids appear to be more fertilie than that of triploids but less so than diploids. Crosses between female tetraploids and male diploids were found to succeed well, whereas the reciprocal crosses almost all failed. Polyploids plants generally have thicker leaves with larger stomata.

Singh and Sharma (1982) observed about 137 polyploids in 7 to 8 years for cytology, morphology and agronomic performance. Out of 56 triploids progenies evaluated for their rooting behavior, yield, cup quality and tolerance to pest and diseases, 5 were identified as promising of which one was released as clone TV 29 in 1990.

The morphological and vegetative organs of tea plant are affected by the parent plants and environmental condition but floral characteristics are relatively stable and provide reliable basis for specific identification.

Pollination: Tea plants showed an appreciable degree of self sterility and invariably set a better crop of seeds with pollen

from another bush nearly four times that of self-fed seed. With efficient cross transfer of pollen, more than 3 % of total seed formed will be self fertilized.

Artificial pollination/ hand cross pollination: healthy flowering branches are chosen for artificial pollination. To avoid contamination, open flowers and immature fruits are removed.

2.2 Germination and Storage of Seeds

The seed contained in a three to four celled capsule is made up of an embryo with two cotyledons enclosed in a thin papery integument and a thick woody shell. The embryo of the tea seeds does not need any 'after ripening' as it germinates readily upon the removal of the seed shell. Germination is to some extent delayed by the seed shell itself, probably because it impedes free liquid and gaseous exchange; mechanical resistance is possibly an added factor **(Tubbs, 1931** and **Visser, *et al.*, 1958).**

With respect to storage , **Visser, *et al.*, 1958** found that the longevity of seeds stored at 0^0C increased with increasing humidity; 60 % of the seeds kept at a humidity of 100 % still germinated after ten months of storage. The storage at below freezing point would extend the period of longevity.

2.3 Vegetative Propagation and Plucking:

Tea can be vegetatively propagated in several ways like budding or grafting on root stocks and air layering. Propagation by cutting was tried out in India by **Tunstall, (1932)**. Now this method is very successful and widely adopted as the only practical means of vegetative manipulation.

With regard to material, use should be made of primary shoots which have not grown for too long after pruning and which are at the stage when terminal and axillary buds are active or near active. Too mature shoots, red wooded, part of the shoot should preferably not be used in order to avoid undue flower development and impeded growth of cuttings. Hard leaf with 3 cm – 3.5 cm of stem and a dormant or slightly developed axil bud is the best cutting. Single node cutting are to be preferred than double node or triple node cuttings (**Anon., 1960; Kehl, 1963; Visser, *et al.*, 1958; Wight, 1960**).

Visser (1958) and **Venkataramai (1961)** found that treatment of cuttings with growth substances stimulate rooting.

Plucking

Terms connected with plucking:

1. STICKS : Branches left on a bush after pruning /skiffing are called sticks.

2. PRIMARIES : The shoots growing out of sticks are called primaries.

3. LATERALS : The branches produced by the primaries are known as laterals.

4. JANAM : A Banjhi bud is enclosed generally by two, occasionally by more than two, cataphylls or bud scales known as Janam (birth scale) in N.E. India. This is seen on the base of a growing shoot (flush) and when pulls off leaves behind scars or tables on stem.

5. FISH LEAF : An appendage intermediate in form between a Janam and a fully serrated leaf usually appear between the Janams at the base of a flush and first normal leaf. This is known as fish leaf or Golpat. This is unserrated or sometime partially serrated.

Maintenance Foliage

All leaves including fish leaves left on the bush below the plucking table are called Maintenance Foliage. Function of the maintenance foliage is to cater the metabolic needs of other plant organs. It also contributes to generating sufficient reserves for the bush to push through leafless period after pruning.

Source

The canopy of maintenance foliage, soil as well as roots is the source for expanding organs.

Sink

All expanding organs are sink like bud, 1+ bud, etc.

Banjhi Period

The rest period between two successive flushes is known as banjhi period. During this period the apical bud becomes smaller in size and remains at rest.

Flush

The period of growth between two successive stages of dormancy is known as flush. Plucking is removal of shoots from plucking table and is synonymous with harvesting in other crops. It has specification towards type of shoots, time interval in which shoots are to be plucked depending on requirement.

Tipping

It refers to first few plucking carried out to form a plucking table after pruning/skiffing.

Standard Plucking

On a plucking table heterogeneous growth is observed. Depending on period of growth, following growth is found on the table :

Buds, 1 + buds, 2 + buds, 3 + buds etc.

4 + buds or more are not normally seen on a table unless plucking time is too prolonged which is unusual in N.E. India. Standard of plucking is classified on the basis of -

(1) What is to be left on the table

(2) What is plucked.

(1) Classification on the basis of what is left on the table.

i) Standard Plucking

Pluck all except small 1 + buds. On standard plucking, plucking table will contain single buds & small 1 + buds.

ii) Black Plucking

Pluck all except buds. On black plucking, plucking table will only buds, 1 + buds, 2 + buds, 3 + buds etc. will have to be plucked from the table.

(2) Classification on the basis of what is plucked:

Type of plucking	**Type of shoots plucked**
Fine plucking	1+Bud, 2+Bud, Single Banjihi
Standard plucking	1+Bud, 2+Bud, 3+Bud, Single Banjihi,
Coarse plucking	All 2+Buds, Double Banjihis, 3+B, 4+B
Very coarse plucking	Double Banjihis, 3+Bud, 4+Bud

Plucking System

It is not always possible to adhere strictly to a particular system of plucking. Normally what we find is of a mixture of Janam & fish leaf plucking in different proportions.

Janam Plucking

In this system of plucking shoot is detached above the Janam. This is the most common practice in N.E. India & has been found to be the best suited.

Fish Leaf Plucking

In this system the shoot is detached above the fish leaf. This system is not common in N.E. India.

Step Up Plucking

In this system, the plucking is carried out above a normal leaf. This is carried out to build a new layer of maintenance foliage under special situation. When the maintenance foliage is affected by infestation of pest & diseases, drought, hail or any other reason, step up plucking is necessary to give a new lease of life in the bush. Furthermore one round of step up plucking in autumn prior to keeping an area up is also beneficial in terms of crop

Creep

This is the natural rise in plucking table after plucking over a period of time. Creep should be ideally between 4-6 cm.

Type of pruning	By end July	By end August	By end of season
Light prune	2.5 cm	3.5 cm	5 - 6 cm
Deep skiff	2.5 cm	3.0 cm	4 - 5 cm
Medium skiff	2.5 cm	3.0 cm	4 cm
Up prune/level off skiffing	2.5 cm	3.0 cm	4 cm

Plucking Round

Plucking round refers to the time interval between two successive plucking. It may very from 6-13 days over a plucking season depending on growth rate or quality requirement. Probable variations in crop in different plucking rounds are given below:-

Crop relative to 7 days plucking –

PLUCKING ROUND	% LOSS / GAIN	
	LP	UP
5	-4	-6
6	-3	-4
7	-	-
8	+4	+4
9	+8	+6
10	+11	+10
11	+16	+11
12	+18	+17
13	+27	+23

Source: Darjeeling tea research and management association.

2.4 Genetic variability

Genetic variability is the basis of all plant improvement programmes. Sufficient genetic variability if present can be exploited for developing superior cultivars. **Vavilov (1951)** was the first to realize that a wider range of variability in any crop provides a better chance of selecting the desirable types. Another important factor, besides genetic variation for characters is their mode of transmission to the next generation. Knowledge of heritability for

different traits is essential for any crop improvement programme because the heritable component is the consequence of genotype and is inherited from one generation to the other.

The exploitation of wide range of genetic variability present in the tea population due to free hybridization among cultivated tea species is one of the important strategies for tea improvement **(Wight, 1956 and Singh 1994)**. In seed grown population about 10% of the bushes produced only 20% of the total crop and .9 % bushes produced as much as or more than 300% of the yield of an average bush possibly due to their inherent superiority in yield.

Singh (1989) found that one out of 40000 bushes of old seed grown population may be selected as golden bush. The Camellia germplasm maintained by Tocklai Experimental Station in India as given in table below :

Species	Source of collection	No. of accessions
Camellia assamica	Assam, Manipur, Sri	2337
C. sinensis	Lanka	35
C. kissi (drupifera)	China , Darjeeling hills	50
C. caudata	Meghalaya	-
Eurya japonica	Assam	7
E. acuminata	N .E. India	2
C. japonica	N .E. India	-
C. sasanqua	USA, Japan	-
C. irrawadiensis	USA, Japan	2
C. rosiflora	Upper Myanmar Sri Lanka	1

Source : Singh, I.D. & Bera, B. 1994. Indian Journal of Plant Genetic Resources.

Wright (1921) reported that heritability components comprised mainly of additive and non additives portion of genetic variance and only the former responded to the selection and estimation of expected genetic advance was important to have an idea of effectiveness of selection. **Burton and Devane (1953)** suggested that genetic coefficient of variation together with heritability estimates would give reliable indication of the extent of improvement expected genetic gain under particular system and supplied true practical information which was needed by a breeder. **Johnson *et al.*, (1955)** also found it more useful to estimate the heritability values together with genetic advance in predicting the expected progress to be achieved through selection. The earlier studies on variability and heritability in tea are reviewed as follows:

Wellensiek (1938), Visser (1969) and Nyirenda (1989) reported that visual assessment of vigour to be an effective method for selecting the small number of high yielding plants from a large population of seedling tea. **Nyirenda (1987)** reported large

variation in productive potential and vigour amongst tea plants. He advocated a thorough screening to identify the best clones for testing in replicated field trials at different sites. **Wight (1556), Barua (1963) & Bezbaruah (1968, 1969)** advocated clonal selection to exploit natural variability for the improvement of tea. Pruning weight was used as a fairly reliable criterion for bush yield **(Visser and Kehl, 1958; Visser, 1969)**.

Visser (1961) recommended surface area of a bush in mature tea field as one of the criterion for estimating yield. The yield per unit area by the field per unit area **(Venkataramani, 1962)**. **Herd and Squire (1976) and Tanton (1981)** reported that seasonal variation in yield depended on variation in the rate of shoot extension and not on the number and weight of growing shoot. The yield of tea was found to be the product of weight of shoots and their number per unit area and these were found complimentary to each other as per **Rahman (1977)**. **Varghese (1977)** found that under South Indian conditions longer rounds produced a high mass of shoots, but these included a larger proportion which could not be manufactured into acceptable tea.

Wickremaratne (1981) reported that phenotypic variations in the morphological traits were characterized by continuous

quantitative differences between individuals indicating that they were controlled by several gene loci. **Barua (1989)** observed that density of plucking points was the only criterion which could give some indication of the shoot yielding capacity of a bush. He also found that yield was the product of shoot number and weight per shoot. **Nyrienda (1991)** reported that bush area, number of branches and shoots per bush may be used as a selection criterion to identify high yielding clones, in the post visual and post - rooting assessment stages of clonal selection programmes.

Singh (1993) found that high heritability coupled with moderately high genetic advance for yield was mostly controlled by additive gene action and considerable yield improvement could be achieved by phenotypic selection alone. **Singh and Chakraborty (1993)** in their experiments on variability assessment in tea reported improvement of tea to be dependent upon the presence of adequate genetic variability. Greater the variability more was the scope for its genetic improvement. They found that genetic advance indicated how much improvement could be made in a trait through selection in future generations and the possible upper limit of genetic improvement could be estimated prior to the practice of selection. **Paul *et al.* (1995)** reported that bush

population even in a single small field showed great variation in growth, branching habit, size, shape, texture and pose of the leaf, as well as quality and yield of the bushes.

Wickramaratne (1981) reported that the ratio of leaf length to leaf width was found to be more useful as a differentiating characteristic than either length or width alone. The angle between leaf tip and axis was more meaningful than that between petiole and axis as an estimate of leaf pose. Other useful discriminative characters were petiole length, leaf size, ratio of apical length to basal length, internode length and girth and length of bud. Useful nonparametric characters were colour, texture and pattern of leaf and pubescence of bud.

Since tea in the field is maintained in the vegetative state, it is necessary to choose vegetative characters for general identification purposes inspite of the relative plasticity of vegetative as compared to reproductive characteristics which makes vegetative characters generally less reliable as diagnostic criteria **(Stebbins, 1967)**. There are hardly any characteristics in tea which show discontinuous variation and on which basis individual genotypes may be separated, clearly and certainly, into discrete groups. Nearly all characters show continuous variation,

which commonly implies polygenic determination and usually requires biometric analyses (**Wickramaratne, 1981).**

Wight (1953), used two characters, patina (whether matt or glossy leaf surface) and pose (whether erect intermediate or dependent) of leaf as an agrotype index in tea. He suggested that the phenotypic groups had a genetic basis and that the contrasting characters had their origins in the two parental types designated *sinensis* and *assamica* from which most of the tea grown in Assam is derived. These and several other leaf characters such as size, colour and texture have been used to differentiate between thee Assam and China jats **(Visser, 1969)**. **Richards and Sebastiampillai (1964)** used size, shape, colour, texture, patina and pose of leaf, type of leaf apex and venation, length of internodes, size and pubescence of bud and some floral characters such as hairiness of ovary and stigmatic features to describe and distinguish between six different clones in Sri Lanka. Clonal differences in leaf shape, size and area were found by **Pethiyagoda and Rajendram (1965) and Krishnapillai and Pethiyagoda (1978)**. Mazumder and Bezbaruah (1978) reported significant differences in leaf size and density in some Toklai released clones.

Tanaka, Kurihara and Yamaguchi (2002) reported that the seed weight was positively correlated with the fresh weight of 6 month old seedlings. No relationship was observed between the seed weight and the number of seeds per fruit in some of the populations derived from natural crosses.

Chen *et al.*, 2005 reported that great variation of morphological characters was apparent within each taxa. All leaf and most flower quantitative characters showed significant differences while all fruit quantitative characters measured did not differ significantly, and, seven (i.e., life form, bud colour, petal texture, pubescence on ovary, style number, stamen location and locule per fruit) of the 33 qualitative characters yielded significant differences.

Dogra and Paul (2001) studied genetic variation for yield per plant, number of primary branches, number of secondary branches, length of growing shoots, density of plucking points, surface area of the bush, caffeine and polyphenol contents of shoots, pruning weight at the end of the growing season and total yield in 13 tea lines grown at Krishi Viswavidyalaya, Palampur,Himachal Pradesh, India, during 1992. They reported

that significant variation at the phenotypic and genetic levels was recorded for all the traits.

Mamati, (2001) reported that selection of desirable clones from seedlings jats was laborious and time consuming exercise since the probability of obtaining a clone combining both yield and quality attributes was low, and sometimes zero. Selection techniques among nursery plants and seedling fields were investigated to initiate early clonal selection. This led to the next phase of hybridization and clonal selections among progenies of polycross and bi-clonal seed gardens with the view of exploiting the potential of selected clones with the hope that their desirable attributes were heritable.

Venkataramani (1972, 1974) reported that selection with light green leaves produced better quality teas than those with dark green leaves and there was a positive association between pubescence and quality.

Wu, Fong and Tauy (1972) studied morphological data on the leaves and flowers of wild tea from 4 different elevations, and of semi-cultivated and local cultivated. Leaf form the wild type resembled *Camellia assamica* more than *Camellia sinensis*. Leaf characters were little affected by environmental conditions and

therefore more useful in distinguishing varieties included length/ width ratio and the position of the widest part.

Fordham and Holgate (1972) described methods for estimating the leaf area from linear dimensions, and constants are given for regressions fitted to data from planting material of both clonal and seedling origin. The constant (k) necessary to satisfy the equation A = kLB, where A = area, L = length of leaf and B = width of leaf at widest point, differed according to planting material. Leaf length and width were less closely related in the seedling population.

Magambo (1977) reported that in general, clones with the largest leaf area indices had the deepest canopies, the greatest ground cover, and smaller leaf angles from the vertical and small leaves. Leaf area indices and angles of leaf position were estimated by the use of inclined point quadrats and by conventional methods. The leaf area indices estimated by the two methods were positively and significantly correlated but estimates of leaf angles were not correlated.

2.5 Correlation analysis and path analysis

Correlation coefficient is a measure of the degree of association between the two traits **(Hayes *et al.*, 1955).** The selection of superior genotypes based on the *per se* performance is usually not very effective. For selecting superior genotypes, the breeder has to choose from the material on the basis of their phenotypic expression. As most of the traits of economic importance are complex, the knowledge of degree of phenotypic and genotypic correlation of the traits is important **(Robinson *et al.*, 1951)**.

Correlations are only helpful in determining the components of a complex trait like yield. Path coefficient analysis proposed by **Wright (1921)** is a standardized partial regression coefficient and permits the portioning of the correlation coefficients into direct and indirect effects. **Dewey and Lu (1959)** were the first to suggest the importance of path coefficient analysis in breeding programmes.

Cohen Stuart (1929, 1930) and Visser (1969) reported correlation between pruned or plucked surface area and yield of individual bushes. The significant positive correlation between the

annual crop in the first year and annual crop in the following seasons confirmed the findings of **Wellensiek (1938)** as quoted by **Visser (1958, 1969)**, who concluded that potential yield could be estimated quite reliably on the basis of the yield of the first season crop.

Portsmouth (1957) found that number of active auxillary buds on unplucked shoots was correlated with the relative yields of different clones and the correlation disappeared on terminal bud removal. **Venkataramani (1963), Grice (1963) and Barua (1965)** found that greater the number of buds sprouted per stem, greater was the density of shoots and it had been considered as one of the most important criteria influencing the yield. **Green (1965)** reported poor correlation between yield of mother bushes and that of derived clones. **Visser (1969)** observed correlations between pruning weight and yield of the previous pruning cycle (0.89 and 0.92) and tipping weight and yield (0.57 to 0.76) of cloned bushes.

Matsushita (1969) reported a positive correlation ($r = 0.70$) between yields of nine year old mother bushes and their four year old cloned progenies. However, **Visser (1969)** did not observe significant correlation between yields of nine year old mother

bushes and their vegetative offspring's in any of the six groups of clones examined by him. He attributed high yield of a fair number of mother bushes to favourable soil conditions.

Visser *et al.* (1969) observed correlations (r = 0.52 to 0.72) between pruned or plucked surface area and yield of individual bushes while working in groups of clones. **Visser (1969)** obtained significant correlations of 0.73 and 0.68 between total leaf area per bush and yield of shoots plucked from two groups of 22 and 26 clones, respectively. **Grice (1969)** did not find seedling vigour to be reliable criteria for predicting yield at maturity. Various workers viz., **Visser (1969); Barua and Dutta (1971); Nyirenda and Ridpath (1984); Nyirenda (1991); and Magambo and Waithaka (1985)** have reported that quantifiable characteristics like bush area and number of flushing points can be used fairly successfully as selection criteria in tea breeding.

Green (1971) did not find any correlation between pruning weights, sizes and yields of mature plants grown from seed and yields of the clones derived from them, both in the early years as well as at maturity. **Barua and Dutta (1971)** reported that density of plucking points was the most important criterion for quick selection (or rejection) of mother bushes through visual

observations and was an estimate of the number of shoots actually plucked from a bush. **Amma (1975)** obtained good correlation between length of growing shoots and yield in small leaf china hybrid populations, where bushes with relatively bigger shoots had an advantage. No such correlation was observed in other countries, where large leaf bushes predominate **(Bezbaruah, 1968; Visser, 1969)**.

Studies in Malawi had shown that seasonal variation in yield between clones and seedlings had been found to depend largely on the number of shoots per unit area of ground and the rate of extension of growing shoot itself **(Squire, 1979; Tanton, 1982)** rather than by soil conditions. **Pool and Nyirenda (1981)** and **Nyirenda and Kayange (1984)** reported a strong correlation of yield with shoot density and number of branches per bush. This correlation had been confirmed by recent work on composite plants **(Nyirenda, 1987)** where bush area, shoot number and yield were all strongly and positively correlated with those of the mother bushes. Clones derived from the bushes exhibited characteristics which were correlated with those of mother bushes, indicating the usefulness of these observations in the

selection of clones for improved performance **(Nyirenda and Ridpath, 1984)**.

Barua (1989) reported pruning weight to be a good index of yield as the number of shoots plucked. **Nyirenda (1991)** found that bush area, number of branches and shoots per bush at the second crop peak were correlated with yield. He concluded that all these growth characters might be reliably used to predict and select high yielding tea clones.

Dev Choudhary (1980) reported that high levels of caffeine enhance the creaming property of black tea, which is responsible for quality. **Sharma (1987)** in his unpublished reports found that caffeine N content of tea shoots was negatively correlated with polyphenols. Caffeine content varied between teas from different clones and jats; standards of plucking, type of prune, maturing, season and stages of processing also influenced the caffeine content of teas. Caffeine content had positive effect on the quality of made teas. The caffeine contents of North East India tea varied between 3 and 5 percent **(Dev Choudhary *et al.*, 1991)**.

2.6 Polyploidy in tea

In tea there are three cultivated and thirteen wild species. Among the cultivated ones: *Camellia Sinensis* (China), *Camellia sinensis var. assamica* (Assam) and *Camellia sinensis var. lasiocalyx* (Combod) and among the wild species *Camellia kissi*, *C. caudata*, *C. irrawadiensis*, *C. japonica* (ornamental), *C. sasnqua* (ornamental), *C. pitardii, C. reticulata, C. varnalis* (hybrid), *C. flava, C. petelotii, C. drupifera, C. taliensis, and C. lutescens* are major ones.

Ranatunga and Gunasekare (2003) studied the effect of polyploidy on the morphological and anatomical attributes related to vegetative and reproductive characteristics was evaluated in colchicines induced tetraploid cultivars of tea [*Camellia sinensis*], grown in Sri Lanka, in comparison with their diploid progenitors (TRI 2023, TRI 2024, TRI 2025, TRI 2026 and DT 95). Attributes such as leaf area, fresh and dry weight of flush, pollen diameter, anther length, stomatal density, stomatal length and breadth, stomatal length and breath ratio, and number of chloroplasts per guard cell were studied to identify the most reliable ploidy indicator in tea. Of the attributes tested, number of chloroplasts

per guard cell significantly varied between the two ploidy levels for all the cultivars. In contrast, fresh weight and dry weight of flush, stomatal length, breadth, and breadth to length ratio showed no significant differences between ploidy levels in any of the cultivars. On the other hand, size of the pollen grain, anther length, leaf area, and stomatal density showed significant differences only in some of the diploids and their induced tetraploids. The results confirmed that the number of chloroplasts per guard cell was a more reliable indicator of the level of ploidy in tea than the other criteria studied.

Open pollination of a triploid resulted in progeny including aneuploids and polyploids. Chromosome number in the progeny varied from 2n =2x =30 to 2n =75, but most were near the tetraploid number. A few were aneusomatic. Variation observed in the morphology of the progeny was considerable, but was directly correlated with ploidy **(Bezbaruah, 1976).**

Tetraploids plants of five clones of tea were obtained after treating the meristematic tissues of their terminal buds of actively growing shoots with 0.2 % and 0.5 % colchicines in 0.1% agar for two to seven days. One plant contained both diploid and tetraploid

cells in different root tips, but by a later examination had reverted to its diploid state **(Sebastiampillai, 1976)**.

Wachira, 1994 proposed that triploid clones produced larger and heavier shoots than diploids, with fewer pluckable shoots per unit area. They also regenerated fewer shoots than diploids during the experimental period and had larger stomata. The shoot extension rate of actively growing shoots was independent of ploidy. Ttriploid axillary buds took longer to reach plucking maturity than diploids.

Jayasurya and Govinarajulu, (1975) studied 17 clones from southern India, two were triploid and the rest diploid. Sundaram, a triploid, showed good adaptability to climatic and soil conditions as well as other desirable characteristics.

2.7 Pollination in tea

Bezbaruah (1975) studied the extent of dispersal of tea pollen by wind, using spore traps at various heights and exposed to different aspects in following trees. He reported that the frequency of occurrence of pollen grains was low, and moreover most of the pollen grains trapped were found to be non-viable. Observations on the insect visiting tea flowers showed that small

flies are the most common, but populations were too low for large-scale pollination. Insects with a long flying range, such as bees and wasps, were rarely observed, indicating that seed gardens need not be isolated in remote places.

Bezbaruah (1974) concluded that tea crops grown for seed in North- east India region need not be isolated in remote places, as visits by insects with a long flying range, such as bees and wasps, are rare. Pollination was usually effected by small flies, but their populations were two low to have much effect. The pollen is heavy and sticky and is not wind borne.

Bezbaruah (1975) reported that flowering in north- east India extends from mid- October to late February with a peak in November and December. Marked variation in flowering time occurred between bushes in clones of both the assamica and combodiensis varieties. The flowering of parental pairs must be carefully synchronized to ensure successful seed production in clonal seed orchards. Pollination is mostly carried out by small flies with short flying range.

2.8 Chemical composition in tea

The quality of any tea in its widest sense and hence valuations, must be dependent upon the chemical composition of the tea. Numerous attempts have been made to investigate the correlations between chemical composition and liquor characters of teas. Though most of the extensive work in this direction has probably remained unpublished, however, one such investigation into Assam tea was reported by **Harrison and Bose (1942)**. Nevertheless the pioneering work of **Tsijimura (1934) and Bradfield (1948)** remained the foundation upon which most of the subsequent work **(Roberts, 1952; Wood, 1964; and Bhatia, 1964)** on tea chemistry has been founded. The liquor characteristics (colour, brightness, strength, flavour) of tea [*Camellia sinensis* (L). O. Kuntze] are developed as a result of complex metabolic changes during processing.

Caffiene plays an important part in the taste and briskness of tea beverage. **Wight and Barua (1954)** reported that upto some low optimum pigmentation of leaf petiole was beneficial and above this low level it was detrimental to quality. **Bhatia (1959)** recorded a decrease in caffeine content as the shoot got older. However,

earlier studies also showed that caffeine content was maximum in the bud, followed by first leaf, and second leaf and third leaf in that order. It was found considerably low in the stem. Work done at Tocklai Experiment Station of the Tea Research Association, Assam, also revealed that bud contains highest amount of caffeine which gradually goes on declining in lower leaves, while stem of shoot contains lowest content of it **(Bhatia, 1961)**.

The quality of tea primarily depended upon the variety (jat) of the bush **(Sanderson, 1964; Anonymous, 1974)** and the agroclimatic conditions **(Ramaswamy, 1964; Devanathan, 1976)**. The human tolerance limit of administereted pure caffeine is 0.65 g per day as quoted by British Pharmaceutical Codex **(Das *et al.*, 1965). Kirthisinghe (1968, 1971)** tested the effect of length of plucking rounds on manufacturing qualities of the harvest and found no difference in the valuation of the finished product.

Caffeine played an important role in determining the taste **(Millin *et al.*,1969)** and briskness **(Roberts, 1962)** of tea beverages. **Dev Chuodhary (1980)** reported that high levels of caffeine enhanced the creaming property of black tea and the ability of black tea infusion to cream and the colour of cream formed important yardsticks employed for evaluating the quality of

tea. **Cloughley (1982)** reported that the caffeine content of made tea is affected by seasonal, genetic, agroclimatic and cultural factors. In tea beverage caffeine concentration ranged from 2-4 per cent **(Blauch and Tarka, 1983)**. Variation in the caffeine level of shoots from May to November was reported to be above 20 per cent in Kenya **(Owuor and Chavanji, 1986)**. According to **Cloughley (1982)** in Malawi, the seasonal variation in caffeine content, however, was as high as 60 per cent. The tender younger shoot which is the consequence so shorter plucking intervals was found to contain higher content of caffeine **(Owuor and Chavanji, 1986)**.

Sharma (1987) in his unpublished results found that caffeine N content markedly influenced by the monthly variations during both the years. During pruned year, a significant increase in caffeine level occurred in July and slowly declined to the lowest level in September. **Sud and Badyal (1989)** reported varietal and seasonal variations in chemical constituents in fourteen seed jats of tea studied throughout four seasons during 1986 and 1987. They found better quality in the spring and summer seasons. According to **Sud and Bhattacharjee (1990)** the winter tea was of better quality than the rainy season tea. Tea produced in off

season contains about 50 per cent less caffeine. **Yaminishi (1990)** found that during manufacturing process of black tea, the content of caffeine increased partly due to release from complex molecules which contain caffeine molecule as a part of its make up. **Gulati and Ravindra Nath (1996)** reported periodical seasonal variations in infusion quality of orthodox Kangra tea over various growth flushes. Caffeine content recorded maximum during early flush and gradual decline through rains flush and slightly recovery thereafter through back-end flush.

Evans (1930) and Bhatia (1964) reported that seasons have marked influence on the polphenolic content mwhich varied significantly among the seasons. Several workers **(Sanderson, 1964; sanderson and Kanapathipillai, 1964)** also observed that the percentage of polyphenols in tea shoots varied with agroclimatic conditions, cultural practices and season of its harvest. **Millein and Ruatidge (1967)** reported that polyphenols are major components of tea shoots and the presecce of high qualities of polyphenols (17-30 %) make tea bush different from other plant species. **Bhatia and Ullah (1968)** showed a progressive decline of polyphenolic content from tender parts to the parts of shoot system.

Sharma (1987) in his unpublished results observed role of environment on quality of polyphenols in tea. Different months exerted a strong influence on the polyphenol content of tea shoots. During the pruned year, the month of June recorded the lowest polyphenols. In the subsequent months also a wide range of fluctuations was observed. During the unpruned year, April had the highest and June the lowest polyphenols, thereafter, an increasing trend was observed t5ill September, followed by decline during October. **Sud and Sharma (1991)** analysed the dried tea leaf throughout the plucking season (April to October). In the beginning of the season various constituents determined, were found to be higher as compared to the rest of season. Caffeine-N and amino acid- N increased, whereas polyphenols decreased considerably towards the end of the season. During the middle of season variations in caffeine, polyphenols were quite marked. They concluded that April flush is superior to the rest of year's pluck.

Chapter 3 MATERIALS AND METHODS

The field experiment was conducted during the year 2006-2007. The details of materials used and methods followed are given below under the following heads.

3.1 Place of experiment

3.2 Experimental materials.

3.3 Characters recorded.

3.4 Statistical analysis.

3.1 Place of experiment

The present investigation was conducted during 2006-07 at Tea Research Centre, Kausani of the G. B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar (Uttarakhand). Tea Research Centre, Kausani is situated in the Kumaon hills of Himalayas at an altitude of 1730 m above the mean sea level.

3.2 Experimental Materials

The experimental material consisted of 5 tea [*Camellia sinensis* (L). O. Kuntze] varieties.

Tea varieties selected for the study are as follows

Serial number	Genotypes
1	T-78
2	AV-2
3	BSS-449
4	UPASI-9
5	Kangrajat

3.3 Characters Recorded

The following different traits were recorded on each variety as follows:

3.3.1. Number of plucking points.

From each variety, fifteen bushes were selected randomly and then the data on number of plucking points were collected for each bush from each genotype.

3.3.2. Surface area of bushes.

From each genotype, fifteen bushes were selected randomly and then length wise data collected thrice and averaged. Similarly

width wise data collected thrice and averaged. The surface area of each bush was determined by multiplying the mean length and mean width.

3.3.3. Length of largest mature (maintenance) leaf.

From each genotype, fifteen bushes were selected randomly and then 5 largest leaves (maintenance) from each bush were taken. The data of leaf length was taken by measuring scale and average length was calculated.

3.3.4. Width of largest mature (maintenance) leaf.

From each genotype, fifteen bushes were selected randomly and then 5 largest leaves (maintenance) from each bush were taken. The data on leaf width was taken by measuring scale and average width was calculated.

3.3.5. Weight of the shoot (bud + 2 leaf).

From each genotype, fifteen bushes were selected randomly and then 5 shoots (bud + 2 leaf) from each bush were taken The weight of shoot (bud+ 2 leaf) was taken in gm by electronic weighing machine.

3.3.6. Weight of the bud.

The bud was detached from the shoot and weight of the bud was taken in gm by electronic weighing machine.

3.3.7. Length of the shoot (bud + 2 leaf).

Length of the shoot (bud + 2 leaf) was taken by using measuring scale in cm for each genotype.

3.3.8. Length of the first leaf of the shoot.

Length of the first leaf of the shoot was recorded in cm by the using measuring scale.

3.3.9. Width of the first leaf of the shoot.

Width of the first leaf of the shoot was recorded in cm by the using measuring scale.

3.3.10. 100 seed weight.

Seeds were collected in large quantity. Then, for weight of 100 seeds, the sampling was carried out fifteen times and weight was taken by weighing machine for each genotype.

For characters, namely, length of the mature leaf, width of the mature leaf, weight of the shoot, weight of the bud, length of the shoot, length of the 1st leaf of shoot, width of the 1st leaf of shoot, the three replication of five bushes were made from selected fifteen bushes. From each bush five observations were recorded and averaged.

3.4 Statistical Analysis

Statistical analysis was carried out at computer lab, G. B. Pant University of Agriculture and Technology, Pantnagar. Mean and variances for various characters and covariance for their combinations are estimated.

3.4.1. Analysis of Mean

The mean of the observations recorded was calculated by the following formula.

$$\overline{X} = \frac{\sum X}{N}$$

Where,

$\overline{X}$ = Arithmetic mean

X = an observation recorded

$\sum$ = summation

N = number of observations in a sample

3.4.2. Analysis of Variance

The following linear model was used to represent the mean performance of i^{th} genotypes in j^{th} plot in a block or replication **(Cochran and Cox, 1962)**

$$Y_{ij} = \mu + gi + bj + eij$$

$$(i = 1, 2, \ldots\ldots\ldots\ldots)$$

$$(j = 1, 2, \ldots\ldots\ldots\ldots)$$

Where,

Y_{ij} = performance of i^{th} genotype in j^{th} block

μ = general mean of population

gi = effect of i^{th} genotype

bj = effect of j^{th} block, and

eij = random error associated with i^{th} genotype and j^{th} block

The analysis variance table was made as follows:

Table 3.4.2 analysis of variance (ANOVA)

Source of variation	**Degree of freedom**	**Sum of square**	**Mean sum of square**	**F- value**
Replication	(r-1)	SS_r	MSr	MSr/MSe
Treatment	(t-1)	SS_t	MSt	MSt/MSe
Error	(r-1)(t-1)	SS_e	MSe	
Total	(rt-1)			

Where,

r = number of replication

t = number of treatments

SSr = sum of square for replication

SSt = sum of square for treatment

SSe = sum of square for error

MSr = mean sum of square for replication

MSt = mean sum of square for treatment and,

MSe = mean sum of square for error

The significant difference among treatment means was tested by 'F' test. Whenever the F test was found to be significant critical differences (CD) was calculated as follow

C.D. = S. Ed X 't'

Where,

't' = total value of 't' at error degree of freedom

S. Ed = standard error difference between two treatment means

$$S.\,Ed = \sqrt{\frac{2MSe}{r}}$$

3.4.3 Correlation

3.4.3.1 Phenotypic Correlation:

The simple phenotypic correlation between pairs of the traits under study as worked out using the following formula:

Phenotypic correlation between character X and Y

$$r_{xy} = \frac{\text{COV XY (P)}}{\sqrt{\text{Var X(P) x Var Y(P)}}}$$

Where,

Cov XY (P) = Phenotypic covariance between character X and Y

Var X (P) = Phenotypic variance of character X

Var Y (P) = Phenotypic variance of character Y

3.4.3.2 Genotypic Correlation

The simple genotypic correlation between pairs of the traits under study as worked out using the following formula:

Genotypic correlation between character X and Y

$$r_{xy} = \frac{\text{COV XY (G)}}{\sqrt{\text{Var X(G) x Var Y(G)}}}$$

Where,

Cov XY (G) = Genotypic covariance between character X and Y

Var X (G) = Genotypic variance of character X

Var Y (G) = Genotypic variance of character Y

3.4.3.3 Environmental Correlation

The simple environmental correlation between pairs of the traits under study as worked out using the following formula:

Environmental correlation between character X and Y

$$r_{xy} = \frac{\text{COV XY (E)}}{\sqrt{\text{Var X(E) x Var Y(E)}}}$$

Where,

Cov XY (G) =Environmental covariance between character X and Y

Var X (G) = Environmental variance of character X

Var Y (G) = Environmental variance of character Y

3.4.4 Estimates of genotypic, phenotypic and environmental coefficients of variation

$$\text{Genotypic coefficient of variation (GCV \%)} = \frac{\sigma_g}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV \%)} = \frac{\sigma_p}{\overline{X}} \text{x100}$$

$$\text{Environmental coefficient of variation (ECV \%)} = \frac{\sigma_e}{\overline{X}} \text{x100}$$

Where,

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

σ_e = Environmental standard deviation

$\overline{X}$ = Grand mean

3.4.5 Heritability

Heritability in broad sense was calculated for each character as suggested by **Allard, 1960.**

$$h^2_{(b)} = \frac{\sigma^2_{gi}}{\sigma^2_{Pi}}$$

Where,

$h^2_{(b)}$ = Heritability in broad sense

σ^2_{gi} = Genotypic variance for character 'i'

σ^2_{Pi} = Phenotypic variance for character 'i'

3.4.6 Genetic Advance

The expected genetic advance from straight selection was calculated according to formula developed by **Johnson *et al.*, (1955).**

$$G.A.\ (S) = h^2_{(b)} \times \sigma^2_{Pi} \times K$$

Where,

G.A. (s) = expected genetic advance

$h^2_{(b)}$ = heritability in broad sense

σ^2_{Pi} = phenotypic variance of character 'i'

K = 2.06 **(**Selection differential at 5 per cent selection intensity as given by **Lush, 1949)**

Genetic advance as percentage of mean = $\frac{\text{ExpectedGA}}{\text{GrandMean}} \times 100$

3.4.7 Comparison of mean and variances

3.4.7.1 Comparison of mean

The difference between any two varietal mean is tested through t-test formula:

$$t_c = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{Var.X_1}{n_1} + \frac{Var.X_2}{n_2}}} \qquad \text{at } (n-1) \text{ d.f.}$$

Where,

$\bar{X}_1$ = mean of 1st variety

$\bar{X}_2$ = mean of 2nd variety

$Var.X_1$ = variance of first variety

$Var.X_2$ = variance of second variety

n_1 = sample size of first variety

n_2 = sample size of second variety

Then we compare the 't' value (calculated) with 't' value (table) on n -1 degree of freedom at 5 % and 1 %. If 't' (calculated) is more then the't' (table) value, mean is significant, it means that there is a significant difference between means of the two varieties.

3.4.7.2 Comparison of variances

The difference between variance of any two varieties is calculated through F – test formula:

$$F_c = \frac{Var.X_1}{Var.X_2} \quad \text{at } (n_1\text{-}1, n_2\text{-}1) \text{ d.f.}$$

Where,

$Var.X_1$ = variety showing higher variance

$Var.X_2$ = variety showing lower variance

n_1 = sample size of X_1 variety

n_2 = sample size of X_2 variety

Then we compare the 'F' value (calculated) with 'F' value (table) on (n_1 -1, n_2-1) degree of freedom at 5 % and 1 %. If 'F' (calculated) is more then the 'F' (table) value, variance is significant, it means there is a significant difference in variance of the varieties.

3.4.8 Path coefficient analysis:

The phenotypic and genotypic correlation coefficients obtained from correlation study, were further partitioned into direct and indirect effects with the help of path coefficient analysis as suggested by **wright (1921)** and applied in plant breeding by **Dewely and Lu (1959).** Weight of the shoot was considered as dependent variable (y) as factors assumed to be influenced by the other characters called independent variables($x_1 \ldots x_i$) as causes. The path coefficient was estimated by solving following sets of simultaneous equations indicating the basic relationship between correlation and path coefficients.

$r_{1y} = P_{1y} + r_{12} P_{2y} + r_{13} P_{3y} + \ldots\ldots\ldots\ldots\ldots + r_{1i}P_{iy}$

$r_{2y} = P_{2y} + r_{21}P_{1y} + r_{23} P_{3y} + \ldots\ldots\ldots\ldots\ldots\ldots + r_{2i} P_{iy}$

$r_{3y} = P_{3y} + r_{31} P_{1y} + r_{32} P_{2y} + \ldots\ldots\ldots\ldots\ldots\ldots + r_3 i\ Piy$

$r_{iy} = P_{iy} + r_{i1} P_{1y} + r_{i2} P_{2y} + \ldots\ldots\ldots\ldots\ldots\ldots + ri\ (i\text{-}1)\ P_{iy}$

Where, r_{1y} to r_{iy} denotes coefficient of correlation between independent variables or characters (1…..i) with dependent character y. r_{12} to r_{i1} to ri (i -1) denote coefficient of correlation among all possible combination of caused factors (independent variables) and P1y to Piy denote the direct path effects of independent variables (1 to i) on the dependent variable y.

The indirect effect of i^{th} independent variable through j^{th} independent variable on dependent variable y was computed as = $P1y \times {}_{ij}$

The above equation can be written in a matrix form as shown below:

$$\underset{\sim}{\mathbf{A}} = \begin{pmatrix} r_{1y} \\ r_{2y} \\ \vdots \\ r_{iy} \end{pmatrix} = \underset{\sim}{\mathbf{B}} \begin{pmatrix} r_{11} & r_{12} & r_{13} & r_{14}\ldots\ldots\ldots r_{1i} \\ r_{21} & R_{22} & r_{23} & r_{24}\ldots\ldots\ldots r_{2i} \\ \vdots & \vdots & \vdots & \vdots \\ r_{i1} & r_{i2} & r_{i3} & r_{i4}\ldots\ldots\ldots r_{ii} \end{pmatrix} X \underset{\sim}{\mathbf{C}} \begin{pmatrix} P_{1y} \\ P_{2y} \\ \vdots \\ P_{iy} \end{pmatrix}$$

Path coefficient was estimated as follows:

$$\underset{\sim}{C} = \underset{\sim}{B}^{-1} \underset{\sim}{A}$$

The effect of residual factors (R) which measure the contribution of rest of the characters is not considered in caused scheme. It was calculated as follows:

$$R^2 = 1 - \sum_{i=1}^{r} P^2_{iy} - 2 \sum_{i,j=1}^{r} P_{iy} P_{jy} r_{ij}$$

Chapter 4 EXPERIMENTAL RESULTS

The experimental results are presented under the following heads:

4.1 Analysis of Variance

4.2 Means and Variability

4.3 Comparison of coefficient of variability, heritability and genetic advance

4.4 Comparison of mean and variance

4.5 Estimates of Character Association

4.6 Path Coefficient Analysis

4.1 Analysis of Variance

The analysis of variance, for ten characters is presented in Table 4.1. Analysis of variance revealed significant differences among the genotypes for all the ten characters.

4.2 Means and Variability

The mean for all genotypes for each character and range of variation, genotypic, phenotypic and environmental coefficients of variation, heritability (broad sense) and genetic advance for all ten characters are given in Tables 4.2and 4.3 respectively.

Source of variation	d.f.	No. of plucking points	Surface area of bush (m^2)	Length of mature leaf (cm)	Width of mature leaf (cm)	Weight of shoot (mg)	Wt of the Bud (mg)	Length of shoot (cm)	Length of 1st leaf of shoot (cm)	Width of 1st leaf of shoot (cm)	100 seed weight (g)
Replications	14	288.34	0.019	0.936	0.162	2702.68	79.08	0.204	0.146	0.018	42.22
Treatments	4	6099.78**	0.3235**	112.04**	18.73**	14547.5**	3546.96**	3.83**	1.247**	0.294**	25256.3**
Error	56	573.72	0.0352	1.418	0.405	1954.57	128.10	0.257	0.161	0.0301	36.78
SEM		6.184	0.048	0.307	0.164	11.41	2.92	0.131	0.103	0.044	1.565

Table: 4.1 ANOVA Table

* CD at 5% significance
**CD at 1% significance

4.2.1 Number of plucking points

Mean number of plucking points ranged from 68.2 (kangrajat) to 136.67 (UPASI-9) with general mean as 86.98. The phenotypic, genotypic and environmental coefficients of variation were 41.11, 31.72 and 26.15, respectively. The broad sense heritability was 0.59 and genetic advance was 50.45.

4.2.2 Surface area of bush (square meter)

Mean surface area of bush ranged from 0.199 (T-78) to 0.584 (Kangrajat) with general mean 0.3368 m^2. The phenotypic, genotypic and environmental coefficients of variation were 69.26, 41.14 and 55.71, respectively. The broad sense heritability and genetic advance were 0.35 and 50.36, respectively.

4.2.4 Length of mature (maintenance) leaf

Mean length of mature leaf ranged from 8.28 cm (kangrajat) to 15.44 cm (BSS-449) with general mean as 12.45. The phenotypic, genotypic and environmental coefficients of variation were 23.8, 21.8 and 9.56, respectively. The broad sense heritability estimate was 0.84 whereas genetic advance was 12.23.

Table: 4.2: Table of means

Characters	No. of plucking points	Surface area of bush (m^2)	Length of mature leaf (cm)	Width of mature leaf (cm)	Weight of shoot (mg)	Weight of bud (mg)	Length of the shoot (cm)	Length of 1^{st} leaf of the shoot (cm)	Width of 1^{st} leaf of the shoot (cm)	100 seed weight (g)
T-78	81.4	0.199	12.32	5.45	141.63	**59.95**	2.76	2.34	0.86	139.75
AV-2	76.73	0.309	11.96	5.06	145.40	29.95	2.98	2.25	0.81	**197.74**
BSS-449	71.93	0.326	**15.44**	**6.69**	**172.06**	51.92	**3.34**	**2.53**	**0.98**	145.65
UPASI-9	**136.6**	0.264	14.28	5.62	167.21	25.66	2.38	1.94	0.94	139.36
Kangrajat	68.2	**0.584**	8.28	3.60	93.54	29.97	2.05	1.83	0.62	81.47

Table: 4.3: General mean, variance, PCV, GCV, ECV, heritability (broad sense), and genetic advance of different traits

Characters	Mean	Range of variation	PCV	GCV	ECV	h^2b	GA (as a % of mean)
No. of plucking points	86.98	22.97 – 1427.82	41.11	31.72	26.15	0.5954	50.45
Surface area of bush (m^2)	0.3368	0.00544 – 0.0119	69.26	41.14	55.71	0.3529	50.36
Length of mature leaf (cm)	12.45	0.512 – 2.46	23.80	21.80	9.56	0.8387	12.23
Width of mature leaf (cm)	5.288	0.123 – 0.673	24.13	20.90	12.06	0.7501	37.29
Weight of the shoot(mg)	142.6	608.21 – 3577.98	36.32	19.28	30.78	0.2818	21.09
Weight of the bud (mg)	39.49	41.03 – 270.06	47.77	38.22	28.65	0.6204	63.00
Length of the shoot (cm)	2.705	0.0983 – 0.3866	26.03	18.03	18.77	0.4801	25.75
Length of the 1^{st} leaf of the shoot (cm)	2.183	0.0755 – 0.3569	22.14	12.33	18.37	0.3106	14.15
Width of the 1^{st} leaf of the shoot (cm)	0.8453	0.012 – 0.054	25.77	15.58	20.52	0.3657	19.41
100 seed weight (gm)	140.3	18.38 – 55.54	29.63	29.31	4.40	0.9779	59.71

4.2.5 Width of mature (maintenance) leaf

Mean width of mature leaf ranged from 3.6 cm (kangrajat) to 6.69 cm (BSS-449) with general mean of 5.28 cm. The phenotypic, genotypic and environmental coefficients of variation were 24.13, 20.9 and 12.06, respectively. Broad sense heritability and genetic advance were 0.75 and 37.29, respectively.

4.2.7 Weight of the shoot

For weight of the shoot, the general mean was 142.6 mg. Mean weight of the shoot ranged from 93.54 mg (kangrajat) to 172.06 mg (BSS-449). The phenotypic, genotypic and environmental coefficients of variation were 36.32, 19.28 and 30.78, respectively. The broad sense heritability was 0.28 and genetic advance was 21.09.

4.2.8 Weight of the bud

Mean weight of the bud ranged from 25.66 mg (UPASI-9) to 59.95 mg (T-78) with general mean as 39.49 mg. The phenotypic, genotypic and environmental coefficients of variation were 47.77, 38.22 and 28.65, respectively. The broad sense heritability and genetic advance were 0.62 and 63.00, respectively.

4.2.9 Length of the shoot

The general mean was 2.71 cm. Mean length of the shoot ranged from 2.05 cm (kangrajat) to 3.34 cm (BSS-449). The phenotypic, genotypic and environmental coefficients of variation were 26.03, 18.03 and 18.77, respectively. The broad sense heritability and genetic advance were 0.48 and 25.75, respectively.

4.2.10 Length of the 1st leaf of the shoot

The general mean was 2.18 cm. The mean length of the 1st leaf of the shoot ranged from 1.83 cm (kangrajat) to 2.53 cm (BSS-449). The phenotypic, genotypic and environmental coefficients of variation were 22.12, 12.33 and 18.37, respectively. The broad sense heritability was 0.31 and genetic advance was 14.15.

4.2.11 Width of the 1st leaf of the shoot

The mean width of the 1st leaf of the shoot ranged from 0.62 cm (kangrajat) to 0.98 cm (BSS-449) with general mean as 0.85 cm. The phenotypic, genotypic and environmental coefficients of variation were 25.77, 15.58 and 20.52, respectively. The broad sense heritability was 0.37 and genetic advance was 19.41.

4.2.12 100 seed weight

The population mean was 140.3 mg and mean 100 seed weight ranged from 81.47 mg (Kangrajat) to 197.74 mg (AV-2). The phenotypic, genotypic and environmental coefficients of variation were 29.63, 29.31 and 4.40, respectively. The broad sense heritability was 0.98 and genetic advance was 59.71.

4.3. Comparison of coefficient of variability, heritability and genetic advance

Comparison of coefficient of variability (Table 4.3) showed that surface area of bush had highest phenotypic coefficient of variation (PCV) and width of mature leaf, length of mature leaf and length of 1st leaf of shoot had lowest phenotypic coefficient of variation (PCV).

Surface area of bush had highest genotypic coefficient of variation (GCV) whereas length of 1st leaf of shoot and width of 1st leaf of shoot had lowest genotypic coefficient of variation (GCV).

Surface area of bush had highest environmental coefficient of variation (ECV) and 100 seed weight and length of mature leaf had lowest environmental coefficient of variation (ECV).

When we consider phenotypic coefficient of variation, genotypic coefficient of variation and environmental coefficient of variation together, among ten traits, surface area of bush had highest phenotypic coefficient of variation, genotypic coefficient of variation and environmental coefficient of variation.

Comparison among heritability of all ten traits showed that 100 seed weight and length of mature leaf had highest heritability where as length of 1st leaf of shoot and weight of the shoot had lowest heritability.

100 seed weight had shown highest genetic advance whereas length of mature leaf and length of 1st leaf of shoot had lowest genetic advance.

Although surface area of bush showed higher phenotypic coefficient of variation, genotypic coefficient of variation, environmental coefficient of variation and higher genetic advance. But it had very low heritability because of higher environmental coefficient of variation (ECV).

4.4 Comparison of mean and variance

4.4.1 Comparison of mean

With 5 varieties, the following comparisons (Table 4.4) were made:

- T-78 Vs AV-2
- T-78 Vs BSS-449
- T-78 Vs UPASI-9
- T-78 Vs Kangrajat
- AV-2 Vs BSS-449
- AV-2 Vs UPASI-9
- AV-2 Vs Kangrajat
- BSS-449 Vs UPASI-9
- BSS-449 Vs Kangrajat
- UPASI-9 Vs Kangrajat

For no. of plucking points, the comparisons, namely, T-78 Vs UPASI-9, AV-2 Vs UPASI-9, BSS-449 Vs UPASI-9 and UPASI-9 Vs Kangrajat were significant that means there was significant difference between these pair of varieties for this character.

For surface area of bush, the comparisons, namely, T-78 Vs AV-2, T-78 Vs BSS-449, T-78 Vs UPASI-9, T-78 Vs Kangrajat, AV-2 Vs Kangrajat, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat showed significant difference for this character.

For length of mature leaf, the comparisons, namely, T-78 Vs BSS-449, T-78 Vs UPASI-9, T-78 Vs Kangrajat, AV-2 Vs BSS-449,

Table 4.4 Comparison of means

		Character 1	Character 2	Character 3	Character 4	Character 5	Character 6	Character 7	Character 8	Character 9	Character 10
Genotype	1----2	0.38439 ns	3.33169 **	0.95963 ns	1.552976 ns	0.203992 ns	6.573197 **	1.043291 ns	0.499486 ns	0.941554 ns	26.12268 **
	1----3	0.945642 ns	3.03515 **	8.629019 **	6.672713 **	1.517108 ns	1.542881 ns	2.850544 *	1.054471 ns	2.024518 ns	2.862594 *
	1----4	2.359018 *	2.24294 *	4.404031 **	0.761279 ns	1.288633 ns	7.529569 **	1.869104 ns	2.358388 *	1.119493 ns	0.181053 ns
	1----5	1.338556 ns	4.19718 **	14.98697 **	11.37161 **	2.878664 *	6.021829 **	3.951361 **	2.940568 *	4.997109 **	36.98796 **
Genotype	2----3	0.632936 ns	0.37133 ns	7.71747 **	6.596074 **	1.632152 ns	6.366289 **	1.94099 ns	2.11862 ns	2.944484 *	20.08618 **
	2----4	3.794571 **	1.45366 ns	4.45934 **	2.026009 ns	1.356437 ns	27.19799 **	3.238122 **	2.642088 *	1.85211 ns	21.88293 **
	2----5	1.155746 ns	2.9631 *	9.655279 **	6.341835 **	4.328164 **	0.006452 ns	5.848401 **	3.420177 **	4.120063 **	52.20677 **
Genotype	3----4	12.68734 **	0.02639 ns	2.272036 *	4.890657 **	0.271421 ns	7.638542 **	5.429133 **	5.02849 **	0.533571 ns	2.479121 *
	3----5	1.394161 ns	2.68886 *	19.46783 **	19.75473 **	5.492996 **	5.51074 **	8.654016 **	5.700295 **	6.779192 **	31.02257 **
Genotype	4-----5	19.21119 **	3.5133 **	13.33004 **	10.12535 **	5.261373 **	1.397075 ns	2.217147 *	1.031149 ns	4.816889 **	26.78256 **

* Significant at 5% level of significance

** Significant at 1 % level of significance

Genotypes

1. T-78
2. AV-2
3. BSS449
4. UPASI-9
5. Kangrajat

Characters:

1. Number of plucking points
2. Surface area of bush
3. Length of the mature (maintenance) leaf
4. Width of the mature (maintenance) leaf
5. Weight of the shoot
6. Weight of the bud
7. Length of the shoot
8. Length of 1st leaf of the shoot
9. Width of 1st leaf of the shoot
10. 100 seed weight

AV-2 Vs UPASI-9, AV-2 Vs Kangrajat, BSS-449 Vs UPASI-9, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant for this character.

For width of mature leaf, the comparisons, namely, T-78 Vs BSS-449, T-78 Vs Kangrajat, AV-2 Vs BSS-449, AV-2 Vs Kangrajat, BSS-449 Vs UPASI-9, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For weight of the shoot, the comparisons, namely, T-78 Vs Kangrajat, AV-2 Vs Kangrajat, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For weight of the bud , the comparisons, namely, T-78 Vs AV-2, T-78 Vs UPASI-9, T-78 Vs Kangrajat, AV-2 Vs BSS-449, AV-2 Vs UPASI-9, BSS-449 Vs UPASI-9 and BSS-449 Vs Kangrajat were significant.

For length of the shoot, the comparisons, namely, T-78 Vs BSS-449, T-78 Vs Kangrajat, AV-2 Vs UPASI-9, AV-2 Vs Kangrajat, BSS-449 Vs UPASI-9, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For length of 1st leaf of the shoot, the comparisons, namely, T-78 Vs UPASI-9, T-78 Vs Kangrajat, AV-2 Vs UPASI-9, AV-2 Vs

Kangrajat, BSS-449 Vs UPASI-9 and BSS-449 Vs Kangrajat were significant that means there was significant for this character.

For width of 1st leaf of the shoot, the comparisons, namely, T-78 Vs Kangrajat, AV-2 Vs BSS-449, AV-2 Vs Kangrajat, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat showed significant difference for this character.

For 100 seed weight, the comparisons, namely, T-78 Vs AV-2, T-78 Vs BSS-449, T-78 Vs Kangrajat, AV-2 Vs BSS-449, AV-2 Vs UPASI-9, AV-2 Vs Kangrajat, BSS-449 Vs UPASI-9, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

When all 10 characters were considered together then only two comparisons, namely, T-78 Vs Kangrajat and BSS-449 Vs Kangrajat which showed significant difference for 9 characters, namely, surface area of bush, length of mature leaf width of mature leaf, weight of the shoot, weight of the bud, length of the shoot, length of the 1st leaf of the shoot, width of 1st leaf of the shoot and 100 seed weight out of 10 characters. That means T-78 and Kangrajat are genetically most diverse genotypes. BSS-449 and Kangrajat also showed significant difference for 9 characters out of 10 characters.

Like wise, comparison between UPASI-9 and Kangrajat was showing significance for 8 characters. That means UPASI-9 and Kangrajat are very diverse genotypes. AV-2 and Kangrajat were also significantly different from each other for similar 8 characters, so they are also diverse genotypes.

UPASI-9 and T-78 showed significant difference for 5 characters so they are also diverse genotypes.

4.4.2 Comparison of variance

With variances of 5 varieties for each character, the following comparisons (Table 4.5) were made:

- T-78 Vs AV-2
- T-78 Vs BSS-449
- T-78 Vs UPASI-9
- T-78 Vs Kangrajat
- AV-2 Vs BSS-449
- AV-2 Vs UPASI-9
- AV-2 Vs Kangrajat
- BSS-449 Vs UPASI-9
- BSS-449 Vs Kangrajat
- UPASI-9 Vs Kangrajat

Table 4.5 Comparison of variances

		Character 1	Character 2	Character 3	Character 4	Character 5	Character 6	Character 7	Character 8	Character 9	Character 10
Genotype	1----2	1.816103 ns	1.334746 ns	3.131115 *	2.452554 ns	2.31538 ns	6.370842 **	1.373665 ns	2.717557 *	1.136363 ns	3.021762 *
	1----3	18.66675 **	2.697740 *	2.837573 *	1.12295 ns	1.456351 ns	1.982091 ns	1.642553 ns	2.738461 *	1.342222 ns	2.466811 ns
	1----4	62.16021 **	1.301471 ns	4.81409 **	1.729927 ns	1.533869 ns	6.582013 **	1.649572 ns	4.715231 **	2.404444 ns	2.786724 *
	1----5	46.23769 **	16.80791 **	1.133072 ns	2.227642 ns	5.882803 **	2.654674 *	3.926754 **	3.739495 **	2.107438 ns	1.026115 ns
Genotype	2----3	10.27847 **	2.021164 ns	1.103448 ns	2.754098 *	1.589849 ns	3.214201 *	1.195744 ns	1.007692 ns	1.525253 ns	1.224966 ns
	2----4	34.22725 **	1.737132 ns	1.5375 ns	1.417721 ns	1.509503 ns	1.033146 ns	1.200854 ns	1.735099 ns	2.732323 *	1.084342 ns
	2----5	25.45984 **	12.59259 **	2.763385 *	5.463414 **	2.54075 *	2.399858 ns	2.858596 *	1.37605 ns	1.636363 ns	2.944856 *
Genotype	3----4	3.329996 *	3.511029 *	1.696552 ns	1.942623 ns	1.053227 ns	3.32074 *	1.004273 ns	1.721854 ns	1.791391 ns	1.129687 ns
	3----5	2.477008 ns	6.230366 **	2.504317 *	1.983739 ns	4.03941 **	1.339329 ns	2.39064 ns	1.365546 ns	2.495867 *	2.404029 ns
Genotype	4----5	1.344362 ns	21.875 **	4.248704 *	3.853658 **	3.83527 **	2.479405 ns	2.380467 ns	1.260927 ns	4.471074 **	2.7158 *

* Significant at 5% level of significance

** Significant at 1 % level of significance

Genotypes

1. T-78
2. AV-2
3. BSS449
4. UPASI-9
5. Kangrajat

Characters:

1. Number of plucking points
2. Surface area of bush
3. Length of the mature (maintenance) leaf
4. Width of the mature (maintenance) leaf
5. Weight of the shoot
6. Weight of the bud
7. Length of the shoot
8. Length of 1st leaf of the shoot
9. Width of 1st leaf of the shoot
10. 100 seed weight

For character no. of plucking points, the comparisons, namely, T-78 Vs BSS-449, T-78 Vs UPASI-9, T-78 Vs Kangrajat, AV-2 Vs BSS-449, AV-2 Vs UPASI-9, AV-2 Vs Kangrajat and BSS-449 Vs UPASI-9 were significant for this character.

For surface area of bush, the comparisons, namely, T-78 Vs BSS-449, T-78 Vs Kangrajat, AV-2 Vs Kangrajat, BSS-449 Vs UPASI-9, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For character, length of mature leaf, the comparisons, namely, T-78 Vs AV-2, T-78 Vs BSS-449, T-78 Vs UPASI-9 AV-2 Vs Kangrajat, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For character, width of mature leaf, the comparisons, namely, AV-2 Vs BSS-449, AV-2 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For character, weight of the shoot, the comparisons, namely, T-78 Vs Kangrajat, AV-2 Vs Kangrajat, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For character, weight of the bud, the comparisons, namely, T-78 Vs AV-2, T-78 Vs UPASI-9, T-78 Vs Kangrajat, AV-2 Vs BSS-449, BSS-449 Vs UPASI-9 and BSS-449 Vs Kangrajat were significant.

For character, length of the shoot, the comparisons, namely, T-78 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For character, length of 1st leaf of the shoot, the comparisons, namely, T-78 Vs AV-2, T-78 Vs BSS-449, T-78 Vs UPASI-9 and T-78 Vs Kangrajat were significant.

For character, width of 1st leaf of the shoot, the comparisons, namely, AV-2 Vs UPASI-9, BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

For character, 100 seed weight, the comparisons, namely, T-78 Vs AV-2, T-78 Vs UPASI-9, AV-2 Vs Kangrajat and UPASI-9 Vs Kangrajat were significant.

When all the ten characters were considered together then comparison, AV-2 Vs Kangrajat was significant for 7 characters. That means AV-2 was significantly different from Kangrajat for 7 characters out of 10 characters for variances.

But in the comparison, AV-2 Vs UPASI-9, it was showing no significance for 8 characters. That means there was no significant difference between AV-2 and UPASI-9 for above 8 characters for variances. (See table 4.5).

When we considered mean and variance together for comparison then AV-2 and Kangrajat showed significant difference for six similar characters. That means AV-2 and Kangrajat are genotypically most diverse genotypes.

But comparison, T-78 Vs AV-2 showed no significant difference for similar five characters. That means T-78 and AV-2 are very similar genotypes.

4.5 Estimates of Character Association

Fo**r** different pair of characters, the correlation coefficients (phenotypic, genotypic and environmental) are presented in Table 4.6. Only three pair of traits, namely, number of plucking points, surface area of bush and length of mature leaf showed positive and significant phenotypic correlation with weight of the shoot, width of 1st leaf of the shoot and width of the mature leaf, respectively.

Surface area of bush showed negative and significant phenotypic correlation with weight of the shoot

4.6 Path Coefficient Analysis

With help of path coefficient analysis, we partition the correlation coefficient into cause and effects. Here we took the character, number of weight of the shoot as dependent variable and the rest nine different traits were used as independent variables (Table 4.7).

The four traits, namely, length of the mature leaf, width of the mature leaf, number of plucking points, and width of the 1st leaf of shoot showed high, positive and direct effects of 0.303, 0.246, 0.243 and 0.241, respectively on weight of the shoot. (See table 4.7)

Table: 4.6 Phenotypic, genotypic and environmental correlation coefficients between different pairs of traits

characters	No. of plucking points	Surface area of bush	Length of mature leaf	Width of mature leaf	Weight of the bud	Length of the shoot	Length of the 1st leaf of the shoot	Width of the 1st leaf of the shoot.	100 seed weight	Weight of the shoot
No. of plucking points		P -0.456 G -0.224 E -0.029	P 0.435 G 0.279 E -0.110	P 0.241 G 0.099 E -0.194	P -0.425 G -0.274 E -0.029	P -0.322 G -0.073 E 0.217	P -0.424 G -0.066 E 0.221	P 0.503 G 0.253 E 0.037	P 0.381 G 0.068 E 0.065	P 0.885* G 0.337 E 0.193
Surface area of bush			P -0.772 G -0.426 E -0.021	P -0.781 G -0.325 E 0.189	P -0.487 G -0.209 E 0.046	P -0.591 G -0.265 E -0.039	P -0.665 G -0.171 E 0.073	P 0.895* G 0.221 E 0.157	P -0.700 G -0.415 E -0.034	P -0.915* G -0.334 E -0.065
Length of mature leaf				P 0.983** G 0.887* E 0.535	P 0.325 G 0.246 E 0.031	P 0.731 G 0.497 E 0.115	P 0.683 G 0.391 E 0.128	P 0.505 G 0.632 E 0.159	P 0.514 G 0.467 E 0.014	P 0.658 G 0.513 E -0.003
Width of mature leaf					P 0.511 G 0.388 E 0.112	P 0.645 G 0.550 E 0.118	P 0.637 G 0.491 E 0.210	P 0.402 G 0.613 E 0.197	P 0.508 G 0.443 E 0.103	P 0.121 G 0.473 E 0.029
Weight of the bud						P 0.594 G 0.273 E -0.128	P 0.629 G 0.431 E 0.124	P 0.367 G 0.209 E 0.066	P 0.036 G 0.009 E -0.215	P 0.212 G 0.133 E 0.084
Length of the shoot							P 0.303 G 0.584 E 0.310	P 0.307 G 0.445 E 0.259	P 0.520 G 0.502 E 0.083	P 0.722 G 0.319 E 0.087
Length of the 1st leaf of the shoot								P 0.660 G 0.444 E 0.335	P 0.600 G 0.347 E 0.138	P 0.643 G 0.234 E 0.062
Width of the 1st leaf of the shoot									P 0.533 G 0.328 E 0.081	P 0.187 G 0.491 E 0.211
100 seed weight										P 0.692 G 0.358 E -0.043

* Significant at 5% level of significance

** Significant at 1% level of significance

Table: 4.7: Direct and indirect effects of different traits on number of plucking points

Characters	No. of plucking points	Surface area of bush	Length of mature leaf	Width of mature leaf	Weight of the bud	Length of the shoot	Length of the 1st leaf of the shoot	Width of the 1st leaf of the shoot.	100 seed weight
No. of plucking points	**0.2429**	0.0007	0.0118	0.0593	0.0182	-0.05	0.0279	0.0106	0.0156
Surface area of bush	-0.1108	**-0.0015**	-0.0097	-0.0331	0.0201	-0.0915	0.0437	-0.0179	-0.1343
Length of mature leaf	0.1059	0.0012	**0.3027**	0.0331	-0.0139	0.005	-0.0449	0.0295	0.0987
Width of mature leaf	0.0586	0.0012	0.0919	**0.2461**	-0.0219	0.027	-0.0550	0.0275	0.0976
Weight of the bud	-0.1034	0.0008	0.0986	0.0468	**-0.0428**	0.092	-0.0545	0.0887	0.0069
Length of the shoot	-0.0784	0.0009	0.0093	0.0171	-0.0254	**0.1549**	-0.0678	0.1707	0.1381
Length of the 1st leaf of the shoot	-0.1032	0.001	0.0079	0.1081	-0.0356	0.1599	**-0.0657**	0.0472	0.1151
Width of the 1st leaf of the shoot.	0.0021	0.0014	0.092	0.0259	-0.0158	0.0219	0.0434	**0.2412**	0.0793
100 seed weight	0.0197	0.001	0.0338	0.0262	-0.0015	0.1116	-0.0394	0.0157	**0.1917**

Residual factor : 0.1617

100 seed weight and Length of the shoot also had positive low direct effect 0.192 and 0.155, respectively on weight of the shoot.

The traits length of the 1st leaf of shoot (-0.0656), weight of bud (-0.0428) and surface area of bush (-0.0015), had negative direct effect on weight of the shoot.

The magnitude of residual effect is 0.1617 and it reveals that the characters included in the present study accounted for most of variation of dependent character (weight of the shoot)

Chapter 5 DISCUSSION

The use of estimates of genetic diversity in plant populations is of prime importance to a breeder for designing an effective breeding programme. Comparison of mean and variances, coefficient of variability, heritability, genetic advance, association between traits and path analysis will produce information on selection of a plant, cultivar, variety and trait(s) for inclusion in selection and breeding programme.

5.1 Analysis of variance

The data presented in the ANOVA table (4.1) shows that there are highly significant differences among all 5 varieties for all ten characters studied. The population means and range of means of characters revealed wide variability, indicating greater scope of selection. It clearly supports the observations and view recorded earlier by **Venkataramani (1962), Grice (1963) and Barua and Bezbaruah (1989)** that screening of large number of bushes may produce one elite clone.

The characters, namely, number of plucking points, surface area of bush, weight of the shoot and weight of the bud showed high phenotypic coefficient of variation (PCV). The characters, number of plucking points, surface area of bush and weight of the bud showed

high genotypic coefficient of variation (GCV). The characters, surface area of bush and weight of shoot showed high environmental coefficient of variation (ECV).

Length of mature leaf and length of 1st leaf of the shoot showed low phenotypic coefficient of variation (PCV). Length of 1st leaf of the shoot, width of 1st leaf of the shoot and length of the shoot showed very low genotypic coefficient of variation (GCV). 100 seed weight and length of mature leaf showed very low environmental coefficient of variation (ECV).

The character surface area of bush showed high phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV).

Length of mature leaf showed very low phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV).

100 seed weight showed low environmental coefficient of variation (ECV) but high phenotypic coefficient of variation (PCV). That means this character less influenced by the environment.

Besides coefficient of variability, the information on heritability is useful in predicting the expected progress to be achieved through selection. The concept of heritability provides a quantitative estimate of

relative importance of heredity and environment in character expression, which ultimately helps in planning an efficient breeding programme. The traits, namely, number of plucking points, length of mature leaf, width of mature leaf, weight of the bud, length of the shoot, and 100 seed weight showed higher broad sense heritability. One trait, weight of the shoot showed low broad sense heritability.

Johnson et al. (1955) emphasized that for estimating the real effects of selection, heritability alone is not sufficient, genetic advance along with heritability is more useful index for effective selection. In present study, higher genetic advance was observed in case of traits, such as, number of plucking points and 100 seed weight whereas lower genetic advance was observed in case of traits, such as, length of the mature leaf, length of the 1st leaf of the shoot and width of the 1st leaf of the shoot.

5.2 Comparison of mean and variance

5.2.1 Comparison of mean

When all 10 characters were considered together then only two comparisons, namely, T-78 Vs Kangrajat and BSS-449 Vs Kangrajat which showed significant difference for 9 characters. That means T-78 and Kangrajat are genetically most diverse genotypes. BSS-449 and

Kangrajat also showed significant difference for 9 characters out of 10 characters.

Like wise, comparison between UPASI-9 and Kangrajat was showing significance for 8 characters. This means UPASI-9 and Kangrajat are very diverse genotypes. AV-2 and Kangrajat were also significantly different from each other for similar 8 characters, so they are also diverse genotypes.

UPASI-9 and T-78 showed significant difference for 5 characters so they are less diverse genotypes.

T-78 Vs AV-2 showed significant difference for only three out of ten traits. So they appeared to very close genotypically.

5.2.2 Comparison of variance

When all the ten characters were considered together then comparison, AV-2 Vs Kangrajat was significant for 7 characters. That means AV-2 was significantly different from Kangrajat for 7 characters out of 10 characters for variances.

But the comparison, AV-2 Vs UPASI-9, was showing no significance for 8 characters. That means there was no significant difference between AV-2 and UPASI-9 for above 8 characters for variances. (See table 4.5).

When we considered mean and variance together for comparison then AV-2 and kangrajat showed significant difference for six similar characters. That means AV-2 and kangrajat are genotypically most diverse clones.

5.3 Studies on association among traits and path coefficient analysis

The estimate of phenotypic and genotypic correlation coefficient**s** **(Johnson *et al., 1955;* Al Jibouri *et al.*, 1958)** provides the base for identifying the characters for ideal plant type and indirect selection. Genetic correlation provides a measure of genetic association between characters and is used in selecting one trait for improving another trait. Genetic correlation may be accounted for linkage or pleiotropy as per **(Mode** and **Robinson, 1959)**.

In the present study, only three pair of traits, namely, number of plucking points, surface area of bush and length of mature leaf showed positive and significant phenotypic correlation with weight of the shoot, width of 1st leaf of the shoot and width of the mature leaf, respectively.

Surface area of bush showed negative and significant correlation with weight of the shoot.

A correlation simply measures the mutual association between two traits, whereas, the path coefficient analysis specifies the causes of

correlations and also measures their relative importance. Thus path analysis is obviously a useful tool to partition the correlation into cause and effects.

The traits, namely, number of plucking points, length of the mature leaf, width of the mature leaf and width of 1st leaf of the shoot showed high and positive direct effect on weight of the shoot.

Correlation studies has shown that trait, number of plucking points show positive and significant correlation with weight of the shoot and there was also positive correlation between length of mature leaf and width of mature leaf. So weight of the shoot can be improved by selecting traits either number of plucking points, length of the mature leaf or width of mature leaf.

Chapter 6 SUMMARY

Five varieties, namely, T-78, AV-2, BSS-449, UPASI-9 and Kangrajat were evaluated for studying the variability and association between ten traits, namely, number of plucking points, surface area of bush, length of mature leaf, width of mature leaf, weight of the shoot, weight of the bud, length of the shoot, length of the 1st leaf of the shoot, width of the 1st leaf of the shoot and 100 seed weight. These varieties were planted at Tea estate, Kausani, Almora during 1996. The tea estate is situated in the Kumaon hills of Himalayas at an altitude of 1730 m above the mean sea level.

The analysis of variance revealed sufficient genetic variability among the varieties for all ten characters. The coefficient of variability at the phenotypic level was highest for surface area of bush followed by weight of the bud and number of plucking points but least for length of the 1st leaf of the shoot. Genotypic coefficient of variability was highest for surface area of bush followed by weight of the bud and number of plucking points and lowest for length of the 1st leaf of the shoot followed by width of 1st leaf of the shoot. The environmental coefficient of variability was highest for surface area of bush but lowest for 100 seed weight. The estimates of broad sense heritability were high for

100 seed weight followed by length of mature leaf, weight of the bud and number of plucking points. The estimates of genetic advance were high for 100 seed weight followed by weight of the bud and number of plucking points.

When all ten characters were considered together then only two comparisons, namely, T-78 Vs Kangrajat and BSS-449 Vs Kangrajat which showed significant difference for nine characters That means T-78 and Kangrajat are genetically most diverse genotypes. Similarly BSS-449 and Kangrajat are also genetically diverse genotypes. Like wise, comparison between UPASI-9 and Kangrajat showed significant difference for eight characters. That means UPASI-9 and Kangrajat are also diverse genotypes. AV-2 and Kangrajat were also significantly different from each other for similar eight characters, so they were also diverse genotypes.

When variances for all the ten characters were considered together then comparison, AV-2 Vs Kangrajat was significant for seven characters. That means AV-2 was significantly different from Kangrajat for seven out of ten characters for variances.

When we considered mean and variance together for comparison then AV-2 and kangrajat showed significant difference for six similar

characters. That means AV-2 and kangrajat are genotypically most diverse genotypes.

Phenotypic correlation studies showed that only three pairs of traits, namely, number of plucking points and weight of the shoot, surface area of bush and width of 1st leaf of the shoot, length of mature leaf and width of the mature leaf showed positive and significant phenotypic correlation. Surface area of bush showed negative and significant correlation with weight of the shoot.

Path analysis revealed that only four traits, namely, length of the mature leaf, width of the mature leaf, number of plucking points, and width of the 1st leaf of shoot showed high, positive and direct effect on weight of the shoot.

Correlation and path analysis revealed that in tea, traits, number of plucking points, length of mature leaf, width of mature leaf and width of 1st leaf of the shoot can be considered important for improving the weight of shoots in tea.

BIBLIOGRAPHY

Allard, R. W. 1960. Principles of Plant Breeding. John Wiley and Sons Inc., New Work. pp. 485.

Amma, S. 1975. Selection of high yielding clones of tea plant (Japanese). *Japan Agricultural Research Quarterly*.8: 214-218

Anonymous. 1974. Annual Scientific Report, Tocklai Experiment Station, pp. 58-59

Anonymous. 2006-07. The economic survey, pp. 167-168.

Barua, D.N. 1963. Characteristics of the Tocklai released clones. *Two and A Bud.* 10 : 26-28

Barua, D.N. 1965. Selection of vegetative clones. *Tocklai Experimental Station, Jorhat. Serial No.* 163 pp. 11-18

Barua, D.N. 1989. Science and practice in tea culture. *Tea Research Association, Calcutta, Jorhat.* 1st edition , pp. 172-173

Barua, D.N. and Dutta, K.N. 1971. Distribution of shoots in plucking surface of tea bush in relation to relation to spacing. *Two and A Bud.* 18: 8-11

Barua, D.N. and Bezbaruah, H.P. 1989. Selection of clones. Tea Research Association. *Tea Encyclopedia.* 204: 1-8

Barua, P.K. 1965. Classification of tea plant species hybrids. *Two and Bud. Tocklai Experimental Station.* 12: 13-27

Bezbaruah, H.P. 1968. Genetic improvement of tea in North-East India its problems and possibilities. *Indian Journal of Genetics and Plant Breeding.* 28 : 126-134

Bezbaruah, H.P. 1969. Economics of a selection scheme. Proceedings of 24th Tocklai Conferrence.

Bezbaruah, H.P. 1975. Pollination in tea [*Camellia sinensis* (L.) O. Kuntze] in North- East India. *Two and A Bud.* 22: 61-63

Bezbaruah, H.P. 1976. Aneuploidy in tea. *Nucleus* 19: 3, 167-169

Bezbaruah, H.P. 1975. Development of flower, pollination and seed-set in tea in North-East India. *Two and A Bud.* 22: 1, 25-30

Bezbaruah, H.P. 1974. Pollination in tea [*Camellia sinensis* (L.) O. Kuntze] in North- East India. *Journal of Plantation Crops.* 2: 2, 6-8

Bezbaruah, H.P. and Dutta, A.C. 1977. Variation in self and cross compatibility in tea- a summary of 40 years of pollination results of Tocklai. *Two and A Bud.* 24 : 22- 30

Bhatia, I. S. 1959. The chemical aspects of tea manufacture. *The Commercial Times. Tea issue,* pp.1-3

Bhatia, I. S. 1964. The role of chemistry in tea manufacture. *Two and A Bud.* XI: 109-117

Bhatia, I. S. and Ullah, M.R. 1961. Oxidation of l- epicatechol gallate during the processing of Assam tea leaf. Chemestry and Industry, pp. 1169.

Bhatia, I. S. and Ullah, M.R. 1968. Polyphenols of tea-IV. Qualitative and quantitative study of the polyphenols of different organs and some cultivated varieties of tea plant. *Journal of Science of Food and Agriculture.* 19: 535-542

Blauch, J.L. and Tarka Jr., S.M. 1983. HPLC determination of caffeine and theobromine in coffe, tea and instant hot cocoa mixes. *Journal of Food Science.* 48: 745-750

Burton, G.W. and Devane, E.H. 1953. Estimating heritability in tall Fescue [*Festuca arundinaceia*] from replicated clonal material. *Agronomy Journal.* 45: 478-481

Chen, J.; Wang, P.; Xia, Y.; Xu, M. and Pei, S. 2005. Genetic diversity and differentiation of *Camellia sinensis* L. (cultivated tea) and its wild relatives to Yunnan province of China, revealed by morphology, biochemistry and allozyme studies. *Genetic Resources and Crop Evolution.* 52 (1): 41-52

Cloughley, J.B. 1982. Factors influencing the caffeine content of black tea. Part- 1. The effect of field variables. *Food Chemestry.* 9: 269-276

Cohen Stuart, C.P. 1929. Researches on the leaf yielding capacity of tea plants (Dutch). *Archives Theaculture, Netherland Industry.* 3: 245-321

Cohen Stuart, C.P. 1930. Researches on the leaf yielding capacity of tea plants (Dutch). *Archives Theaculture, Netherland Industry.* 4: 276-288

Das, D.N., Ghosh, J.J., Bhattachariya, K.C.and Guha, B.C. 1965. *Indian Journal of Applied Chemestry.* 28: 15

Dev Choudhury, M.N. 1980. Role of some chemical constituents in tea quality. Paper read in the 3rd meeting of the society of Biological Chemists, Jorhat Branch, Tocklai Experimental Station, Assam.

Dev Choudhury, M.N., Rahman, F. and Barbora, B.C. 1991. Caffeine content in teas of North-East India, A Review. *Two and A Bud.* 38: 3-8

Devanathan, M.A.V. 1976. The quantification of coefficient analysis of crested wheat grass seed production. *Agronomy Journal.* 51: 515-518

Dewey, D.R. and Lu, K.H. 1959. Correlation and path coefficient analysis of crested wheat grass seed production. *Agronomy Journal.* 51: 515-518

Dogra, R.K. and Paul, S. 2001. Genetic variability in local selections of tea [*Camellia sinensis* (L.) O. Kuntze] in Himachal Pradesh. *Himachal Journal of Agricultural Research.* 27 (1/2): 71-76

Evans, D.I. 1930. Report of the Biochemist for 1929. *Report on Tea Research Institute, Ceylon Bulletin No.* 4: 20-28

Fang, Y.; Meng, Z.; Li, X.; Qiao, Y.; Mei, L. and Liang,Y. 2004. Analysis of anatomical structure on tea leaves in Shandong Province. *Journal of Tea Science.* 24(3): 190-196

Fordham, R. and Holgate, M. 1972. Estimation of leaf area of tea [C*amellia sinensis* L.] from linear measurements. *Journal of Horticutural Science.* 47: 2, 131-135

Green, M.J. 1965. Report of the Tea Research Institute of East Affrica, pp.58-59

Green, M.J. 1971. An evaluation of some criteria used in selecting large yielding tea clones. *Journal of Agricultural Science.* 76: 143-156

Grice, W.J. 1963. Bush selection and vegetative propagation in Darjeeling. *Indian Tea Association, Darjeeling Memorandum No*. 3: 1-22

Grice, W.J. 1969. A second progress report on the yield of tea clones receiving two levels of nitrogen at maturity. *Two and A Bud.* 16: 46-48

Gulati, Asha and Ravidranath, S.D. 1996. Seasonal variation in quality of Kangra tea [C*amellia sinensis* (L.) O. Kuntze] in Himachal Pradesh. Journal *of Science of Food and Agriculture.* 71: 231-236

Harada, S. 1957. Studies on utilization of polyploidy in the tea plant I (Jap. With Eng. summ.). *Study of Tea, Tokai-Kinki Agr. Sta..* 17: 7-12

Harrison, C.J. and Bose, S.S. 1942. Sankhya, *Indian Journal of Statistics* 16, 151. Pauling, L. 1969. "College of Chemistry". 4th Indian reprint, Vakils, Feffer and Simons Private Limited, Bombay, pp.718.

Hayes, H.K., Immer, F.H. and Smith, D.C.1955. Methods of plant breeding. McGraw- Hill Book Company, Incorporation New York, London, Toronto. *Student Edition,* pp. 439

Herd, E.M. and Squire, G.R. 1976. Observations on the winter dormancy in Malawi. *Journal of Horticultural Science.* 51: 267-279

Jayasurya, P. and Govindarajulu, V. 1975. Chromosome numbers in some tea clones. *Planters' Chronicle, India* .70: 7, 185-186

Johnson, H.W., Robinson, H.F. and Comstock, R.C. 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy Journal.* 47: 314-318

Kingdom-Ward, F. 1950. Does wild tea exit? *Nature,* 165: 297-298

Kirthisinghe, D. 1968. Report of technologist for 1967. *Annual Report of Tea Research Institute Ceylon.* Part-II pp. 112-116

Kirthisinghe, D. 1971. Report of technologist for 1970. *Annual Report of Tea Research Institute Ceylon.* Part-II, pp. 112-116

Krishnapillai, S. and Pethiyagoda, U. 1978. *Tropical Agriculture* (Trinidad). 55 : 351-358

Magambo, M.J.S. 1977. Canopy characteristics of seven clones of tea [C*amellia sinensis* L.] estimated by the use of inclined point quadrats. *Tropical Agriculture.* 54: 3, 205-211

Magambo, M.J.S. and Cannell, M.G.R. 1981. Dry matter production and partition in relation to yield of tea. *Experimental Agriculture.* 17: 33-38

Magambo, M.J.S. and Waithaka, K. 1985. The effect of pruning at different heights on yields, dry matter production and partitioning in clonal tea [C*amellia sinensis*] in Kenya. *Experimental Agriculture.* 21: 67-72

Mamati, G.E. 2001. Tea: Trends of improvement in Kenya. *Tea.* 22 (2): 125-130

Matsushita, s. 1969. Tasting for the important characters in the early stage of Assam hybrid tea plant l. Correlation of the main characters between seedlings and those clones (Japanese). *Kyushu Agricultural Researc.h* 31: 71-72

Millin, D.J., Crispin, D.J. and Swaine, D. 1969. Nonvolatile components of black tea and their contribution to the character of the beverage. *Journal of Agriculture and Food Chemestry.* 17: 717-722

Millin, D.J. and Rustidge, D.W. 1967. Teas manufacture process. *Biochemistry.* 2: 9-13

Mukhopadhyay, A.N. 2004. Tea research and development- Present status and future strategies for Northeast India. *International Journal of Tea Science*. Vol. 3: 311-317

Nyirenda, H.E. 1987. Selection criteria for high productivity and vigour in Tea [C*amellia sinensis* (L.) O. Kuntze]. Ph. D. thesis. University College of Wales.

Nyirenda, H.E. 1989. Effectiveness of assessment of vigour and productivity in young varieties. old bushes and mature clones of tea [*Camellia sinensis*]. *Annals of Applied Biology.* 115: 327-332

Nyirenda, H.E. 1991. Use of growth measurements and foliar nutrient content as criteria for clonal selection in tea (*Camellia sinensis*). *Experimental Agriculture.* 27: 47-52

Nyirenda, H.E. and Kayange, C.W. 1984. Effect of root stock on components of yield in tea [*camellia sinensis* (L.) O. Kuntze] 2-stem circumference and number of branches. *Journal of Horticultural Science.* 59: 589-594

Nyirenda, H.E. and Ridpath, V.E.T. 1984. Criteria for clonal selection in tea [*Camellia sinensis* L.]. l. The relation between mother bushes and their clonal derivatives for bush area, shoot number and yield. *Experimental Agriculture.* 20: 339-343

Owour, P.O. and Chavanji, A.M. 1986. Caffeine content in clonal tea. Seasonal variation and effects of plucking standard under Kenyan conditions. *Food Chemistry.* 20: 225-233

Paul, S., Misra, S.K. and Gupta, V.P. 1995. Evaluation, enhancement and conservation of tea germplasm in Kangra Valley. *Indian Journal of Plant Genetic Resources.* 8 : 209-213

Paul, S., Sharma, D.K., Sharma, K.L. and Misra, S.K. 1994. Genetic variability for yield and quality in tea [*Camellia sinensis*] clones. *Indian Journal of Agricultural Science.* 64: 314-319

Pethiyagoda, U. and Rajendram, N.S. 1965. *Tea Quarterly.* 36: 48-58

Pool, P.A. and Nyirenda, H.E. 1981. Effects of rootstocks on the components of yield in tea [*Camellia sinensis* L.]. *Journal of Horticultural Science.* 56:121-123

Portsmouth, G. B. 1957. Interclonal variations in the effects of apical dominance. *Tea Quarterly.* 28 : 30-43

Rahman, F. 1977. Plucking of mature tea. *Two and A bud.* 24: 3-7

Ramaswamy, M.S. 1964. Chemival basis of liquoring characteristics of Ceylon tea. 3. The effect of elevation and climatic conditions on the composition of tea liquors. *Tea Quarterly.* 35 : 164-167

Ranatunga, M.A.B. and Gunashekare, M.T.K. 2003. A comparative assessment of some morphological and anatomical attributes to identify markers for screening polyploidy genotypes of tea [*Camellia sinensis* L.]. *Sri Lanka Journal of Tea science.* 68 (1): 12-19

Roberts, E. A. H. 1952. Chemistry of tea fermentation. *Journal of Science of Food and Agriculture.* 3: 19-21

Roberts, E. A. H. 1962. Economic importance of flavonoid substances ; tea fermentation. The chemistry of Flavonoid substances, Geissman T.A. (ed). Pergamon Press, Oxford. pp. 468-512

Robinson, H.I., Comstock, R.E. and Harvey, P.H. 1951. Genotypic and phenotypic correlation in corn and their implications in selection. *Agronomy Journal.* 43: 282-287

Sanderson, G. W. 1964. The chemical composition of fresh tea flush as affected by clone and climate. *Tea Quarterly.* 35:101-109

Sanderson, G. W. and Kanapathipillai, P. 1964. Further studies on the effect of climate on the chemical composition of fresh tea flush. *Tea Quarterly* 35: 222-229

Sebastiampillai, AR. 1976. A simple technique for the induction of polyploids in tea. *Tea Quarterly.* 46: 1-2, 12-15

Sealy, J. 1937. Species of Camellia in cultivation. *Horticultural Society.* 62: 352-369

Sealy, J. 1948. *Camellia sinensis*. Curtis' Bot. Mag. 164: 9684

Sealy, J. 1958. A revision of the genus Camellia. *Royal Horticultural Society, London.* 62: 211-213

Sharma, K. L. 1987. Studies on the effect of different sources of nitrogenous fertilizers on the yield and quality of chinary hybrid type of tea [*Camellia sinensis* L.] grown in Himachal Pradesh. Ph. D. thesis. Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, H.P.

Simura, T. 1952. On the morphology of tea plant- Morphology and Physiology of the triploid plants. *Study of tea* .7: 9-14

Singh, I.D. and Chakraborty, S. 1993. Application of biometrical genetics in tea breeding. *Two and A Bud.* 40: 11-14

Singh, I.D. and Chakraborty, S. and Bordoloi, S.C. 1995. Estimates of genetic variability of yield in tea [*Camellia sinensis* L.] in North-East India. *Indian Journal of Genetics and Plant Breeding.* 55 : 20-23

Singh, I.D. and Chakraborty, S. and Prodhan, S.K. 1993. Genetic variability, heritability and genetic advance of yield in tea [*Camellia sinensis* L.]. *Two and A Bud.* 40: 38- 40

Stebbins, J.R. and Ledyard, G. 1967. Variation and Evolution in Plants. New Yord and London : Columbia University Press.

Sud, R.G and Badyal, J. 1989. varietal and seasonal variations in chemical constituents of tea [C*amellia sinensis* (L.) O. Kuntze] in Himachal Pradesh. *Sri Lanka Journal of Tea Science.* 58: 73-78

Sud, R.G and Bhattacharjee, B.K. 1990. Quality evaluation of tea [*Camellia sinensis*] of Kangra valley. *Indian Journal of Agricultural Sciences.* 60: 660-664

Sud, R.G and Sharma, K.L. 1991. Chemical analyses of green tea shoots-I. Seasonal variations of soluble matter, caffeine, polyphenols and various nitrogenous fractions. *Himachal Journal of Agricultural Research.*17: 43-46

Squire, G.R. 1979. Weather, physiology and seasonality of tea yields in Malawi. *Experimental Agriculture.* 15: 321-330

Tanton, T.W. 1981. Growth and yield of tea bush. *Experimental Agriculture.* 17: 323-331

Tanton, T.W. 1982. Environmental factors affecting the yields of tea. l. Effect of soil temperature, day light and dry air. *Experimental Agriculture.* 18: 53-63

Toyao, T. 1965. Correlation and genetical analysis of several characteristics of the tea plant at stage of individual selection of the tea plant. *Study of tea.* 30: 1-4 (Plant Breeding Abs. 1966: 4662)

Tsujimura, M. 1934. Scientific papers. *Institute of Physical Chemistry Research (Tokyo).* 24: 149

Tubbs, F.R. 1931. The germination of tea seeds. *Tea Quarterly.* 5: 66-69

Tunstall, A.C. 1932. Annual report. *Indian Tea Ass. Sc. Dept. for* 1932. pp.39-50

Varghese, M.A. 1977. Towards attaining 150 million kg tea production in 1985. Optimizing plucking systems for maximum harvest. *Proceedings: First Joint Area Scientific Seminar, UPASI. Tea Scientific Department.*34: 35-48

Vavilov, N.I.1951. The origin, variation, immunity and breeding of cultivated plants. Transactions from Russia by Chester, K.S. *Chronica Botanica.*13: 1-364

Venkataramani, K.S. 1961. The effect of growth substances on rooting of tea cutting. *Annual Report UPASI Sci. Department Tea Sect. for* 1959/60: 49-58

Venkataramani, K.S. 1962. First progress report on tea selection. *Annual Report, UPASI Scientific Department, Tea Section.* 62: i-vii

Venkataramani, K.S. 1963. Second progress report on tea selection. UPASI. *Tea Section Department Bulletin.* 22: i-v

Venkataramani, K.S. 1972, 1974. Yield and quality criteria in tea clonal selection. Proceedings of the First National Symposium on Plantation Crops, December 8-9: 7-10; 14 ref

Visser, T. 1961. Report of the plant physiologist. *Annual Report Tea Research Institute Ceylon, pp.* 84-87

Visser, T. 1969. Outlines of perennial crop breeding in tropics. Ferwerda, F.P., Veenhman, H., Wit. F. and Zonen, N.V., (eds.) Wageningen, The Netherlands pp. 459-493

Visser, T. and Kehl, F.H. 1958. Selection and vegetative propagation of tea. *Tea Quarterly.* 29: 76-86

Wachira, F.N. 1994. Triploidy in tea [*Camellia sinensis*]; effect on yield and yield attributes. *Journal of Horticultural Science.* 69: 53-60

Wellensiek, S.J. 1938. Flower biology and crossing technique in tea (Dutch). Archives Theaculture, Netherland Industry 12: 127-140

Wickramaratne, M.R.1981. Variation in some leaf characteristics in tea [*Camellia sinensis* L.] and their use in the identification of clones. *Tea Quarterly.* 50: 183-189

Wright, S. 1921. Correlation and causation. *Journal of Agricultural Research* 20: 557-585

Wight, W. 1956. Commercial selection and breeding of tea in India. *World Crops.* 8: 263-268

Wight, W. 1953. Toklai Experimental Station Annual Report – 34-43

Wight, W. 1962. The classification revised. *Cuss. Sc.* 31: 289-299

Wight, W. and Barua, P.K. 1954. Morphological basis of quality in tea. *Nature.* 173: 630-631

Wood, D.J., Bhatia, I.S., Chakraborty, S., Dev Choudhury, M.N., Deb, S.B., Roberts, E.A.H. and Ullah,M.R. 1964. The chemical basis of quality in tea. l. Analysis of freshly plucked shoots. *Journal of Science of Food and Agriculture.* 15: 8-25

Wu, C.; Fong, J. and Tauy, J. 1972. Observation on the morphological characters of wild tea on Mt. Meiyuan, Taiwan. II. *Taiwan Agricultural Quarterly.* 8 :3, 133-160; 7 plant.; 10 ref

Yanaka, J.; Kurihara, D. and Yamaguchi, S. 2002. Seed and pollen parents affect the weight of F1 seeds and the number of days until emergence in tea. *Japan Agricultural Research Quarterly.* 36 (4) : 189-193

Yaminishi, Tei. 1990. Bitter compounds in tea. In: Bitterness in foods and beverages (ed. Russell L. Rouseff) Elsevier, pp. 159-168

VITA

The author was born on 11th april 1982 He passed his High School from pantnagar inter college, pantnagar with 54 % marks and intermediate from pantnagar inter college, pantnagar with 66.4 % marks. Then he joined Govind Ballabh Pant University of Agriculture & Technology, Pantnagar in 2000 for his B.Sc. Agriculture and completed his degree in 2004 with 79.57 % marks. There after he joined College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar in 2005 for M.Sc. (Agriculture) with major in Genetics and Plant Breeding and minor in Molecular Biology and Biotechnology and in the year 2006 he completed his M.Sc. programme.

Address:
Jitendra Bhaskar
S/o Sri. R. D. Bhaskar
Q. No. 651/22, Chakferi Double Storey, Pantnagar
District- Udham Singh Nagar
Uttrakhand-263145

ABSTRACT

Name : **Mr. Jitendra Bhaskar** **ID.No. : 27940**

Semester : **First, 2005-2006** **Degree: M.Sc.Ag**

Major : **Genetics and plant breeding**

Minor : **Molecular biology and biotechnology**

Department : **Genetics and plant breeding**

Thesis Title : **"Correlation and path analysis in tea [*Camellia sinensis* (L). O. Kuntze]**

Advisor : **Dr. D. Roy**

The field experiment was conducted on five varieties at Tea Research Station, Kausani, Uttarakhand to understand nature and magnitude of variation present among the tea germplasm and to characterize the different clones. Data were recorded on ten characters for each genotype. The phenotypic coefficient of variability was highest for surface area of bush followed by weight of the bud and number of plucking points but lowest for length of the 1st leaf of the shoot. Genotypic coefficient of variability was highest for surface area of bush followed by weight of the bud and number of plucking points and lowest for length of the 1st leaf of the shoot followed by width of 1st leaf of the shoot. 100 seed weight, length of mature leaf, weight of the bud and number of plucking points showed high heritability. The genetic advance was high for 100 seed weight followed by number of plucking points and weight of the shoot. Comparison of mean showed that T-78 Vs Kangrajat**,** BSS-449 Vs Kangrajat and UPASI-9 Vs Kangrajat, combinations are genetically diverse. Comparison of variance shows that AV-2 and Kangrajat are genetically diverse genotypes. Comparison of both mean and variance shows that AV-2 and kangrajat are genotypically most diverse genotypes.

Correlation coefficients at the genotypic level reveal that only three pair of traits, namely, number of plucking points and weight of the shoot, surface area of bush and width of 1st leaf of the shoot, length of mature leaf and width of the mature leaf showed positive and significant phenotypic correlation. Surface area of bush showed negative and significant correlation with weight of the shoot.

Path analysis revealed that only four traits, namely, length of the mature leaf, width of the mature leaf, number of plucking points, and width of the 1st leaf of shoot showed high, positive and direct effect on weight of the shoot.

Correlation and path analysis revealed that in tea, traits, number of plucking points, length of mature leaf, width of mature leaf and width of 1st leaf of the shoot can be considered important for improving the weight of shoot in tea.

(Dr. D. Roy)
Advisor

(Jitendra Bhaskar)
Author