

**STUDIES ON  
VARIABILITY, GENETIC DIVERGENCE  
AND CROP IMPROVEMENT IN TEA  
(*Camellia assamica* (Masters) Wight)**

*Thesis submitted in part fulfilment of requirements for  
the Degree of Doctor of Philosophy in Botany  
of the University of Calicut*

by

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**CERTIFICATE**

Certified that this thesis entitled “**STUDIES ON VARIABILITY, GENETIC DIVERGENCE AND CROP IMPROVEMENT IN TEA (*Camellia assamica* (Masters) Wight)**”, embodies the results of a piece of bona fide research work carried out as part fulfilment of requirements for the degree of Doctor of Philosophy in Botany of the University of Calicut by Mr. B. Ramasubramanian under my guidance and supervision and that no part of the thesis has been submitted for any other degree.

I further certify that all helps and sources of information availed of in this connection have been duly acknowledged.

Calicut University  
10 June 2005




  
(K.V.MOHANAN)

## DECLARATION

This is to declare that the thesis entitled “**STUDIES ON VARIABILITY, GENETIC DIVERGENCE AND CROP IMPROVEMENT IN TEA (*Camellia assamica* (Masters) Wight)**” submitted by me for the degree of Doctor of Philosophy in Botany of the University of Calicut has not formed the basis for the award of any other degree/ diploma.

Calicut University

10 June 2005

  
**B.Ramasubramanian**

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**Dedicated to my parents**

**G. BALAKRISHNAN**

**B. LAKSHIMI**

**(They made me who am I)**

# CONTENTS

## PREFACE

## LIST OF TABLES

## LIST OF FIGURES

<b>Chapter 1</b>	<b>INTRODUCTION</b>	<b>1</b>
<b>1.1</b>	<b>Cultivated species of tea</b>	<b>1</b>
1.1.1	China tea ( <i>Camellia sinensis</i> (L) O. Kuntze)	3
1.1.2	Assam tea ( <i>Camellia assamica</i> (Masters) Wight)	3
1.1.3	Cambod tea ( <i>Camellia assamica</i> ssp. <i>lasiocalyx</i> (Planch, ex Watt) Wight)	4
<b>1.2</b>	<b>Morphology of tea plants</b>	<b>4</b>
<b>1.3</b>	<b>Ecoclimatic requirements</b>	<b>4</b>
<b>1.4</b>	<b>Origin and variability</b>	<b>5</b>
<b>Chapter 2</b>	<b>REVIEW OF LITERATURE</b>	<b>8</b>
<b>2.1</b>	<b>Taxonomy</b>	<b>8</b>
<b>2.2</b>	<b>Origin and distribution</b>	<b>9</b>
<b>2.3</b>	<b>Morphology</b>	<b>10</b>
<b>2.4</b>	<b>Floral biology</b>	<b>10</b>
<b>2.5</b>	<b>Pollination</b>	<b>11</b>
<b>2.6</b>	<b>Development of fruit</b>	<b>11</b>
<b>2.7</b>	<b>Seeds and seed germination</b>	<b>12</b>
<b>2.8</b>	<b>Cytology</b>	<b>12</b>
<b>2.9</b>	<b>Physiology</b>	<b>13</b>
2.9.1	Photosynthesis	13
2.9.2	Dry matter accumulation and harvest index	14

	<b>2.10</b>	<b>Crop improvement</b>	14
	2.10.1	Exploitation and conservation of genetic resources	15
	2.10.2	Selection	16
	2.10.3	Vegetative propagation of tea	19
	2.10.4	Development of biclonal seed stock	20
	2.10.5	Evaluation of cultivars	20
	<b>2.11</b>	<b>Molecular studies</b>	21
<b>Chapter 3</b>		<b>MATERIALS AND METHODS</b>	23
	<b>3.1</b>	<b>Nursery experiment</b>	41
	<b>3.1.1</b>	<b>Planting of single nodal cuttings/ seeds</b>	41
	<b>3.1.2</b>	<b>Nursery observations</b>	42
	3.1.2.1	Percentage of survival	42
	3.1.2.2	Root growth	42
	3.1.2.3	Shoot growth	43
	<b>3.2</b>	<b>Field experiments</b>	43
	<b>3.2.1</b>	<b>Juvenile growth pattern and juvenile performance of Assam tea</b>	44
	3.2.1.1	Shoot weight- three leaves and a bud	45
	3.2.1.2	Internodal length (B&F)	45
	3.2.1.3	Internodal length (F&S)	45
	3.2.1.4	Internodal length (S&T)	45
	3.2.1.5	Leaf angle	45
	3.2.1.6	Leaf area	46
	3.2.1.7	Number of branches	46
	3.2.1.8	Branch angle	46
	3.2.1.9	Branch length	46
	3.2.1.10	Chlorophyll content	46
	3.2.1.11	Proline content	47

3.2.1.12	Protein content	47
3.2.1.13	Polyphenol content	47
3.2.1.14	Catechin content	48
<b>3.2.2</b>	<b>Genetic control of characters in Assam tea</b>	49
<b>3.2.3</b>	<b>Genetic variability in Assam tea</b>	49
3.2.3.1	Analysis of variance	50
3.2.3.2	Phenotypic and genotypic variance	50
3.2.3.3	Coefficients of variation	50
3.2.3.4	Heritability (broad sense)	51
3.2.3.5	Genetic advance under selection	51
<b>3.2.4</b>	<b>Correlation of characters in Assam tea</b>	51
<b>3.2.5</b>	<b>Character association in Assam tea</b>	51
<b>3.2.6</b>	<b>Genetic divergence in Assam tea</b>	52
<b>3.2.7</b>	<b>Comparative analysis of overall performance of the Assam tea cultivars studied</b>	52
<b>Chapter 4</b>	<b>RESULTS AND DISCUSSION</b>	53
<b>4.1</b>	<b>Nursery experiment</b>	53
4.1.1	Percentage of survival	53
4.1.2	Root growth	57
4.1.3	Shoot growth	59
<b>4.2</b>	<b>Field experiments</b>	69
<b>4.2.1</b>	<b>Juvenile growth pattern in Assam tea</b>	69
4.2.1.1	Shoot weight of three leaves and a bud	69
4.2.1.2	Internodal length (B&F)	73
4.2.1.3	Internodal length (F&S)	77
4.2.1.4	Internodal length (S&T)	81

4.2.1.5	Leaf angle	85
4.2.1.6	Leaf area	89
4.2.1.7	Number of branches	93
4.2.1.8	Branch length	97
4.2.1.9	Branch angle	101
4.2.1.10	Chlorophyll content	105
4.2.1.11	Proline content	109
4.2.1.12	Protein content	113
4.2.1.13	Polyphenol content	117
4.2.1.14	Catechin content	121
<b>4.2.2</b>	<b>Juvenile growth index in Assam tea</b>	<b>125</b>
<b>4.2.3</b>	<b>Genetic control of characters in Assam tea</b>	<b>133</b>
4.2.3.1	Growth characters	133
4.2.3.2	Phytochemical characters	141
<b>4.2.4</b>	<b>Genetic variability in Assam tea</b>	<b>145</b>
4.2.4.1	ANOVA (Analysis of variance)	146
4.2.4.2	Phenotypic and genotypic variation	150
4.2.4.3	Heritability (broad sense)	151
4.2.4.4	Genetic advance under selection	152
<b>4.2.5</b>	<b>Correlation of characters in Assam tea</b>	<b>152</b>
<b>4.2.6</b>	<b>Character association in Assam tea</b>	<b>155</b>
<b>4.2.7</b>	<b>Genetic divergence in Assam tea</b>	<b>158</b>
<b>4.2.8</b>	<b>Performance analysis in Assam tea</b>	<b>161</b>
<b>Chapter 5</b>	<b>SUMMARY AND CONCLUSION</b>	<b>168</b>
	<b>REFERENCES</b>	<b>174</b>

## PREFACE

Tea is the most widely drunk non alcoholic beverage. The tender shoots of three taxa of the genus *Camellia*- *C. sinensis* (China tea), *C. assamica* (Assam tea) and *C. assamica* ssp. *lasiocalyx* (Cambod tea) yield commercial tea.

China tea is narrow leaved, Assam tea broad leaved and Cambod tea with intermediate leaves. Tea plants are trees by nature, but they are pruned to convenient height so as to increase the production of pluckable shoots and also to make the process of plucking easier.

The Indian subcontinent is rich in genetic diversity of tea and proper evaluation of the genetic resources may enhance the scope of selection and other breeding programmes to improve tea production and the quality of tea produced.

The present study is a humble effort to screen the diversity of Assam tea so as to study the juvenile growth pattern of the crop, to assess the extent of genetic variability of it, to generate new information on the genetics of agronomic characters of the crop and also to analyze the nature and distribution of such characters on a plant breeding perspective.

## LIST OF TABLES

3.1. Accessions of Assam tea used for the present study	23
3.2. Weather data of the study area (2001)	26
3.3. Weather data of the study area (2002)	26
3.4. Weather data of the study area (2003)	27
3.5. Weather data of the study area (2004)	27
3.6. Morphological and phytochemical characters studied	44
4.1. Percentage of survival of seedlings/ cuttings after six months of nursery planting in the fifty accessions of Assam tea studied	54
4.2. Root growth of one year old plants in the fifty accessions of Assam tea studied	57
4.3. Shoot growth of one year old plants in the fifty accessions of Assam tea studied	63
4.4. Variation of shoot weight of three leaves and a bud (g) in juvenile plants of the fifty accessions of Assam tea studied	70
4.5. Variation of internodal length between bud and first leaf in juvenile plants of the fifty accessions of Assam tea studied (cm)	73
4.6. Variation of internodal length between first and second leaf in juvenile plants of the fifty accessions of Assam tea studied (cm)	77
4.7. Variation of internodal length between second and third leaf in juvenile plants of the fifty accessions of Assam tea studied (cm)	81
4.8. Variation of leaf angle in juvenile plants of the fifty accessions of Assam tea studied (degrees)	85

4.9.	Variation of leaf area (cm <sup>2</sup> ) between bud and first leaf in juvenile plants of the fifty accessions of Assam tea studied	89
4.10.	Variation of number of branches in juvenile plants of the fifty accessions of Assam tea studied	93
4.11.	Variation of branch length in juvenile plants of the fifty accessions of Assam tea studied (cm)	97
4.12.	Variation of branch angle in juvenile plants of the fifty accessions of Assam tea studied (cm)	101
4.13.	Variation of total chlorophyll content in juvenile plants of the fifty accessions of Assam tea studied (mg/g weight of leaf)	105
4.14.	Variation of proline content in juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)	109
4.15.	Variation of protein content in juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)	113
4.16.	Variation of polyphenol content in juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)	117
4.17.	Variation of catechin content in juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)	121
4.18.	Juvenile growth index in the case of the fifty accessions of Assam tea studied (value points attributed to the accessions in relation to characters)	126
4.19.	Juvenile growth index in the case of the fifty accessions of Assam tea studied (growth indices in relation to each character and total growth indices of accessions)	129
4.20.	Frequency distributions of growth characters of Assam tea studied	133
4.21.	Frequency distributions of phytochemical characters of Assam tea studied	141

4.22. Variability of growth characters in the case of the fifty accessions of Assam tea studied	147
4.23. Variability of phytochemical characters in the case of the fifty accessions of Assam tea studied	149
4.24. Correlation coefficients of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied	154
4.25. Factor analysis of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied (percentage of variance contributed by each factor and cumulative percentage of variance)	156
4.26. Factor analysis of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied- factor loadings	156
4.27. Factor analysis of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied- character association	157
4.28. Cluster analysis in the case of the fifty accessions of Assam tea studied	159
4.29. Performance analysis in the case of the fifty accessions of Assam tea studied (value points attributed to accessions in relation to characters)	162
4.30. Performance analysis in the case of the fifty accessions of Assam tea studied (performance index in relation to characters and overall performance index)	164
4.31. Performance analysis in the case of the fifty accessions of Assam tea studied- the best ten performers	167

## LIST OF FIGURES

1.1. Three leaves and a bud- the economically important part of the tea plant	2
3.1. Variability of the mother leaf in the case of the accessions of Assam tea studied	28
4.1. Percentage of survival of seedlings/cuttings six months after nursery planting in the fifty accessions of Assam tea studied	56
4.2. Root length (cm) of one year old plants in the fifty accessions of Assam tea studied	60
4.3. Fresh root weight (g) of one year old plants in the fifty accessions of Assam tea studied	61
4.4. Dry root weight (g) of one year old plants in the fifty accessions of Assam tea studied	62
4.5. Shoot length (cm) of one year old plants in the fifty accessions of Assam tea studied	65
4.6. Fresh shoot weight (g) of one year old plants in the fifty accessions of Assam tea studied	67
4.7. Dry shoot weight (g) of one year old plants in the fifty accessions of Assam tea studied	68
4.8. Variation of shoot weight of three leaves and a bud (%) during second and third years of growth in the fifty accessions of Assam tea studied	72
4.9. Variation of internodal length (B&F) (%) during second and third years of growth in the fifty accessions of Assam tea studied	76
4.10. Variation of internodal length (F&S) (%) during second and third years of growth in the fifty accessions of Assam tea studied	80

4.11. Variation of internodal length (S&T) (%) during second and third years of growth in the fifty accessions of Assam tea studied	84
4.12. Variation of leaf angle (%) during second and third years of growth in the fifty accessions of Assam tea studied	88
4.13. Variation of leaf area (%) during second and third years of growth in the fifty accessions of Assam tea studied	92
4.14. Variation of number of branches (%) during second and third years of growth in the fifty accessions of Assam tea studied	96
4.15. Variation of branch length (%) during second and third years of growth in the fifty accessions of Assam tea studied	100
4.16. Variation of branch angle (%) during second and third years of growth in the fifty accessions of Assam tea studied	104
4.17. Variation of total chlorophyll content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied	108
4.18. Variation of proline content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied	112
4.19. Variation of protein content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied	116
4.20. Variation of polyphenol content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied	120
4.21. Variation of catechin content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied	124

4.22. Frequency curves of the growth characters of Assam tea studied	135
4.23. Frequency curves of the phytochemical characters of Assam tea studied	142
4.24. Cluster analysis in the case of the fifty accessions of Assam tea studied- dendrogram	160

# INTRODUCTION

B. Ramasubramanian “Studies on variability, genetic divergence and crop improvement in tea (*Camellia assamica* (Masters) Wight ) Thesis. Department of Botany, University of Calicut, 2005

# Chapter I

## INTRODUCTION

The family Theaceae consists of 30 genera and 500 species, of which *Camellia* has been treated unique since 2737 BC, for its unique aroma and flavour (Harler, 1964 and Eden, 1976). The brew, which is obtained from the leaves of this genus, is being used to make the beverage tea. 'Three leaves and a bud' of growing branches form the economically important part of tea plant (Fig. 1.1). This genus provides employment for more than two lakh people in India. India is the largest producer and consumer of tea and at present tea is cultivated in an area of about 4,31,000 ha. in India and annual production is about 846 million kg of made tea. World production of tea is about 3016 million kg. India accounts for 28% of the global tea production and 16% of shipments. 76% of the tea produced in India is consumed domestically and the rest is exported. It earns a foreign exchange of over Rs.1, 899 crores per year. Tamil Nadu, Karnataka, Kerala and the northeast are the major tea growing regions of India (Hudson *et al.*, 1997).

### 1.1. Cultivated species of tea

Tea is a heterogeneous plant with many overlapping morphological, biochemical and physiological attributes. However, the cultivated tea populations comprise of three distinct taxa, *Camellia sinensis* (L.) O.Kuntze (China type), *Camellia assamica* (Masters) Wight (Assam type) and *Camellia assamica*

**Fig. 1.1. Three leaves and a bud- the economically important part of the tea plant**



ssp. *lasiocalyx* (Planch ex Watt) Wight (Cambod type), which are known to produce commercially acceptable tea (Bezbaruah, 1999).

#### **1.1.1. China tea (*Camellia sinensis* (L.) O. Kuntze)**

China tea grows into a big shrub, about 1-3 m in height, with numerous stems arising from the base of the bush near the ground level, giving rise to a dome shaped bush when fully grown. Leaf blades are generally leathery and dark green. Marginal veins of the leaf are generally indistinct. Flowers are borne singly or in pairs in the cataphyllary leaf axils. All the five sepals are persistent and leathery. Petals are 7 to 8 in number, cup shaped. Ovary white, densely hairy, three locular. Stigma is apical, capsule 1 to 3 loculate, containing 1 to 3 seeds (Bezbaruah, 1999).

#### **1.1.2. Assam tea (*Camellia assamica* (Masters) Wight)**

Assam tea grows in to a small tree with a vertical branching system and a distinct trunk, sometimes up to one third of the height of the tree. The tree generally grows to a height of about 10 m to 15 m. Leaves are typically dependant and thin glossy with more or less acuminate apex and distinct marginal veins. Leaf blades are mostly broadly elliptic, 8 to 20 cm long and 3.5 to 7.5 cm wide. Flowers are single or in pairs developing from the cataphyllary leaf axils. Sepals are 5 to 6 in number, unequal, leathery and persistent. Petals are 7 to 8 in number, white and devoid of any pigmentation. Ovary is three locular. Style is typically three and stigma linear. Fruit and seed more or less same as in China type (Bezbaruah, 1999).

### **1.1.3. Cambod tea (*Camellia assamica* ssp. *lasiocalyx* (Planch, ex Watt) Wight)**

Cambod tea reaches a height of about 6 to 8 m. Leaves are more or less erect, glossy and yellowish green when young and light green at maturity. Size of the leaf is intermediate between those of Assam and China types and leaves are generally elliptic. Ovary 3 to 4, sometimes 5 locular. Styles are 3 to 5 in number, free. Fruit and seed are similar to that of other varieties (Bezbaruah, 1999).

### **1.2. Morphology of tea plants**

Tea plant is an evergreen shrub or a small tree. It exhibits orthotropic, semi-orthotropic or plagiotropic branching patterns. Leaves are simple, alternate and serrate. Flowers are regular and bisexual and are borne in the axils of leaves. Sepals are five in number, free and persistent. There are five to seven petals, which are waxy and internally concave. Stamens are numerous, varying between 100 and 300. Ovary is free, superior, three to many celled with one to many ovules in each cell. Fruit is a capsule and usually contains one to three seeds (Bezbaruah, 1999).

### **1.3. Ecoclimatic requirements**

The original habitat of the tea plant is Southeast Asia with warm wet summer and dry cold winter. Tea is a rain fed crop. It requires a rainfall of about 150 cm per annum. The temperature range required is between 13°C and 30°C. Relative humidity should be around 80% but not less than 40% and the area should not be prone to frost and heavy wind. Tea plant requires strong acidic soil with pH between 4.5 and 5.5. At present commercial

cultivation of tea extends from 44°N to 34°S. It enjoys the elevation of 300 m to 2500 m above mean sea level. Most of the tea estates are located in slopes having 10% to 33% gradient (Eden, 1976).

#### **1.4. Origin and variability**

Central China is considered to be the primary centre of variability of tea. Southwest China is considered the secondary centre and India and Japan the tertiary centres of variability (Harler, 1964).

Tea is an outbreeding crop, exhibiting great diversity in its form and shape. A large base of genetic variability is available in the tea research centres of the tea growing countries for crop improvement programmes. In India also such variability is available. Majority of the tea plantations in South India are of seedling origin and this seedling progeny has got tremendous variability due to the highly heterozygous nature of tea plant. The wide bush to bush variation in any field of seed grown tea will be apparent to any observer but the extent of variability is perhaps not fully realized until yields or yield components of a large number of bushes are recorded separately (Tunstall, 1931; Wellensiek, 1934; Tubbs, 1932).

Tea plant improvement programme was initiated in United Planters' Association of South India Tea Research Foundation (UPASI- TRF), Valparai, Tamil Nadu, India during early 1960s, and it has resulted in the release of 28 clones and 5 bicultural seed stocks with distinct morphological features, yield capacity and

quality attributes (Venkataramani and Sharma, 1975; Sharma and Satyanarayana, 1989).

A few bushes may yield 4 to 5 times or even more than the average yield of a population, while some other bushes in the same field may perform below the average. It is a concrete evidence to show that the yield of a particular bush hinges not only on the climatic factors but also on the genetic nature of it.

The potential yielding period of a tea bush is about 60 to 70 years and the planters/farmers are forced to replant them with new clones/seeds/grafts. Thus, uprooting of old tea areas and their replacement by vegetative clones and clonal seed progenies coupled with the encroachment of the natural habitats of the existing seedling populations have drastically eroded the germplasm base of the crop. To conserve the wide genetic variation and moreover to prevent the eradication of the old seedling populations by the introduction of new varieties, there is a need and urge to collect, conserve and evaluate all the available seedling populations and to use them for breeding programmes.

With this objective, an effort was initiated in 1999 to collect and conserve the old seedling populations of tea in UPASI-TRF from all over the country. As a result, more than 200 accessions, which include Assam and China types, have been collected and planted in the experimental farm of UPASI-TRF.

The present study has been carried out as a part of evaluation of the above germplasm collection in which fifty

accessions of Assam type tea cultivars have been evaluated for their variability based on growth, yield and phytochemical parameters.

# REVIEW OF LITERATURE

B. Ramasubramanian “Studies on variability, genetic divergence and crop improvement in tea (*Camellia assamica* (Masters) Wight ) Thesis. Department of Botany, University of Calicut, 2005

## Chapter II

### REVIEW OF LITERATURE

#### 2.1. Taxonomy

As already mentioned, tea is a heterogeneous plant with many overlapping morphological, biochemical and physiological attributes. *Camellia sinensis*, *Camellia assamica* and *Camellia assamica* ssp. *lasiocalyx* are known to produce commercially acceptable tea (Bezbaruah, 1999).

Tea taxonomy is still a challenge, but does not receive much attention because of the complexities involved. Kaempfer (1712) first described the tea plant in detail under the generic name *Thea*. In 1753, Linnaeus, in his "*Species Plantarum*," used the name *Thea sinensis* for the tea plant and described another ornamental species as *Camellia japonica*. Robert Sweet (1818) united both the genera in to one genus *Camellia*. In 1935, the International Botanical Congress finally adopted *Camellia* as the correct name of the genus (Bezbaruah, 1999).

In 1958, Sealy included about eighty species under this genus in his famous monograph 'A Revision of the Genus *Camellia*.' The species were grouped under twelve different sections according to the affinities of their floral characters. Sealy recognized two varieties of cultivated tea- *Camellia sinensis* var. *sinensis* (China tea) and *Camellia sinensis* var. *assamica* (Assam tea). Wight (1962) raised the two varieties to the status of species and also advocated the recognition of a third variety, generally

referred to as Cambod tea as a subspecies of *Camellia assamica* and named it ssp. *lasiocalyx* (Bezbaruah, 1999).

## 2.2. Origin and distribution

Tea originated in the China centre according to Vavilov (1926). Kingdon-Ward (1950) was inclined to assume two centres of origin and dispersal of different kinds of tea. According to him, tea probably originated in a primary centre somewhere in Mongolian plateau, about 60<sup>0</sup> N or further north of it, which was dispersed along two axes associated with glaciation from that region. It was further assumed that one of the axes, probably of *assamica* and *cambodiensis* had a southern migration, again dispersed from a secondary centre somewhere near the junction of the borders between India, Burma, China and Tibet. From the geographical evidence of the distribution of tea, dispersal from the secondary centre in three different directions along the sources of the three great rivers, Yang-Tse, Mekong and Brahmaputra was suggested (Bezbaruah, 1999).

According to Ukers (1935), Robert Bruce was the discoverer of Assam tea plant. However, Bazbaruah (1999) reported that Maniram Dewan discovered the plant. It is also believed that Dewan could have brought the plant to the notice of Bruce during his visit to Rangpur in 1823. Though the matter of the real discoverer of Assam tea plant has not yet been satisfactorily settled, the honour of discovery is usually attributed to Robert Bruce who was supposed to have seen the wild plant growing in some hills near Rangpur. Currently more tea is made from the Assam type of bushes than from China type. Several

reports say that the content of catechins in the tea leaves is much higher in Assam type than in China type (Nakagawa, 1970; Yamanashi, 1999).

### **2.3. Morphology**

Morphological differences in size of the plant, shape, texture and pose of the leaves are well known. Certain chemical and biochemical and anatomical differences are also associated with these morphological variations (Bezbaruah, 1999).

China tea grows into a big shrub, about 1-3 m in height, with numerous stems arising from the base of the bush near the ground level, giving rise to a dome shaped bush when fully grown (Bezbaruah, 1999).

Sealy (1958) recognized two forms with in this species on the basis of leaf size- *macrophylla* with leaves 4-14 cm long and 2.2-5.0 cm wide and *parvifolia* with extremely small leaves, 1.5-6 cm long and 1-2.2 cm wide. In both the forms leaves are short stalked, blades elliptic with characteristically obtuse or broadly obtuse apex, connate base, bluntly serrulate to sinuate serrulate with more or less incurved teeth. Leaf blade generally leathery dark matty grey, glabrous above, light green and villose below when young, becoming sparsely villose as the leaf grows. Petiole short, 3-7 cm long, stout, generally giving the leaf an erect pose.

### **2.4. Floral biology**

Wu (1963) was the first to study the morphological characters of tea flower. He observed significant difference in

floral characters among the Chinese varieties themselves. From the anatomical study of floral parts, he suggested that tea flowers should be classified as central placental type instead of parietal placental type. Flower development of tea plant is not inhibited by low light intensity or by low carbohydrate content. Though there are several reports (Cohen Stuart 1918; Bakhtadze, 1932; Barua, 1970; Bezbaruah, 1975) from all the tea growing countries in the world on flower morphology, development of flower buds and pollination and fruit set, reports on embryology and flower anatomy are scanty.

### **2.5. Pollination**

The tea plant shows an appreciable degree of self sterility and invariably sets a better crop of seed with pollen from another plant (Wight, 1938). In hybridization, soon after emasculating the flower buds, the pollen grains are either dusted with the help of a brush or the stamens collected from the selected pollen parents are gently touched over the stigmatic surface.

### **2.6. Development of fruit**

The corolla withers off after 24 to 48 hours of pollination and droops from the pedicel along with anther lobes leaving the ovary exposed. Although fertilization takes place during the flowering period, *i.e.*, from October to January in India, the first external sign of development of fruits become evident by about March. Further development proceeds at an appreciable rate, so that the fruit attains considerable size and a hard seed coat is formed inside the pericarp towards the end of May. By about

August, the fruits attain full size and the development of embryo and cotyledons is also complete (Singh, 1999).

### **2.7. Seeds and seed germination**

Each capsule generally contains one to three (some times four) seeds. The seeds have a hard testa outside and the embryo is covered in between two large cotyledons. Tea seeds are recalcitrant; they lose viability within a few days after shedding from the plant (Bhattacharjee and Singh, 1994). Their viability can be maintained by surface sterilizing with 0.01% Mercuric chloride solution for fifteen minutes and subsequent cold temperature (0-5°C) storage (Rahman, 1987).

### **2.8. Cytology**

According to Kondo (1977) and Ackerman (1971), most of the cytological investigations carried out in tea showed a remarkably constant number  $2n=30$  in all cases except for a few natural triploids. Bezbaruah (1971) reported that the ploidy level in the genus *Camellia* ranged up to hexaploid with  $2n=90$  chromosomes. In 1975, Dutta and Choudhuri found that *Camellia sinensis* has four median and eleven sub median chromosomes thus confirming the basic chromosome number as 15.

Aneuploidy was reported by Bezbaruah (1971) and Ackerman (1971) with unusual chromosome numbers of  $2n = 32, 33, 38, 42, 58, 59, 61$  and  $63$  in tea. The length of tea chromosomes ranged from  $1.28 \mu\text{m}$  to  $3.44 \mu\text{m}$ . Bezbaruah (1968) reported that the chromosomes of Wilson's *Camellia* (*Camellia irrawadiensis*) ranged in length from  $2.4 \mu\text{m}$  to  $3.4 \mu\text{m}$  with an

average diameter of 1.0  $\mu\text{m}$ . Karyotypic study revealed that the clones belonging to the three major types of cultivated tea did not show any major differences in their gross morphology (Bezbaruah, 1971).

## **2.9. Physiology**

Tea clones show wide variation in their morphophysiological behaviour. Significant difference in net photosynthesis was observed among Assam, China and Cambod types (Rajkumar *et al.*, 1993). Among the cultivars, Assam hybrids had a relatively higher net photosynthetic rate than China and Cambod varieties.

### **2.9.1. Photosynthesis**

Photosynthesis is the key physiological function in tea as in other crops. Maintenance leaves of the canopy in tea are the factories, which produce the required raw material for the entire plant through various metabolic functions. Photosynthetic efficiency of a tea leaf in fixing the atmospheric carbon dioxide and partitioning of assimilates is governed principally by the environmental conditions, management practices and genetic potential of the plant (Marimuthu *et al.*, 1994).

The relationship between the age of a tea leaf and the net photosynthetic rate remains unsettled. A progressive increase in photosynthetic rate was recorded for four months. Then the photosynthetic rate slowly declined, but even seven month old tea leaves showed sustainable photosynthetic rate (Rajkumar *et al.*, 1998). Tea leaves attained peak efficiency and self sufficiency in

photosynthesis when they were fully expanded and remained photosynthetically active for a long period according to Manivel (1989). A drop in photosynthesis is mainly due to the addition of a new leaf, which increases the canopy density, which in turn disrupts the penetration of radiant energy. Variation in photosynthesis within a tea shoot may be attributed to its physiological maturity. Young tea leaves are heterotrophic in nature and depend on other sources for more photosynthates (Rajkumar *et al.*, 1999).

### **2.9.2. Dry matter accumulation and harvest index**

The ratio between the total biomass and the economic yield is known as harvest index. Based on the agronomic studies, Tanton (1979) reported that 67 per cent of dry matter had been lost in respiration in a year by a mature tea bush under Malawi conditions. Only 35 per cent of the dry matter produced is partitioned into different plant components. Out of the 35 per cent, less than 10 per cent of assimilates get partitioned into economically important crop shoots in tea (Hadfield, 1976). The economic yield of tea plants progressively decreased with age while partitioning towards uneconomic plant parts increased drastically. Accumulation of dry matter depended on the rate of export of photosynthates from the mother leaf to the growing regions (Manivel and Hussain, 1982).

### **2.10. Crop improvement**

Introduction, selection and hybridization are the mainstay of the improvement programmes for superior planting material in any crop. The first efforts to improve the tea plant started by way

of introduction and selection of superior jats. The first scientific attempt to select improved tea in Northeast India was made by Stiefelhagen brothers in 1860 by establishing standard sources of the tea seeds (Singh, 1999).

The seed grown plants were not uniform as they were genetically diverse. In some cases the yield and quality were unpredictable but the planters wanted uniform plantations and as a result clonal method of propagation also came to existence (Singh, 1999).

#### **2.10.1. Exploration and conservation of genetic resources**

Genetic resources programme is one of the priorities in crop improvement research. The priority areas should be viewed primarily from three different angles namely collection of variability, evaluation of collected cultivars and conservation. The old seed grown tea populations representing over 75% acreage of the South Indian plantations are highly heterogeneous and thus are the gold mines of genes. The need for collecting tea germplasm in India has gained further importance due to massive uprooting of old seed grown sections to be replaced with a few popular clones such as UPASI 9, UPASI 3, ATK, TRF 1, CR 6017, SA 6, etc., which will lead to narrow genetic base. If genetic variability of such areas are not collected and conserved now, they will be lost for ever. Such an alarming situation of the tea germplasm in India leads us to intensify the efforts of collecting the genetic diversity and conserving and utilizing the same. The wide bush to bush variation in any field of seed grown tea will be apparent to any observer but the extent of variability is perhaps

not fully realized until yields or yield components of a large number of bushes are recorded separately (Tunstall, 1931; Wellensiek, 1934; Tubbs, 1938).

### **2.10.2. Selection**

Different workers have suggested selection criteria for yield and yield related characters in tea. Size and surface area of a bush in a mature tea field are the criteria recommended for estimating yield by Visser (1969). A positive correlation between yield and leaf size was observed by Satyanarayana and Sharma in 1982. In a mixed population where chinary bushes also exist, selection for leafiness will tend to be biased in favour of the shrubby China type. In general, such bushes will be less productive in areas where large leaf Assam type bushes can be grown.

Leaf size, which is related to size and weight of shoot has also been used as a yield criterion. Correlation between leaf size, leaf number and yield were observed by Toyao (1966). A good correlation between length of the growing shoots and yield was observed by Amma (1975).

Satish Paul and Sharma (1996) studied the genetic variability in thirteen local selections of tea for seven yield contributing characters *viz.*, number of primary branches, number of secondary branches, total number of leaves, internodal length, girth of stem, leaf area and specific leaf weight. They found that the genetic correlation provides a measure of genetic association between characters.

Satish Paul and Gupta (1996) evaluated three parameters namely productivity, responsiveness and stability of six tea cultivars and observed varietal differences.

From South India in 1966, Venkataramani clearly pointed out that seedling plants in a population exhibit tremendous variation amongst themselves with regard to different characters. It is not therefore surprising to assume that some of the variations are such as to adopt the plants possessing them better to the conditions in which they grow. It is a common knowledge that in a tea field, some bushes are attacked less by fungi, mites etc., and that some bushes recover quickly from pruning than others. The paper emphasized the advantage of such variations and the author tried to build up potentially useful planting material.

When the selection programme was started in UPASI-TRF, prime importance was given to yield and quality. Resistance to blister blight and mites received only secondary consideration because immunity or high resistance to blister blight and quality do not go hand in hand. In practice no one selection could be really resistant to all pests and diseases and a selection that is satisfactory for yield and quality might not highly or totally be susceptible to the most common pests and diseases (Venkataramani, 1966).

It has been pointed out that selection of the mother bush is the most important and that the future of the vegetatively propagated progeny would greatly depend on initial selection. But

the combination of high crop yield and outstanding cup qualities is not likely to occur in more than one out of 40,000 bushes (Anonymous, 1961). This article stressed the importance of initial selection for vigour and growth on the basis of eye judgment based on the number of stems per unit area, the thickness of individual stems and the size of the bush.

Clonal selection is an important and widely adopted method of plant improvement in any crop. Satyanarayana and Sharma (1981) extensively studied the biometric parameters of tea like serratures along the leaf margins, leaf area, shoots per unit area and pruning weights and their association with yield. Despite the variation in the density of shoots in different zones (from central to peripheral zone) they noticed a strong and positive association between the shoots per unit area and yield in various zones. They reported that no single criterion could be applied in isolation for yield prediction; but a combination of criteria, more importantly, total leaf area as determined on the basis of total dry matter, density and weight of shoots and pruning weights.

The UPASI Tea Scientific Department started work on tea selection on high elevation estates in the Nilgiris in April 1961. Initial marking of the bushes was done by eye judgment, examining almost every individual bush for such features as recovery from pruning, wood formation, branching habit, flushing behaviour, colour and size of leaves and pubescence of leaves and buds (Venkataramani, 1962). In 1964, Venkataramani and Padmanabhan found that light leaved selections were generally

superior to dark green selections in the colour and strength of liquor.

### **2.10.3. Vegetative propagation of tea**

The genetic make up of perennial crops is highly heterozygous and the unique characteristics of such plants are lost if they are propagated by seed. For commercial purposes it is essential to have certain desirable characters such as high yield, good quality and resistance to pests and diseases. Since seed propagation does not ensure the availability of plants true to the parent, the propagation of superior varieties has to be done through vegetative means in tea.

In 1957, Venkataramani reported three main types of rooting viz., vertical rooters, horizontal or surface rooters and intermediate rooters. The author opined that the age of the parent bush has no material effect on the economic life of the vegetatively propagated clonal progeny.

In 1958, Venkataramani reported that vegetative propagation of tea was governed by many factors both internal and external, such as clonal source, nature of the cutting, rooting medium and growth promoting substances such as light, temperature and humidity.

Tea clonal selection pioneered by Venkataramani between the 1950s and 1960s led to the release of 24 clones (UPASI 1 to UPASI 24) for commercial purpose. Among these, UPASI 9 and

UPASI 3 were found to be highly promising. This monumental work left 708 promising mother bushes.

#### **2.10.4. Development of biclonal seed stock**

Development of biclonal seed stock is another line of tea plant improvement that was initiated in the late 1970s and early 1980s in UPASI Tea Scientific Department. Over the years, a total of 146 crosses between clones in different combinations were carried out (Satyanarayana and Sharma, 1993). In 1993, Satyanarayana and Sharma released five biclonal seed stocks, BSS-1 to BSS-5.

#### **2.10.5. Evaluation of cultivars**

In 1975, Venkataramani and Sharma extensively studied the important characteristics of 24 UPASI clones. Mohanan and Sharma (1981) assigned 12 UPASI clones to the three known taxa *Camellia sinensis*, *Camellia assamica* and *Camellia assamica* ssp. *lasiocalyx*. In 1991, Satyanarayana and Sharma studied seven selections, numbered PICS-1 to PICS-7. Following a careful evaluation, the selections PICS-1, PICS-4 and PICS-6 have been released as UPASI 25, UPASI 26 and UPASI 27 respectively. Balasubramanian *et al.* released a clone TRF 1 from biclonal progenies in 2001. This clone registered a yield record of 11481 kg made tea / ha / yr.

In 1981, Satyanarayana and Rao studied the leaf area in tea. Dry weight of tea leaf was found to have a direct and significant association with the actual leaf area. Biometric parameters like serratures along leaf margin, leaf area, shoots per

unit area and the pruning weights were examined for their association with actual yields (Satyanarayana and Sharma, 1981). Leaf characters such as shape, surface, margin, base, apex, colour, pigmentation and posture of leaves were studied to prepare an artificial key for the identification of UPASI clones (Ilango and Sharma, 1990). Similarly 22 chemical parameters were studied in crop shoots and mature leaves of twenty five UPASI clones by Sreedhar *et al.* (1990).

### **2.11. Molecular studies**

William *et al.* (1990) firstly used the oligonucleotide segments with arbitrary sequence (containing GC 50-80%) as primers and used the genomic DNA of some prokaryotes and eukaryotes as the template to conduct PCR amplification, and a series of polymorphic segments (RAPD) were obtained. It was also proved that the amplified DNA segments with same molecular weight in different species were homogenous. Since this technique showed the advantage of low cost, time-saving nature, absence of isotopic pollution, need of very small amounts of DNA and abundant diversities yielded, it was widely used in the detection of genetic diversity, constitution of genetic maps, recognition of cultivars, analysis and collection of germplasm, research on the evolution and origin of species as well as the detection of genetic stability. Technological advances, such as RFLP and RAPD have been used successfully in tea to clarify some taxonomic questions concerning the origin of cultivated tea and to analyze populations (Waucheria *et al.*, 1995) and also to investigate the genetic basis of tea quality (West *et al.*, 1996).

Nakamura (1983) reported first successful protoplast isolation in tea. However, *Agrobacterium* mediated gene transfer has not been completely successful ( Palni *et al.*, 1999). Zehra *et al.* (1996) have reported induction of hairy roots in tea.

Due to the presence of wide genetic variation and the crisis caused by the eradication of old seedling populations by the introduction of new varieties, there is a need to collect the seedling populations as much as possible for future breeding programmes. With this objective an effort has been started in the year 1999 to collect the old seedling populations of tea in UPASI-TRF-TRI from all over India. As a result, more than two hundred accessions (which include Assam, China and non tea varieties) have been collected and planted. Fifty accessions of Assam tea from the above collection have been utilized for the present study.

The objective of the present study is to evaluate the above accessions for the assessment of the nature and extent of variability present and the estimation of biometric parameters and genetic divergence. Certain phytochemical parameters like total chlorophyll content, proline content, protein content, polyphenol content and catechin content are also included in the study. It is hoped that the present investigation may contribute additional information towards the knowledge on the existing variability of Assam tea at morphological and phytochemical levels. Morphological variations are very important on yield point of view and phytochemical parameters on quality point of view.

# MATERIALS AND METHODS

B. Ramasubramanian “Studies on variability, genetic divergence and crop improvement in tea (*Camellia assamica* (Masters) Wight ) Thesis. Department of Botany, University of Calicut, 2005

## Chapter III

### MATERIALS AND METHODS

In order to study the variability of Assam type tea cultivars available in India, 50 accessions were selected for the present investigation (Table 3.1 and Fig 3.1). The materials available with the germplasm resources of UPASI Tea Research Foundation, Valparai, Tamil Nadu, India, situated in the Anamallais region of Western Ghats, which has been recently recognized as National Active Tea Germplasm by National Bureau of Plant Genetic Resources (NBPGR)) were utilized. The weather data of the study area for the study period (2001 to 2004) are given in tables 3.2 to 3.5.

Table 3.1. Accessions of Assam tea used for the present study

Sl. No.	Accession	Source
1	UPASI 1	Valparai, Tamil Nadu
2	UPASI 2	Valparai, Tamil Nadu
3	UPASI 3	Valparai, Tamil Nadu
4	UPASI 4	Valparai, Tamil Nadu
5	UPASI 5	Valparai, Tamil Nadu
6	UPASI 6	Valparai, Tamil Nadu
7	UPASI 7	Valparai, Tamil Nadu
8	UPASI 8	Valparai, Tamil Nadu
9	UPASI 12	Valparai, Tamil Nadu

10	UPASI 13	Valparai, Tamil Nadu
11	UPASI 14	Valparai, Tamil Nadu
12	UPASI 16	Valparai, Tamil Nadu
13	UPASI 17	Valparai, Tamil Nadu
14	UPASI 18	Valparai, Tamil Nadu
15	UPASI 21	Valparai, Tamil Nadu
16	UPASI 22	Valparai, Tamil Nadu
17	UPASI 24	Valparai, Tamil Nadu
18	UPASI 25	Valparai, Tamil Nadu
19	UPASI 26	Valparai, Tamil Nadu
20	UPASI 27	Valparai, Tamil Nadu
21	TRF 1	Valparai, Tamil Nadu
22	ATK 1	Valparai, Tamil Nadu
23	TTL 1	Valparai, Tamil Nadu
24	TTL 2	Valparai, Tamil Nadu
25	TTL 5	Valparai, Tamil Nadu
26	TRI 2025	Valparai, Tamil Nadu
27	TRI 2026	Valparai, Tamil Nadu
28	TRI 2043	Valparai, Tamil Nadu
29	C 17	Valparai, Tamil Nadu
30	BSB 1	Valparai, Tamil Nadu
31	CR 6017	Valparai, Tamil Nadu
32	NLT 17/10	Valparai, Tamil Nadu

33	AK	Valparai, Tamil Nadu
34	BSS 1	Valparai, Tamil Nadu
35	BSS 2	Valparai, Tamil Nadu
36	BSS 3	Valparai, Tamil Nadu
37	LSM	Valparai, Tamil Nadu
38	PK 1	Valparai, Tamil Nadu
39	K 18	Valparai, Tamil Nadu
40	TPA	Valparai, Tamil Nadu
41	TTSS 1	Tocklai, Assam
42	ST 463	Tocklai, Assam
43	ST 450	Tocklai, Assam
44	ST 520	Tocklai, Assam
45	ST 464	Tocklai, Assam
46	ST 444	Tocklai, Assam
47	ST 447	Tocklai, Assam
48	ST 462	Tocklai, Assam
49	TR 11	TRI, Sri Lanka
50	TV 6	Valparai, Tamil Nadu

Table 3.2. Weather data of the study area (2001)

Month	Rainfall (mm)	Rainy days	Sun shine hours	Temperature		Relative humidity (%)		Evapo-ration (mm)	Wind speed (km/hrs)
				Max	Min	830	1430		
January	26.8	2	6.39	26.6	12.3	85.7	62.6	2.4	3
February	25.2	2	8.4	27.9	10.9	86.8	67.5	2.8	2
March	84.8	6	6.52	28	13.4	88.3	67.9	2.5	2
April	327	14	4.59	26.7	16.4	92.4	83.3	1.9	2
May	220	11	6.35	26.5	16.7	89	80	2.1	3
June	864	27	1.04	22.3	17.3	94.3	88.2	1.1	1
July	1016	27	1.28	22.2	17.2	94.5	88.4	1	1
August	424.8	25	1.41	22.1	16.6	93.7	87.8	1	0
September	352.8	15	4.47	24.7	14.9	91.1	83.6	1.8	2
October	293.8	16	3.46	24.3	16.3	91	84	1.2	1.5
November	285.6	10	5.3	25.3	15.9	89.9	87	1.7	2
December	20.6	3	6.59	26.6	12.3	85.4	68.1	2.4	2
Total	3941.4	158	55.8	303.2	180.2	1082.1	948.4	21.9	21.5
Average	328.45	13.17	4.65	25.27	15.02	90.18	79.033	1.83	1.79

Table 3.3. Weather data of the study area (2002)

Month	Rainfall (mm)	Rainy days	Sun shine hours	Temperature		Relative humidity (%)		Evapo-ration (mm)	Wind speed (km/hrs)
				Max	Min	830	1430		
January	0.4	0	7.45	26.5	11.4	86.4	64.6	2.5	2
February	9.4	2	7.15	27.4	11.2	85	56.5	2.9	3
March	91.4	3	7.58	29	12.5	84.9	53.3	3.4	0
April	17.8	3	7.34	27.9	14	88.9	76.2	2.6	1
May	254.4	14	5	26.6	16.2	89.2	81.7	2.1	2
June	496.2	19	2.05	23.6	19.3	92.5	85.6	1.4	1
July	343.6	21	2.21	23.2	18.4	92.5	85.4	1	0
August	825.8	26	2.1	21.8	17.9	94.9	90	1.2	0
September	166.7	7	6.55	25.2	14.3	87.3	78.2	2.6	2
October	378	18	3.42	24.5	18.1	92	88.5	1.6	2
November	117.6	8	5.13	25.5	17.7	89.5	88.6	1.8	2
December	13.6	2	7.32	26.8	11.9	84.2	67	2.3	2
Total	2714.9	123	63.3	308	182.9	1067.3	915.6	25.4	17
Average	226.24	10.25	5.28	25.67	15.24	88.94	76.300	2.12	1.42

Table 3.4. Weather data of the study area (2003)

Month	Rainfall (mm)	Rainy days	Sun shine hours	Temperature		Relative humidity (%)		Evapo-ration (mm)	Wind speed (km/hrs)
				Max	Min	830	1430		
January	13.6	1	8.13	27.1	9.5	85	67	2.7	2
February	78.2	3	7.33	27.9	12.4	88	63	2.6	2
March	123	5	8.04	28.6	13.4	87	69	2.6	2
April	64.2	6	6.38	27.8	14.2	90	80	2.3	2
May	129.8	10	5.18	27	18	87	81	2.2	2
June	464.6	20	3.48	24	17	90	82	2.5	2
July	622	28	1.19	22.7	18.1	94	89	1	1
August	544.6	22	3.05	23.7	17.9	93	86	1.2	2
September	180	11	5.01	24.8	16	87	81	1.3	2
October	657.5	23	4.1	24.6	16.9	90	86	1.5	2
November	38.2	13	4.5	25.8	15.3	87	77	1.6	2
December	0	0	8.1	26.5	11	85	66	2.3	2
Total	2915.7	142	64.49	310.5	179.7	1063	927	23.8	23
Average	242.98	11.83	5.37	25.88	14.98	88.58	77.250	1.98	1.92

Table 3.5. Weather data of the study area (2004)

Month	Rainfall (mm)	Rainy days	Sun shine hours	Temperature		Relative humidity (%)		Evapo-ration (mm)	Wind speed (km/ hrs)
				Max	Min	830	1430		
January	7.2	1	8.2	27.3	10.5	87	60	2.7	1
February	7	1	8.37	28.3	10.8	88	50	2.8	2
March	161.8	4	8.22	30.1	13.3	87	48	3.5	2
April	307	12	8.22	30.1	17.9	87	48	3.6	3
May	937	23	2.5	24.5	18.1	91	84	1.6	2
June	1839.7	24	2.02	23	17.8	93	88	1.2	2
July	1071.8	30	1.3	22.4	18.1	94	90	1.2	1
August	1362.8	18	2.48	22.9	17.7	94	83	1.3	2
September	495	20	135.15	24.7	16.6	91	85	1.6	2
Total	6189.3	133	176.46	233.3	140.8	812	636	19.5	17
Average	515.78	11.08	14.71	19.44	11.73	67.67	53.000	1.63	1.42

Fig 3.1 Variability of mother leaves in the case of the 50 accessions of Assam tea studied



UPASI 1



UPASI 2



UPASI 3



UPASI 4



UPASI 5



UPASI 6



UPASI 7



UPASI 8



UPASI 12



UPASI 13



UPASI 14



UPASI 16



UPASI 17



UPASI 18



UPASI 21



UPASI 22



UPASI 24



UPASI 25



UPASI 26



UPASI 27



TRF 1



ATK 1



TTL 1



TTL 2



TTL 5



TRI 2025



TRI 2026



TRI 2043



C 17



BSB 1



CR 6017



NLT 17/10



AK



BSS 1



BSS 2



BSS 3



LSM



PK 1



K 18



TPA



TTSS 1



ST 463



ST 450



ST 520



ST464



ST - 444



ST 447



ST 462



TRII



TV 6

Studies on morphological, physiological and phytochemical characters were carried out at nursery and field levels to analyze the juvenile growth pattern, genetics of characters, the extent of variability, correlation of characters, character association, clustering of genotypes and comparative performance of the different accessions of Assam tea. All routine cultural operations including plant protection measures, manuring and foliar application of nutrients were carried out as per the UPASI recommendations (Hudson *et al.*, 1997).

### **3.1. Nursery experiment**

#### **3.1.1. Planting of single nodal cuttings/seeds**

The nursery experiment was laid out in CRD in the case of the 50 accessions with three replications and 30 plants per replication. Single nodal preparations were adopted for 38 cultivars. However, 12 accessions were propagated through seeds since they were newly introduced from Assam. In seed planting sinkers were surface sterilized with fungicide (Indofil M 45) and sown in sand bed at a spacing of 5 cm × 5 cm with a 400 g polythene sheet covering. Watering and fungicide applications were done at regular intervals as per the UPASI recommendations (Hudson *et al.*, 1997). As soon as the seeds cracked, they were removed from the sand bed and sown in sleeves filled with sand and soil mixture.

Raising tea plants from single node cuttings has now been widely and successfully adopted as an economic method of vegetative propagation. Single nodal cuttings were collected from nucleus mother bushes, as per the recommendations of UPASI

(Verma and Palani, 1997). Single nodal cuttings with healthy mother leaves were planted in nursery sleeves filled with sand and soil as per the recommendations of Venkataramani (1958).

### **3.1.2. Nursery observations**

Observations on three characters were made in the case of nursery plants as detailed below.

#### **3.1.2.1. Percentage of survival**

Tea cuttings prefer acidic rooting medium. In general, a period of 10-12 weeks is required for rooting of tea cuttings. Percentage of survival was calculated by direct observation after six months from planting them in nursery. Grey blight disease caused by a fungus *Pestalotia theae* is a major problem in nursery. Generally *Pestalotia* attacks older leaves thus affecting the survival of tea cuttings.

#### **3.1.2.2. Root growth**

Roots develop an intimate and dynamic association with soils in which they grow and from which they extract mineral nutrients and water. Root systems of tea plants are very extensive, often accounting for more than 50% of total plant body weight. Root length, fresh root weight and dry root weight were observed in one year old nursery plants with metric scale and gravimetric method respectively by destructive sampling of three plants per replication.

### **3.1.2.3. Shoot growth**

Shoot gives mechanical strength to plants. In particular, tea shoot has immense value when compared to other plants. Shoot length, fresh shoot weight and dry shoot weight were observed in one year old nursery plants with metric scale and gravimetric method respectively by destructive sampling of three plants per replication.

Mean, range, grand mean, standard deviation and coefficient of variation were calculated in the case of the characters and analysis of variance carried out to test the significance of variation.

### **3.2. Field experiments**

One-year-old seedlings of the accessions were transplanted in the field under RBD with three replications and 15 plants per replication. Uniform and standard recommendations were followed. Observations on nine morphological characters (Table 3.6) were made for three consecutive years starting from the first year and on five phytochemical characters for two consecutive years starting from the second year and the data pooled and analyzed for the study of juvenile growth pattern of tea. Observations made on three year old plants were analyzed to study the genetic control of characters, genetic variability, correlation of characters, character association and genetic divergence and also to identify superior cultivars from the accessions.

Table 3.6. Morphological and phytochemical characters studied

Sl. No.	Characters
1	Shoot weight 3L&B
2	Internodal length between bud and first leaf (B&F) (cm)
3	Internodal length between first and second leaves (F&S) (cm)
4	Internodal length between second and third leaves (S&T) (cm)
5	Leaf angle (degrees)
6	Leaf area (cm <sup>2</sup> )
7	Branch length (cm)
8	Branch angle (degrees)
9	Number of branches
10	Chlorophyll content (mg/g weight of leaf)
11	Proline content (% of dry weight)
12	Protein content (% of dry weight)
13	Polyphenol content (% of dry weight)
14	Catechin content (% of dry weight)

### 3.2.1. Juvenile growth pattern and juvenile performance of Assam tea

Nine growth characters were periodically observed at yearly interval for three years so as to analyze the growth pattern of juvenile tea plants and five phytochemical characters were analyzed at the end of the second and third years so as to study the variation in phytochemical characters in relation to age (Table 3.6). The characters analyzed and the pattern of analysis are given below.

#### **3.2.1.1. Shoot weight- three leaves and a bud**

'Three leaves and a bud' has immense value in made tea production. Three fresh leaves and a bud were collected from three plants in the first year and from all the plants in the second and third years in the case of the fifty accessions and shoot weight observed gravimetrically and averaged.

#### **3.2.1.2. Internodal length (B&F)**

Internodal length between the bud and the first leaf was recorded at the end of the first year, second year and third year and analyzed statistically.

#### **3.2.1.3. Internodal length (F&S)**

Internodal length between the first leaf and second leaf was also recorded and analyzed as above to study the variation in relation to age.

#### **3.2.1.4. Internodal length (S&T)**

Variation in internodal length between the second leaf and third leaf was also analyzed to study the variation in relation to age.

#### **3.2.1.5. Leaf angle**

Leaf angle was observed by using a circulo-oculometer in the field for all the plants in the case of all the cultivars at the end of the first, second and third years of growth. The angle that the mother leaf of mature twig made with its internode was taken by extending a thread attached to the oculometer along the tip of the

leaf concerned, which kept the central part of ocular scale at the node.

#### **3.2.1.6. Leaf area**

To determine the leaf area, maintenance leaves from the canopy were detached and were outlined on a graph sheet, which was used to find out their area. Values obtained for three leaves at random were averaged in the case of each plant.

#### **3.2.1.7. Number of branches**

Number of side branches is the index of the frame of a bush and hence this parameter has been included in the present investigation. Variation among the cultivars in number of branches arising from the mother stem was recorded at the end of the first, second and third years of growth.

#### **3.2.1.8. Branch angle**

Branch angle was recorded for all the plants of all the cultivars studied in the field to find out the variation among the cultivars. The angle that the side branches from the middle stem below 20 cm profuse of the bush canopy area made with their respected main frame was observed by circulo-oculometer.

#### **3.2.1.9. Branch length**

Branch length was observed for all the cultivars in the field by using metric scale method. For the study of branch length, recently matured greenish laterals from the upper 20 cm layer of bush canopy were used.

#### **3.2.1.10. Chlorophyll content**

Chlorophyll content was measured with chlorophyll meter (Minolta, Japan). Actively growing mother leaves were selected for studying this parameter. The units thus obtained with chlorophyll meter were converted in to mg chl / g fresh weight according to Jeyaramraja *et al.* (2003).

#### **3.2.1.11. Proline content**

About 0.5 g of plant material was extracted using 10 ml of 3% aqueous sulpho salicylic acid. The filtrate (2 ml), 2 ml glacial acetic acid and 2 ml acid ninhydrin were added in a test tube and heated in a boiling water bath for 1 hour and the reaction was terminated by placing the tube in ice bath. Exactly 4 ml toluene was added to the mixture and stirred well for 20–30 seconds. Then the toluene layer was separated and warmed to room temperature. The red colour intensity was measured at 520 nm against series standards of proline (Sadasivan and Manickam, 1996).

#### **3.2.1.12. Protein content**

Protein was estimated by Lowry<sup>*et al.*</sup> (1951) method. Fresh tea shoots (500 mg) were extracted with 5-10 ml of the buffers. 0.1 ml and 0.2 ml of the sample extract were made up to 1 ml with water and 5 ml of alkaline copper solution was added. Then 0.5 ml of Folin-ciocalteau reagent was added. Exactly after 30 minutes blue colour was developed and read at 660 nm.

#### **3.2.1.13. Polyphenol content**

Fresh tea shoots (2 g) were extracted with 95% ethanol. The extract was filtered in to 100 ml volumetric flask. The residue

was washed repeatedly with ethanol. Finally, the filtrate was made up to the volume with 95% ethanol. An aliquot (2 ml) of the extract was diluted with distilled water and used for estimation of polyphenols and catechins.

The method of Dev Choudhury and Goswami (1983) was followed for the estimation of polyphenol content. 1 ml of Folin-ciocalteau reagent (1:1 dilution) was added to 1ml of the ethanol extract followed by 2 ml of 20%  $\text{Na}_2\text{CO}_3$  and the mixture was heated in a boiling water bath for 1 min. The mixture was shaken well, diluted to 25 ml with distilled water and then allowed to stand for 15 minutes for the completion of reaction. The blue colour developed was read at 700 nm. Since the polyphenols and catechins play a vital role in determining the quality of tea, these biochemical parameters have been analyzed to study the variation among the cultivars.

#### **3.2.1.14. Catechin content**

The method of Swain and Hillis (1959) was followed. 2 ml of ethanol extract was pipetted out into a test tube and added 6.5 ml of Vanillin reagent (1 g Vanillin was dissolved in 100 ml of 70% V/V Sulphuric acid). The mixture was diluted to 10 ml with distilled water and shaken well in a cold water bath to prevent temperature going above 35°C. Exactly after 15 minutes, the absorbance of red colour was read at 500 nm against reagent blank. Standard calibration curve was prepared using known quantities of catechins.

The characters were analyzed for linear growth pattern from field planting up to the age of three years and percentage of variation calculated and analyzed for the purpose. Juvenile growth index has been calculated for each character in the case of the fifty accessions by converting the relative growth performance of the accessions in relation to each character, converting them in to coefficients in relation to the accession with the maximum performance and adding them up to get the overall juvenile performance index and relative rank of juvenile growth performance of the accessions studied.

### **3.2.2. Genetic control of characters in Assam tea**

A total of fifty accessions of tea belonging to *Camellia assamica*, 49 collected from different parts of India and one collected from Sri Lanka and maintained in the germplasm conservatory of UPASI Tea Research Institute, Valparai were used for the present investigation. Details of the accessions are presented in Table 3.5.

Genetic control of nine morphological and five phytochemical characters (Table 3.6) has been analyzed based on the frequency distributions of the variables concerned. For the purpose data on 150 plants belonging to the 50 accessions with three observations per accession were pooled and analyzed.

### **3.2.3. Genetic variability in Assam tea**

The experiment was laid out in randomized block design with three replicates and 15 plants per plot. Internodal cuttings were used for 38 accessions and seedlings for 12 accessions as

planting materials. Nine morphological characters and five phytochemical characters were recorded at the end of the third year of growth and analyzed statistically.

Genetic variability was analyzed based on ANOVA (Panse and Sukatme, 1985), phenotypic and genotypic variance (Singh and Choudhary, 1985), coefficients of variation (Burton and Devane, 1953), heritability (Jain, 1982) and genetic advance under selection (Abraham, 2000).

### **3.2.3.1. Analysis of variance**

Analysis of variance (ANOVA) was carried out to test the significance of variations between accessions. Test of significance was done with reference to standard F table (Fisher and Yates, 1963).

### **3.2.3.2. Phenotypic and genotypic variance**

Phenotypic and genotypic variances for the different characters studied were estimated as per Singh and Choudhary (1985).

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{MSS for treatment} - \text{MSS for error}}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma^2 p) = \sigma^2 g + \sigma^2 e$$

where  $\sigma^2 e$  is error variance.

### **3.2.3.3. Coefficients of variation**

Phenotypic and genotypic coefficients of variation were estimated following Burton and Devane (1953).

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

where  $\sigma_g$  = the genotypic standard deviation and

$\bar{X}$  = grand mean for the character.

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma_p \times 100}{\bar{X}}$$

where  $\sigma_p$  = the phenotypic standard deviation.

#### 3.2.3.4. Heritability (broad sense)

Heritability (broad sense) is the fraction of the total variance that is heritable and is estimated as the percentage of genotypic variance over phenotypic variance (Jain, 1982).

$$H^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

#### 3.2.3.5. Genetic advance under selection

Genetic advance under selection was calculated using the following formula (Abraham, 2000).

$$GA = \frac{KH^2 \sigma_p}{\bar{X}}$$

where  $H^2$  = heritability in the broad sense;  $\sigma_p$  = phenotypic standard deviation;  $K$  = selection differential which is 2.06 at 5% intensity of selection in large samples (Allard, 1960).

—  
 $\bar{X}$  = grand mean for the character

#### 3.2.4. Correlation of characters in Assam tea

Correlation of the characters has been found out as given by Rangaswamy (1995).

### **3.2.5. Character association in tea**

Biometric study of the morphological traits and phytochemical characters of the genotypes has been used to analyze character association in tea. Factor analysis by means of principal component analysis was carried out for the purpose with the help of the software STATISTICA.

### **3.2.6. Genetic divergence in Assam tea**

Though statistically significant variability can be observed between different genotypes of a plant species, they can be grouped into different clusters of genetically closer accessions based on genetic divergence studies. Fifty accessions of Assam tea planted in the live gene bank of UPASI-TRF, Valparai constituted the material for the investigation. Observations on nine morphological characters and five phytochemical characters were subjected to cluster analysis using the soft ware STATISTICA, following UPGMA procedure (Unweighted Pair Group Mathematical Average procedure) (Sneath and Sokal, 1973).

### **3.2.7. Comparative analysis of overall performance of the Assam tea cultivars studied**

Comparative analysis of overall performance of the 50 accessions of *assamica* tea was carried out based on the study of performance index (Hrideek *et al.*, 2002). For the purpose, grades were attributed to the accessions based on their performance in the case of each character, the grades converted in to coefficients based on the accession with maximum performance in the case of each character and overall rank of performance worked out in the case of each accession.

# RESULTS AND DISCUSSION

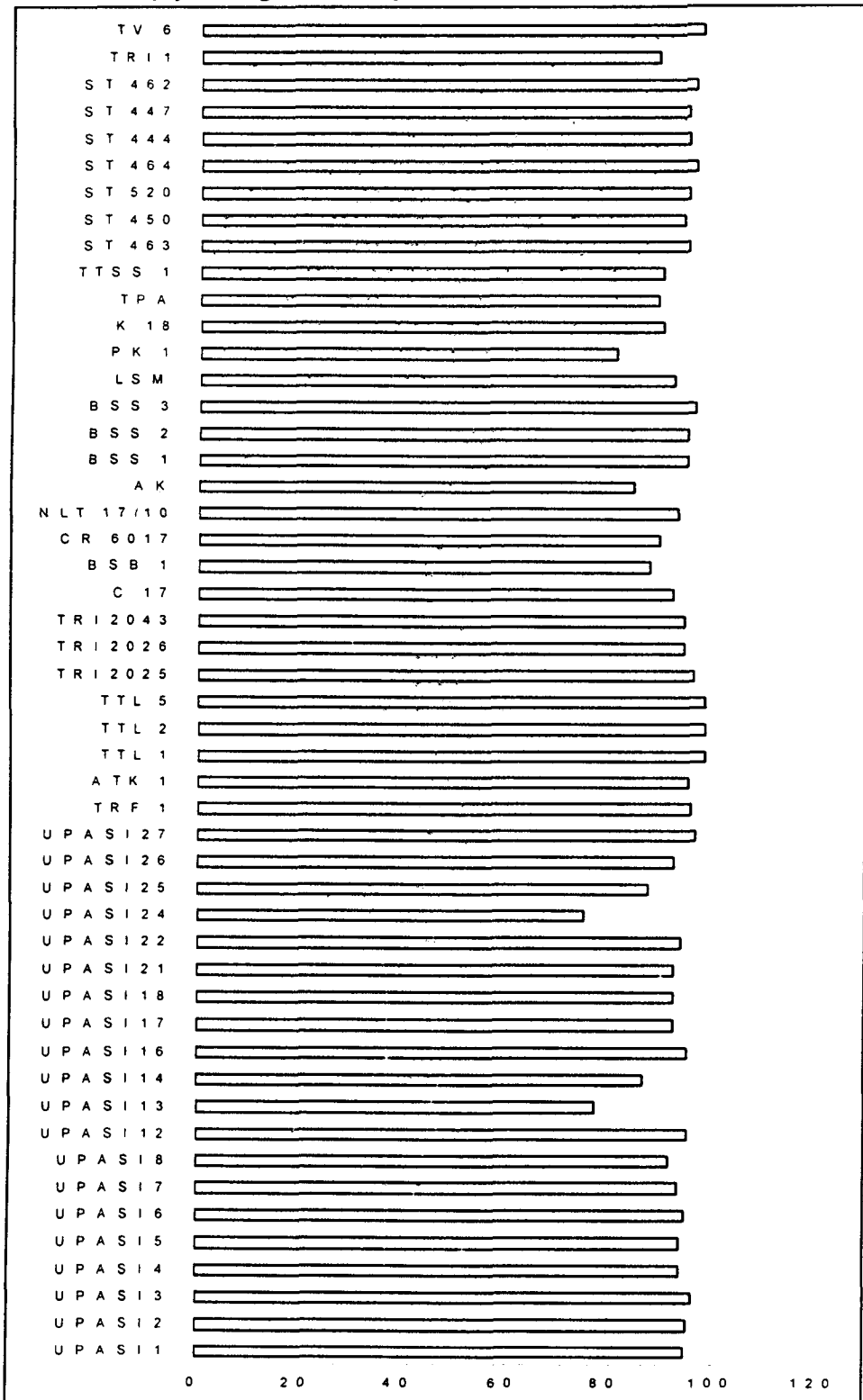
B. Ramasubramanian “Studies on variability, genetic divergence and crop improvement in tea (*Camellia assamica* (Masters) Wight ) Thesis. Department of Botany, University of Calicut, 2005

Table 4.1. Percentage of survival of seedlings/cuttings after six months of nursery planting in the fifty accessions of Assam tea studied

Sl. No	Accessions	Percentage of survival
1	UPASI 1	95.0
2	UPASI 2	95.2
3	UPASI 3	96.0
4	UPASI 4	94.0
5	UPASI 5	94.0
6	UPASI 6	95.0
7	UPASI 7	93.5
8	UPASI 8	91.5
9	UPASI 12	95.5
10	UPASI 13	77.5
11	UPASI 14	86.6
12	UPASI 16	95.5
13	UPASI 17	92.5
14	UPASI 18	92.5
15	UPASI 21	92.5
16	UPASI 22	94.0
17	UPASI 24	75.0
18	UPASI 25	87.5
19	UPASI 26	92.5
20	UPASI 27	96.5
21	TRF 1	95.9
22	ATK 1	95.5
23	TTL 1	98.5
24	TTL 2	98.5
25	TTL 5	98.6
26	TRI 2025	96.0
27	TRI 2026	94.4

28	TRI 2043	94.5
29	C 17	92.0
30	BSB 1	87.5
31	CR 6017	89.5
32	NLT 17/10	93.0
33	AK	84.7
34	BSS 1	95.0
35	BSS 2	95.0
36	BSS 3	96.0
37	LSM	92.0
38	PK 1	81.0
39	K 18	90.0
40	TPA	89.0
41	TTSS 1	90.0
42	ST 463	95.0
43	ST 450	94.0
44	ST 520	95.0
45	ST 464	96.0
46	ST 444	95.0
47	ST 447	95.0
48	ST 462	96.0
49	TRI 1	89.0
50	TV 6	97.5
Range		75.0-98.6

Fig. 4.1. Percentage of survival of seedlings/cuttings six months after nursery planting in the fifty accessions of Assam tea studied



#### 4.1.2. Root growth

Root growth at nursery level was studied in the case of one year old seedlings in terms of root length, fresh root weight and dry root weight. Three seedlings per accession were used for the purpose by destructive sampling. Root length among the nursery plants of the cultivars varied from 10.6 cm to 30.6 cm (Table 4.2 and Fig 4.2). TRI 2025 recorded the maximum root length followed by UPASI 1 whereas UPASI 14 recorded the minimum root length.

Table 4.2. Root growth of one year old plants in the fifty accessions of Assam tea studied

Sl. No	Accessions	Root length (cm)	Fresh root weight (g)	Dry root weight (g)
1	UPASI 1	28.4	1.9	0.4
2	UPASI 2	26.7	1.7	0.4
3	UPASI 3	23.4	1.5	0.4
4	UPASI 4	23.5	1.1	0.2
5	UPASI 5	26.4	1.5	0.3
6	UPASI 6	27.6	1.3	0.2
7	UPASI 7	28.0	0.8	0.2
8	UPASI 8	27.3	1.1	0.2
9	UPASI 12	24.5	1.7	0.3
10	UPASI 13	28.3	1.5	0.2
11	UPASI 14	10.6	0.5	0.1
12	UPASI 16	28.3	1.3	0.3
13	UPASI 17	18.3	0.8	0.3
14	UPASI 18	22.0	2.0	0.3
15	UPASI 21	21.4	1.4	0.2
16	UPASI 22	26.4	1.1	0.1

17	UPASI 24	11.9	0.6	0.2
18	UPASI 25	22.5	1.2	0.2
19	UPASI 26	21.6	0.9	0.1
20	UPASI 27	21.3	0.8	0.1
21	TRF 1	22.7	1.5	0.3
22	ATK 1	21.9	1.2	0.2
23	TTL 1	22.0	1.1	0.2
24	TFL 2	21.4	0.9	0.2
25	TTL 5	24.0	1.2	0.2
26	TRI 2025	30.6	1.8	0.3
27	TRI 2026	27.3	1.8	0.4
28	TRI 2043	25.3	1.0	0.2
29	C 17	23.6	1.3	0.2
30	BSB 1	23.5	1.3	0.3
31	CR 6017	21.7	1.0	0.2
32	NLT 17/10	16.8	0.7	0.1
33	AK	17.7	0.8	0.2
34	BSS 1	20.0	1.0	0.3
35	BSS 2	21.1	1.0	0.3
36	BSS 3	23.1	1.5	0.4
37	LSM	22.6	1.2	0.2
38	PK 1	23.8	1.4	0.3
39	K 18	24.9	1.9	0.3
40	TPA	18.6	1.0	0.2
41	TTSS 1	19.8	1.0	0.3
42	ST 463	20.5	1.1	0.2
43	ST 450	21.6	1.1	0.4
44	ST 520	20.0	1.0	0.3
45	ST 464	21.7	1.5	0.4
46	ST 444	26.6	1.5	0.3

47	ST 447	21.6	1.9	0.4
48	ST 462	20.7	1.8	0.5
49	TRI 1	18.7	1.0	0.5
50	TV 6	23.8	1.5	0.3
Grand Mean		22.7	1.3	0.3
Range		10.6-30.6	0.5-2.0	0.1-0.5
SD		3.9	0.4	0.1
CV		17.1	33.3	33.3
F		3811.625**	65.02085**	7.799769**

\*\* : significant at 5% and 1% levels

Maximum fresh root weight was observed in UPASI 18, followed by UPASI 1 (Table 4.2 and Fig 4.3). UPASI 14 had the minimum fresh root weight. TRI 1 and ST 462 showed the maximum dry root weight (Table 4.2 and Fig 4.4).

All the three root parameters studied showed significant variation among the accessions indicating the influence of genotypic differences on root growth in Assam tea.

#### 4.1.3. Shoot growth

Shoot growth at nursery level was also studied in the case of one year old seedlings of Assam tea by destructive sampling of three seedlings per accession in terms of shoot length, fresh shoot weight and dry shoot weight. Shoot length of one year old seedlings among the cultivars varied from 11 cm to 27.1 cm (Table 4.3 and Fig 4.5). Maximum shoot length was observed in TRI 2026, followed by UPASI 18, ST 444 and TTL 1. Minimum shoot length was observed in CR 6017 obtained from South India.

Fig. 4.2. Root length (cm) of one year old plants in the fifty accessions of Assam tea studied

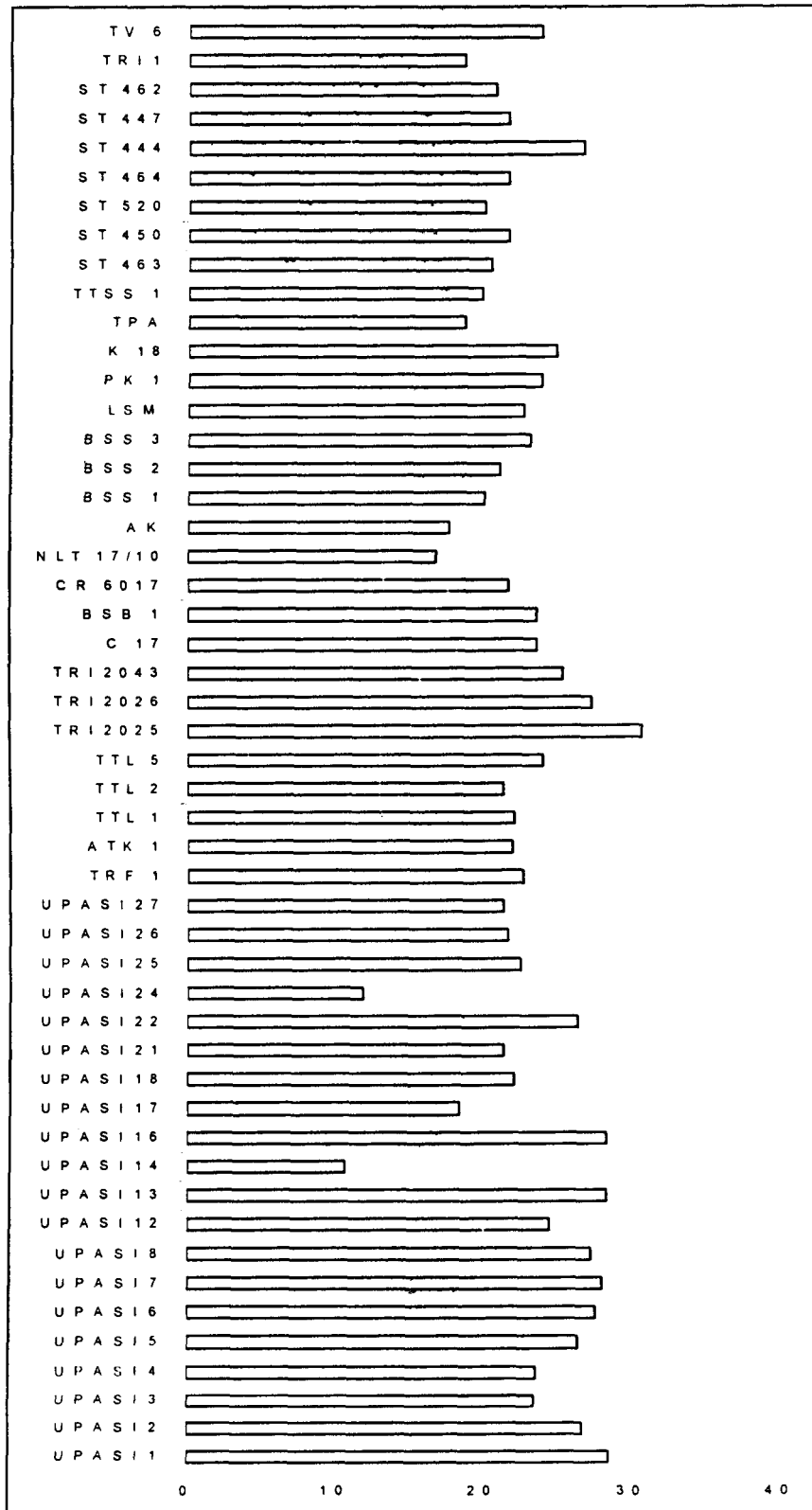


Fig. 4.3. Fresh root weight (g) of one year old plants in the fifty accessions of Assam tea studied

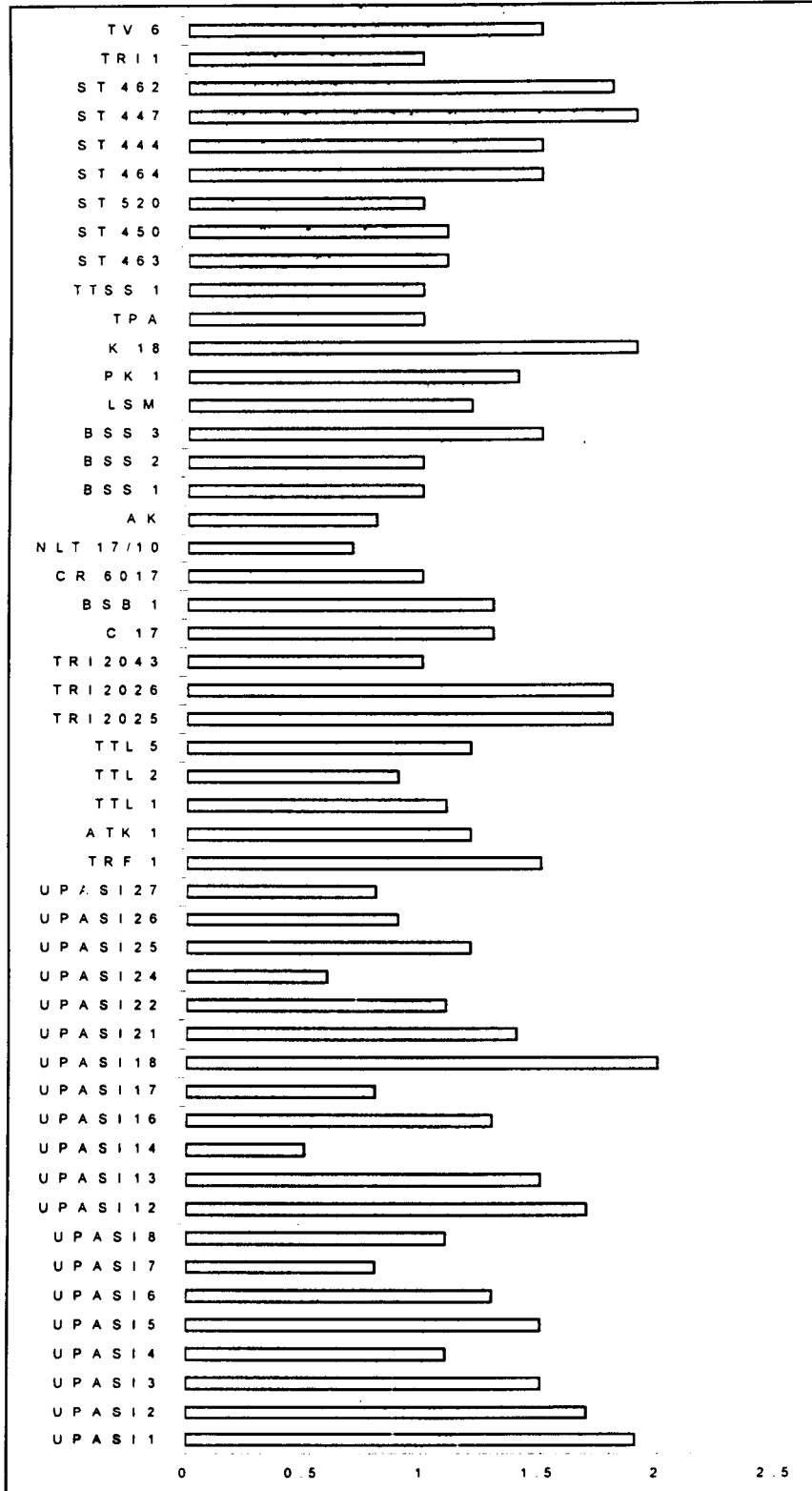


Fig. 4.4. Dry root weight (g) of one year old plants in the fifty accessions of Assam tea studied

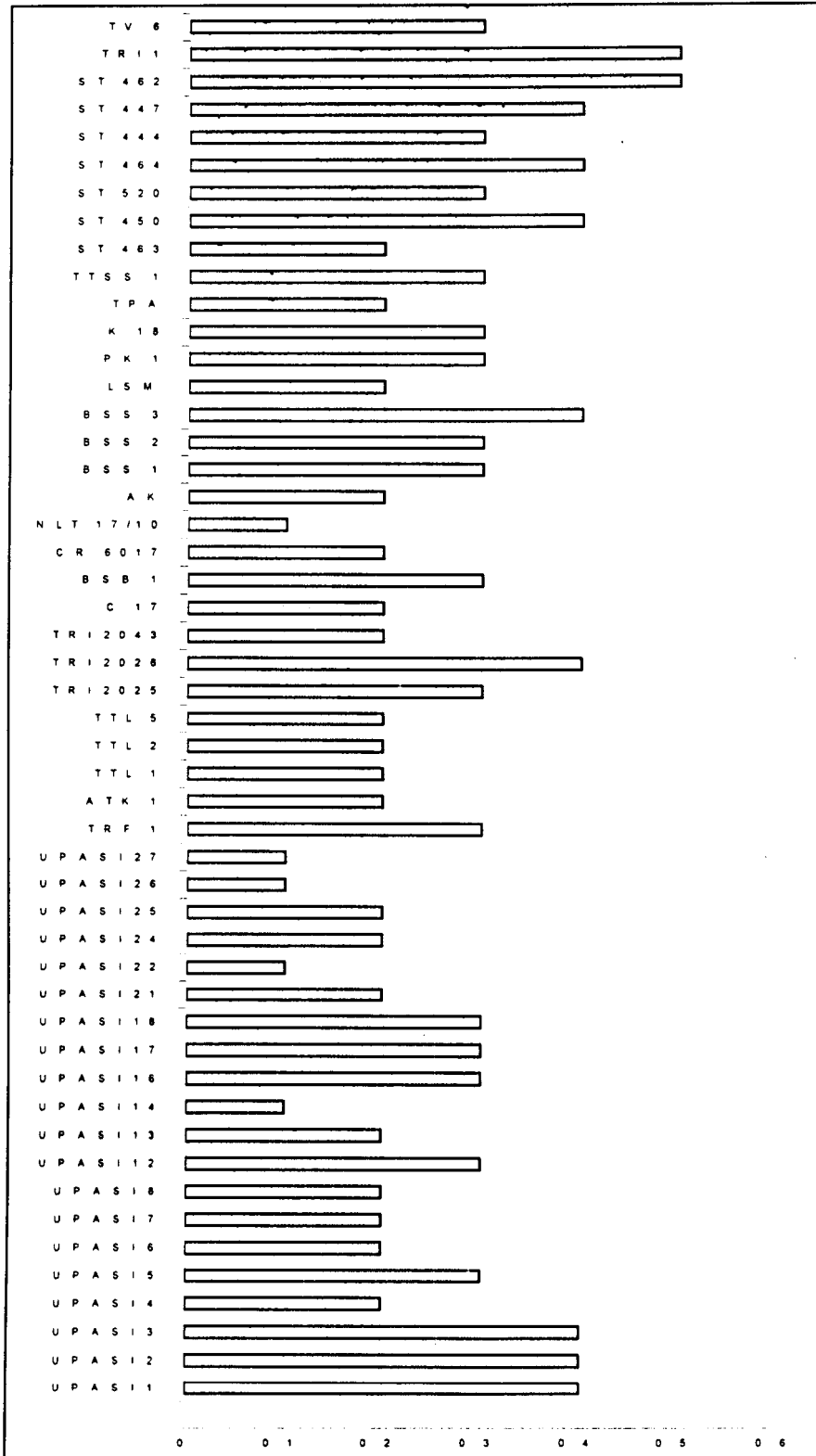


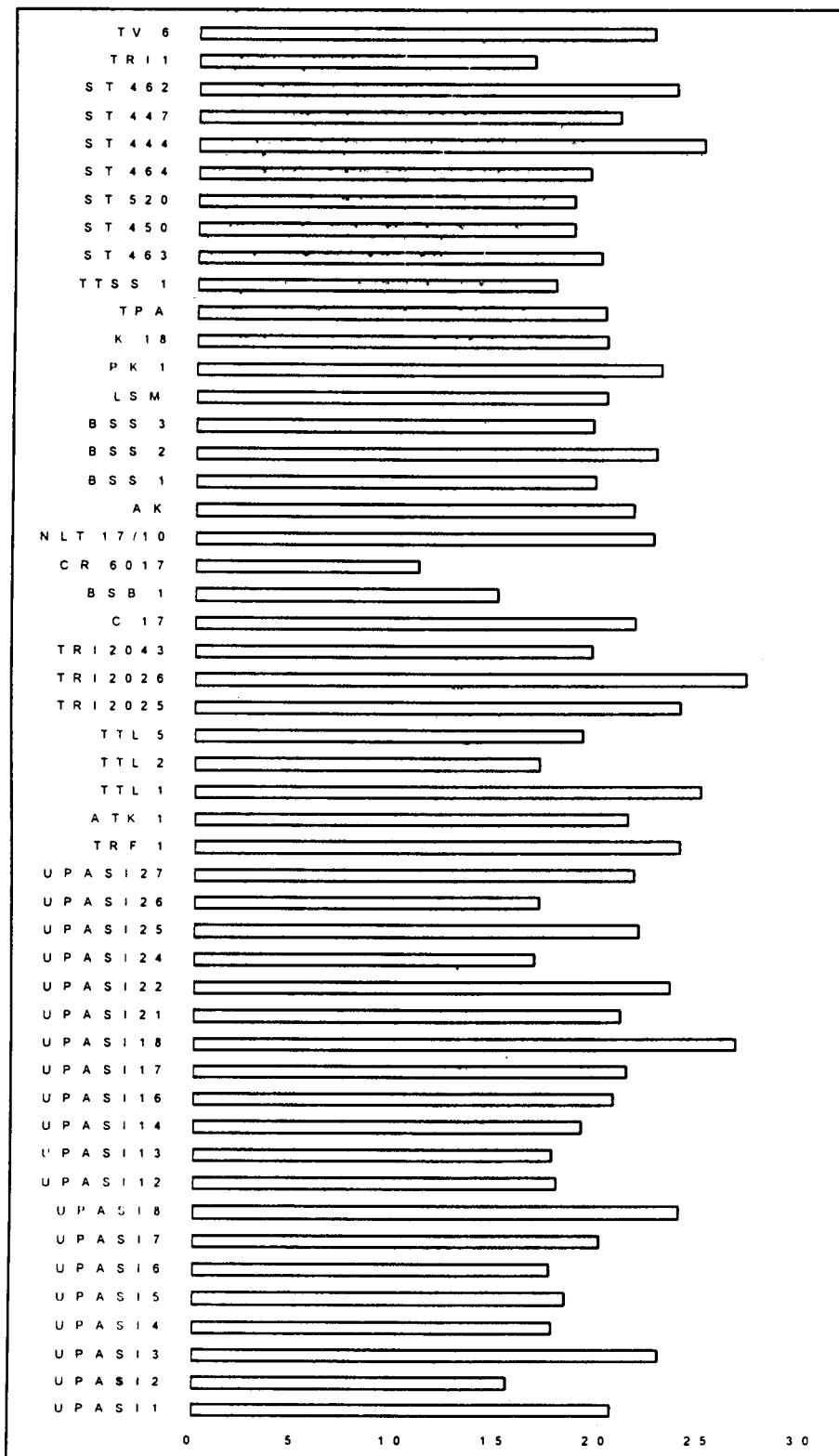
Table 4.3. Shoot growth of one year old plants in the fifty accessions of Assam tea studied

Sl. No	Accessions	Shoot length (cm)	Fresh shoot weight (g)	Dry shoot weight (g)
1	UPASI 1	20.6	6.0	1.7
2	UPASI 2	15.4	5.3	1.5
3	UPASI 3	22.9	8.0	2.1
4	UPASI 4	17.7	4.6	1.4
5	UPASI 5	18.3	4.2	1.3
6	UPASI 6	17.5	5.6	1.6
7	UPASI 7	20.0	4.2	1.3
8	UPASI 8	23.9	5.6	1.5
9	UPASI 12	17.9	5.3	1.1
10	UPASI 13	17.7	4.9	1.3
11	UPASI 14	19.1	3.3	1.0
12	UPASI 16	20.7	6.0	1.8
13	UPASI 17	21.3	5.0	1.7
14	UPASI 18	26.7	6.7	1.6
15	UPASI 21	21.0	6.3	1.8
16	UPASI 22	23.4	5.8	1.5
17	UPASI 24	16.8	3.7	1.0
18	UPASI 25	21.9	6.1	1.6
19	UPASI 26	17.0	4.2	1.3
20	UPASI 27	21.7	5.6	1.6
21	TRF 1	23.9	6.1	1.8
22	ATK 1	21.3	5.0	1.2
23	TTL 1	24.9	6.3	1.9
24	TTL 2	17.0	5.5	1.7
25	TTL 5	19.1	5.5	1.6
26	TRI 2025	23.9	7.2	2.0
27	TRI 2026	27.1	8.5	2.3

28	TRI 2043	19.5	5.0	1.3
29	C 17	21.7	5.2	1.6
30	BSB 1	14.9	4.4	1.3
31	CR 6017	11.0	3.0	0.9
32	NLT 17/10	22.6	4.8	1.4
33	AK	21.6	5.3	1.5
34	BSS 1	19.7	5.1	1.5
35	BSS 2	22.7	5.9	1.7
36	BSS 3	19.6	4.9	1.3
37	LSM	20.2	5.4	1.7
38	PK 1	22.9	5.3	1.5
39	K 18	20.2	5.0	1.3
40	TPA	20.1	4.8	1.2
41	TTSS 1	17.7	4.9	1.4
42	ST 463	19.9	4.7	1.2
43	ST 450	18.5	4.3	1.3
44	ST 520	18.6	3.8	1.3
45	ST 464	19.3	4.2	1.2
46	ST 444	24.9	6.1	1.9
47	ST 447	20.8	5.1	1.6
48	ST 462	23.5	5.3	1.5
49	TRI 1	16.6	4.6	1.6
50	TV 6	22.4	5.4	1.5
Grand Mean		20.35	5.3	1.5
Range		11.0-27.1	3.0-8.5	0.8-2.3
SD		3.1	1.0	0.3
CV		15.2	18.8	20.0
F		1514.888**	172.2508**	11.67464**

\*\* : significant at 1% and 5% levels

Fig. 4.5. Shoot length (cm) of one year old plants in the fifty accessions of Assam tea studied



TRI 2026 recorded the maximum fresh shoot weight followed by TRI 2025 (Table 4.3 and Fig 4.6). CR 6017 showed the lowest fresh shoot weight. Maximum dry shoot weight was also shown by TRI 2026 (Table 4.3 and Fig 4.7). The variation among the different accessions was found to be statistically significant thus indicating the influence of the genotype on the shoot growth pattern of seedlings in Assam tea. The observations further emphasize the importance of genotypic differences in the growth of tea seedlings and the potential that remains latent in the genetic diversity of the crop that can be utilized for selection of better genotypes based on nursery performance itself. Juvenile performance of crop plants has been used by earlier workers to select promising genotypes (Abraham, 2000).

Fig. 4.6. Fresh shoot weight (g) of one year old plants in the fifty accessions of Assam tea studied

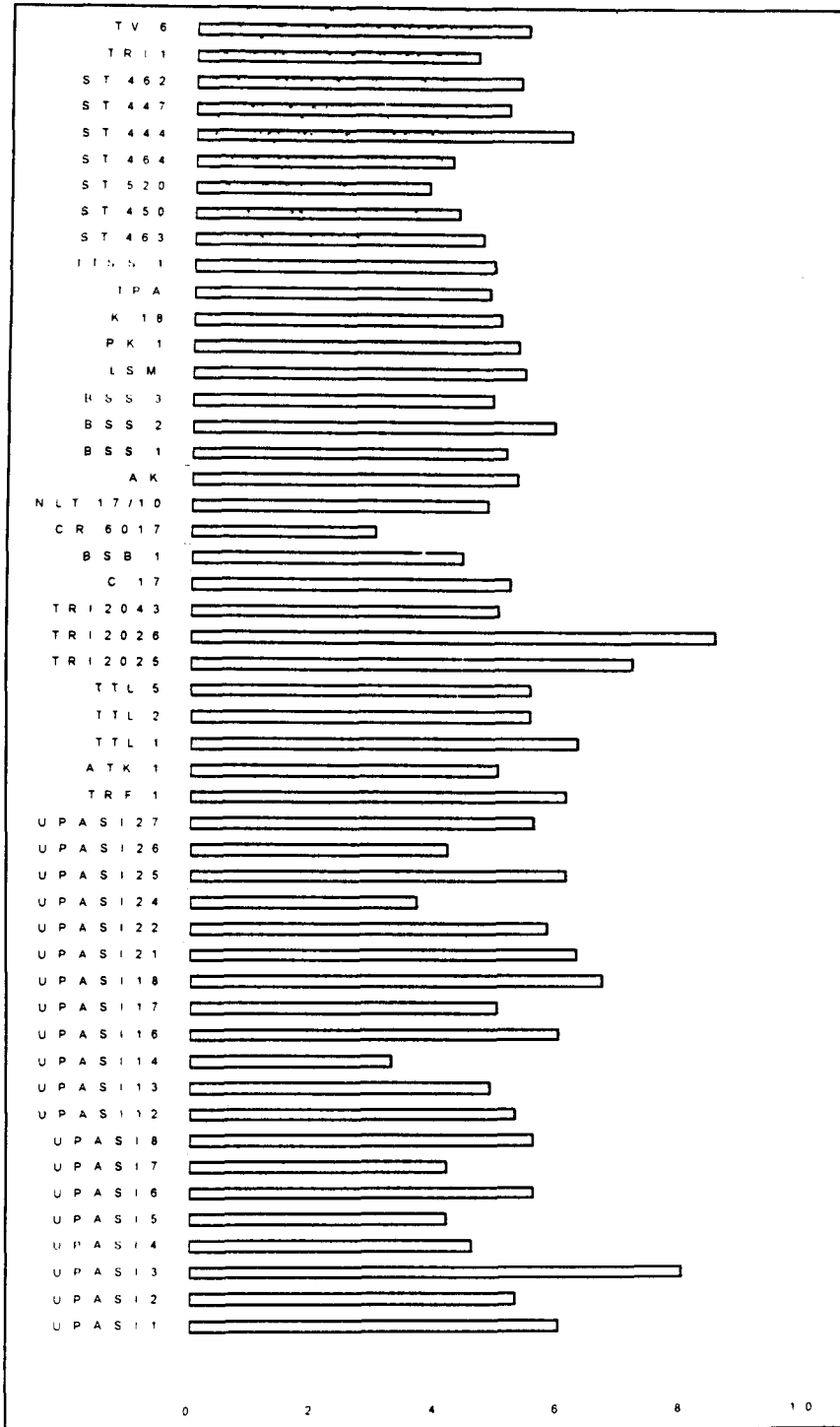
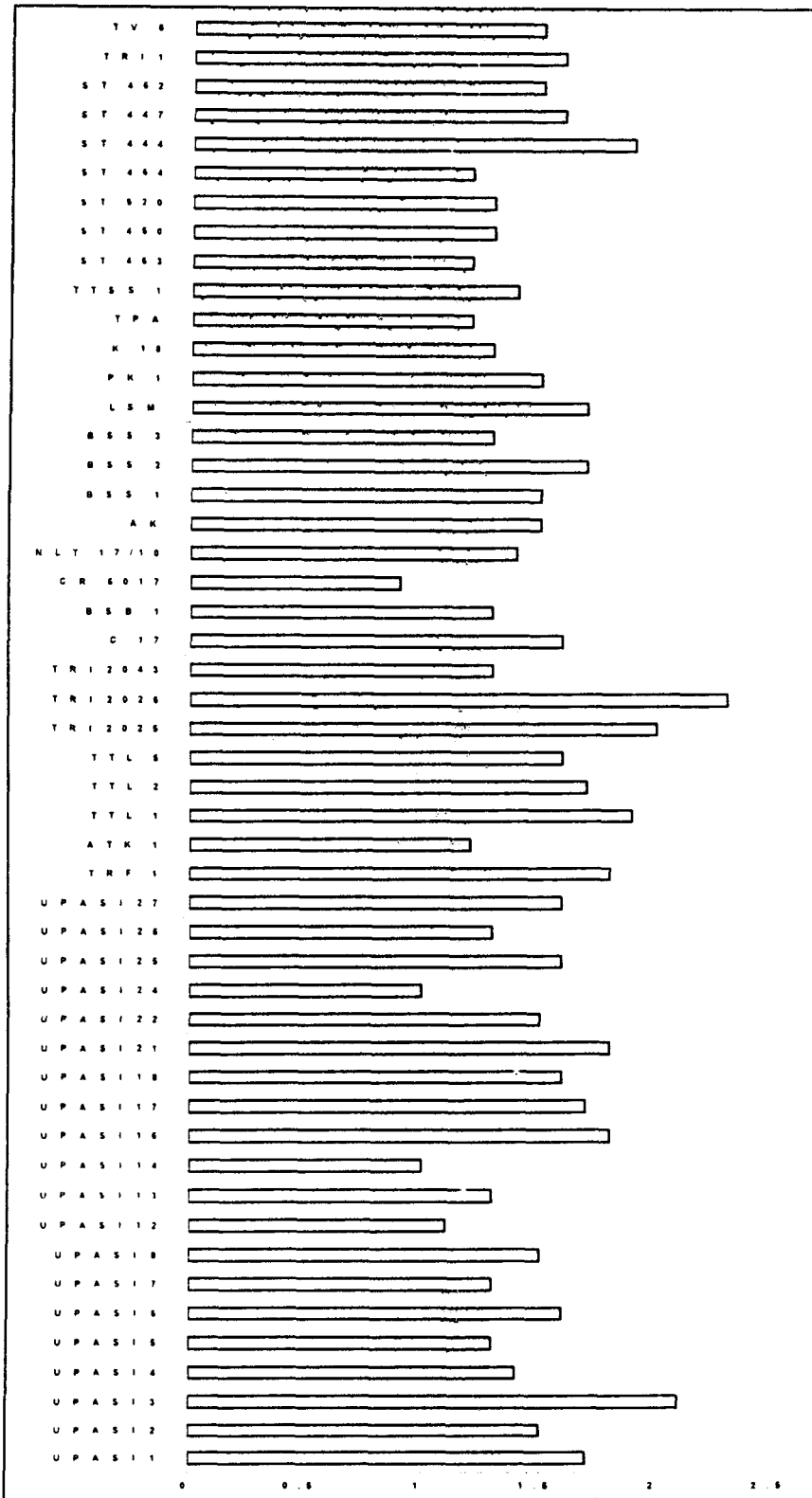


Fig. 4.7. Dry shoot weight (g) of one year old plants in the fifty accessions of Assam tea studied



## **4.2. Field experiments**

### **4.2.1. Juvenile growth pattern in Assam tea**

Juvenile growth performance of perennial plants can be considered an indicator of their future vigour and performance. Nine biometric parameters were observed at the end of the first, second and third years of growth and five phytochemical characters were observed at the end of the second and third years of growth and analyzed comparatively to study the juvenile growth pattern of Assam tea. The observations are presented and discussed below under appropriate heads.

#### **4.2.1.1. Shoot weight of three leaves and a bud**

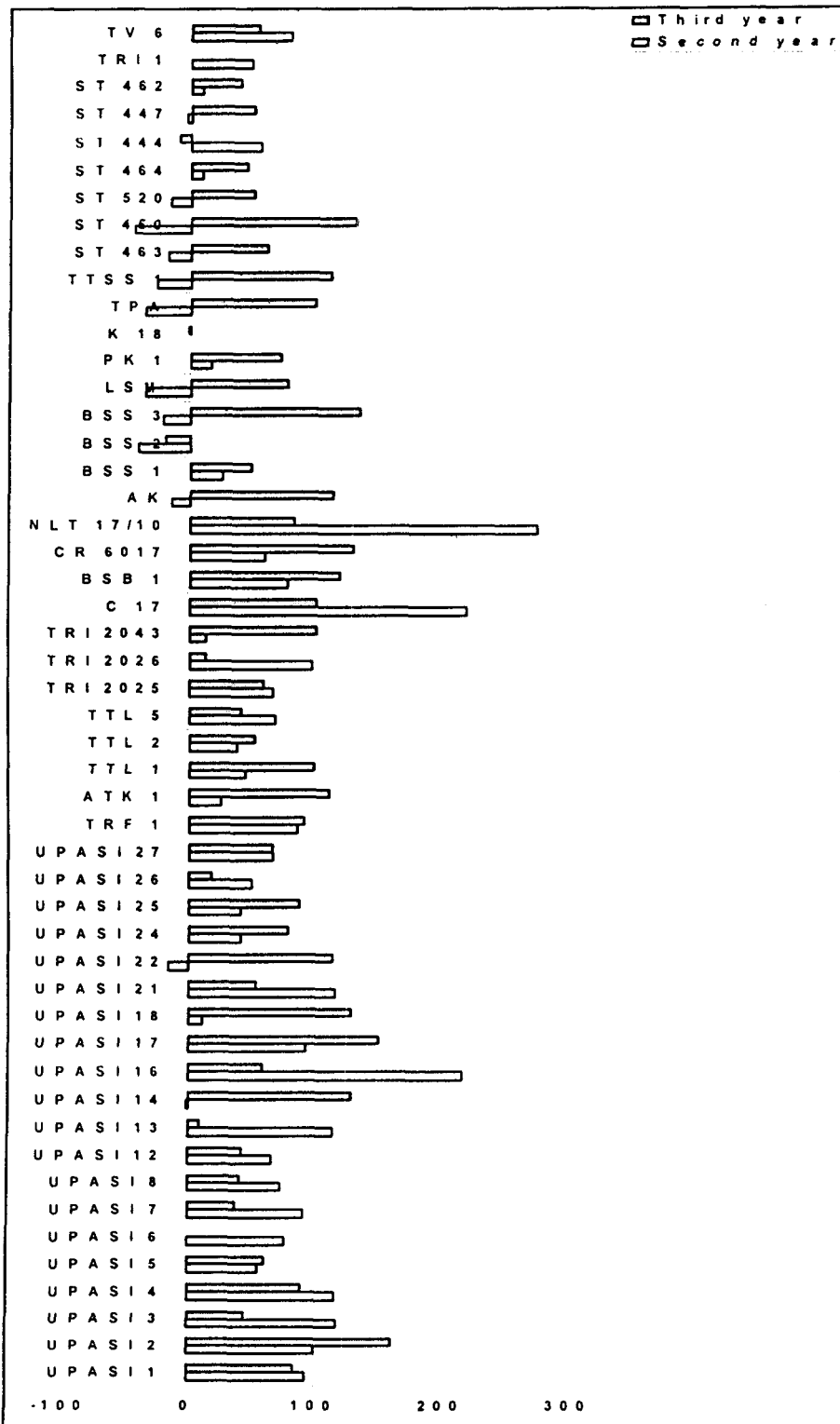
Shoot weight of three leaves and a bud is a threshold character in tea since it contributes directly towards the quantity of made tea produced. Maximum shoot weight (three leaves and a bud) was shown by ST 450 followed by BSS 2 and ST 520 at the end of the first year (Table 4.4 and Fig. 4.8). At the end of the second year, maximum shoot weight (three leaves and a bud) was shown by ST 444 and TRI 2026 followed by ST 464 and TRF 1 and at the end of the third year, maximum shoot weight (three leaves and a bud) was shown by TRI 1 and ST 450 followed by BSB 1. Some cultivars showed continuous increase in shoot weight in relation to age. However, some other varieties did not show such a relationship. Maximum increase in shoot weight was shown by NLT 17/10 at the end of the second year and by UPASI 2 at the end of the third year. The variability of the character got reduced in relation to age of the plants.

Table 4.4. Variation of shoot weight of three leaves and a bud (g) in juvenile plants of the fifty accessions of Assam tea studied

Sl. No	Accessions	First year	Second year	Percentage of variation	Third year	Percentage of variation
1	UPASI 1	0.31	0.60	93.6	1.1	83.3
2	UPASI 2	0.25	0.50	100.0	1.3	160.0
3	UPASI 3	0.51	1.11	117.7	1.6	44.1
4	UPASI 4	0.32	0.69	115.6	1.3	88.4
5	UPASI 5	0.52	0.81	55.8	1.3	60.5
6	UPASI 6	0.51	0.90	76.5	0.9	0.0
7	UPASI 7	0.42	0.80	90.5	1.1	37.5
8	UPASI 8	0.41	0.71	73.2	1.0	40.9
9	UPASI 12	0.42	0.70	66.7	1.0	42.9
10	UPASI 13	0.52	1.11	113.5	1.2	8.1
11	UPASI 14	0.71	0.70	-1.4	1.6	128.6
12	UPASI 16	0.32	1.01	215.6	1.6	58.4
13	UPASI 17	0.31	0.60	93.6	1.5	150.0
14	UPASI 18	0.63	0.70	11.1	1.6	128.6
15	UPASI 21	0.42	0.91	116.7	1.4	53.9
16	UPASI 22	0.83	0.70	-15.7	1.5	114.3
17	UPASI 24	0.72	1.01	40.3	1.8	78.2
18	UPASI 25	0.72	1.01	40.3	1.9	88.1
19	UPASI 26	0.73	1.10	50.7	1.3	18.2
20	UPASI 27	0.72	1.20	66.7	2.0	66.7
21	TRF 1	0.59	1.10	86.4	2.1	90.9
22	ATK 1	0.72	0.90	25.0	1.9	111.1
23	TTL 1	0.70	1.01	44.3	2.0	98.0
24	TTL 2	0.81	1.12	38.3	1.7	51.8
25	TTL 5	0.72	1.21	68.1	1.7	40.5
26	TRI 2025	0.72	1.20	66.7	1.9	58.3
27	TRI 2026	0.72	1.42	97.2	1.6	12.7

28	TRI 2043	0.71	0.80	12.7	1.6	100.0
29	C 17	0.22	0.70	218.2	1.4	100.0
30	BSB 1	0.52	0.92	76.9	2.0	117.4
31	CR 6017	0.44	0.70	59.1	1.6	128.6
32	NLT 17/10	0.22	0.82	272.7	1.5	82.9
33	AK	0.93	0.80	-14.0	1.7	112.5
34	BSS 1	0.81	1.01	24.7	1.5	48.5
35	BSS 2	1.72	1.02	-40.7	1.0	-19.6
36	BSS 3	1.02	0.81	-20.6	1.9	134.6
37	LSM	1.23	0.79	-35.8	1.4	77.2
38	PK 1	0.71	0.82	15.5	1.4	70.7
39	K 18	0.91	0.91	0.0	0.9	-1.1
40	TPA	1.41	0.91	-35.5	1.8	97.8
41	TTSS 1	1.22	0.90	-26.2	1.9	111.1
42	ST 463	1.22	1.00	-18.0	1.6	60.0
43	ST 450	1.82	1.00	-45.1	2.3	130.0
44	ST 520	1.42	1.20	-15.5	1.8	50.0
45	ST 464	1.22	1.32	8.2	1.9	43.9
46	ST 444	0.91	1.42	56.0	1.3	-8.5
47	ST 447	1.03	1.00	-2.9	1.5	50.0
48	ST 462	0.92	1.01	9.8	1.4	38.6
49	TRI 1	0.82	1.22	48.8	2.3	0.88
50	TV 6	0.62	1.11	79.0	1.7	53.2
Grand Mean		0.75	0.94	25.33	1.6	69.9
Range		0.22- 1.82	0.50- 1.42		0.9- 2.3	
SD		0.37	0.21		0.34	
CV		49.3	22.3		21.2	

Fig. 4.8. Variation of shoot weight of three leaves and a bud (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.2. Internodal length (B&F)

Internodal length between bud and first leaf is an important yield contributing character in tea because longer internodes produce more biomass directly increasing made tea production. There was not much variation among the cultivars studied in the case of this character (Table 4.5 & Fig 4.9). However, maximum internodal length between bud and first leaf was shown by UPASI 27, K 18, and TPA in the first year and UPASI 8, UPASI 18, UPASI 27, TRI 2025, TRI 2026, BSS 2, PK 1, K 18, TPA and TTSS 1 in second year. In the third year, UPASI 7 showed the highest internodal length between bud and first leaf. Maximum increase in internodal length (B&F) was shown by UPASI 1 in the second year and UPASI 7 in the third year. Variability of the character was the maximum in three year old plants when compared with one year old and two year old plants.

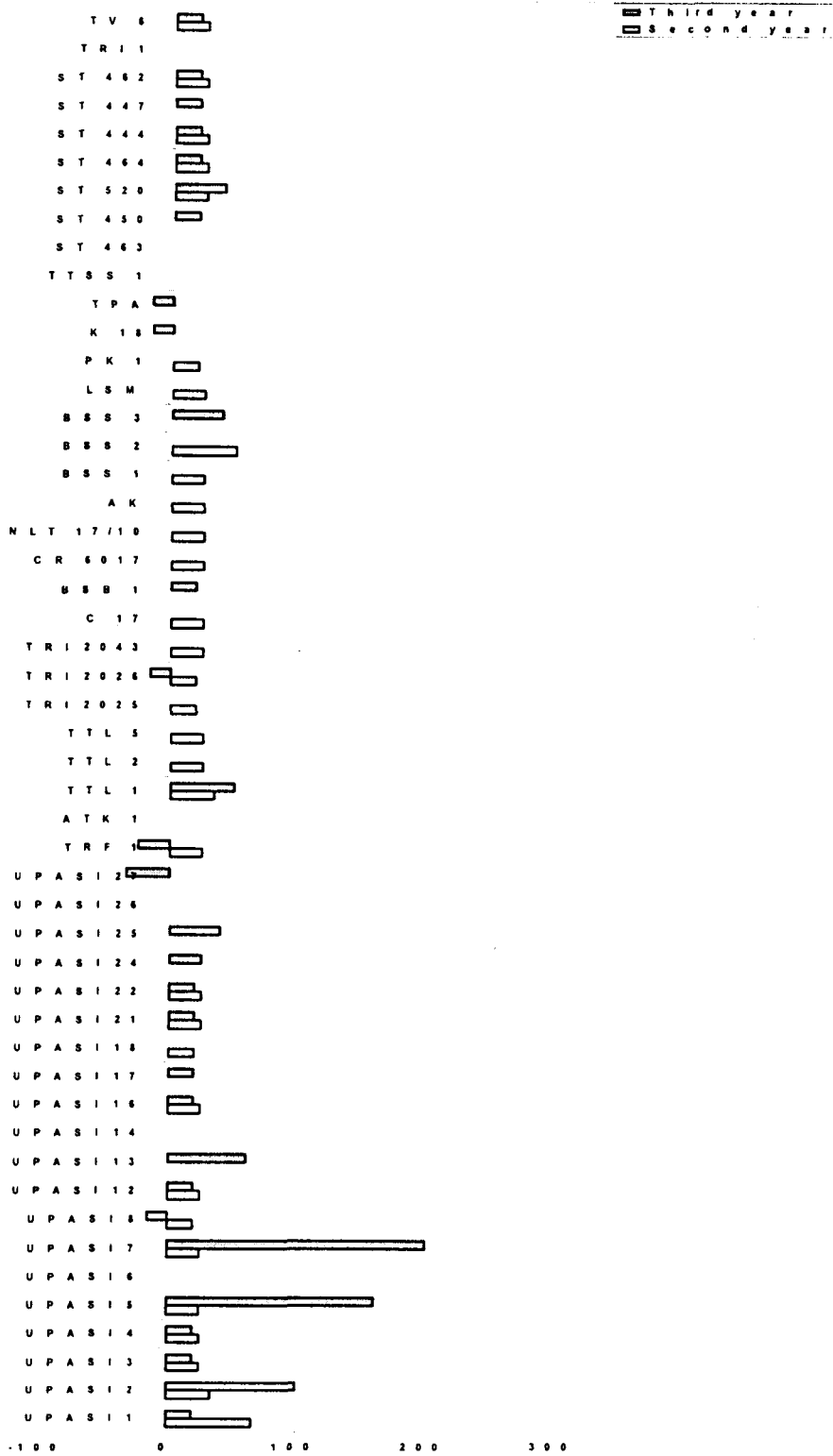
Table 4.5. Variation of internodal length between bud and first leaf in juvenile plants of the fifty accessions of Assam tea studied (cm)

Sl. No	Accessions	First year	Second year	Percentage of variation	Third year	Percentage of variation
1	UPASI 1	0.3	0.5	66.7	0.6	20.0
2	UPASI 2	0.3	0.4	33.3	0.8	100.0
3	UPASI 3	0.4	0.5	25.0	0.6	20.0
4	UPASI 4	0.4	0.5	25.0	0.6	20.0
5	UPASI 5	0.4	0.5	25.0	1.3	160.0
6	UPASI 6	0.5	0.5	0.0	0.5	0.0
7	UPASI 7	0.4	0.5	25.0	1.5	200.0
8	UPASI 8	0.5	0.6	20.0	0.5	-16.7
9	UPASI 12	0.4	0.5	25.0	0.6	20.0
10	UPASI 13	0.5	0.5	0.0	0.8	60.0

11	UPASI 14	0.5	0.5	0.0	0.5	0.0
12	UPASI 16	0.4	0.5	25.0	0.6	20.0
13	UPASI 17	0.5	0.5	0.0	0.6	20.0
14	UPASI 18	0.5	0.6	20.0	0.6	0.0
15	UPASI 21	0.4	0.5	25.0	0.6	20.0
16	UPASI 22	0.4	0.5	25.0	0.6	20.0
17	UPASI 24	0.4	0.4	0.0	0.5	25.0
18	UPASI 25	0.5	0.5	0.0	0.7	40.0
19	UPASI 26	0.5	0.5	0.0	0.5	0.0
20	UPASI 27	0.6	0.6	0.0	0.4	-33.3
21	TRF 1	0.4	0.5	25.0	0.4	-25.0
22	ATK 1	0.5	0.5	0.0	0.5	0.0
23	TTL 1	0.3	0.4	33.3	0.6	50.0
24	TTL 2	0.4	0.5	25.0	0.5	0.0
25	TTL 5	0.4	0.5	25.0	0.5	0.0
26	TRI 2025	0.5	0.6	20.0	0.6	0.0
27	TRI 2026	0.5	0.6	20.0	0.5	-16.7
28	TRI 2043	0.4	0.5	25.0	0.5	0.0
29	C 17	0.4	0.5	25.0	0.5	0.0
30	BSB 1	0.5	0.5	0.0	0.6	20.0
31	CR 6017	0.4	0.5	25.0	0.5	0.0
32	NLT 17/10	0.4	0.5	25.0	0.5	0.0
33	AK	0.4	0.5	25.0	0.5	0.0
34	BSS 1	0.4	0.5	25.0	0.5	0.6
35	BSS 2	0.4	0.6	50.0	0.6	0.0
36	BSS 3	0.5	0.5	0.0	0.7	40.0
37	LSM	0.4	0.5	25.0	0.5	0.0
38	PK 1	0.5	0.6	20.0	0.6	0.0
39	K 18	0.6	0.6	0.0	0.5	-16.7
40	TPA	0.6	0.6	0.0	0.5	-16.7

41	TTSS 1	0.6	0.6	0.0	0.6	0.0
42	ST 463	0.5	0.5	0.0	0.5	0.0
43	ST 450	0.5	0.5	0.0	0.6	20.0
44	ST 520	0.4	0.5	25.0	0.7	40.0
45	ST 464	0.4	0.5	25.0	0.6	20.0
46	ST 444	0.4	0.5	25.0	0.6	20.0
47	ST 447	0.5	0.5	0.0	0.6	20.0
48	ST 462	0.4	0.5	25.0	0.6	20.0
49	TRI 1	0.5	0.5	0.0	0.5	0.0
50	TV 6	0.4	0.5	25.0	0.6	20.0
Grand Mean		0.5	0.5		0.6	
Range		0.3- 0.6	0.4- 0.6		0.4- 1.5	
SD		0.07	0.05		0.19	
CV		14.0	10.0		31.7	

Fig. 4.9. Variation of internodal length (B&F) (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.3. Internodal length (F&S)

Internodal length between first and second leaf is also a yield contributing character. This character was maximum in TRF 1 in the first and second years and in TTSS I in the third year (Table 4.6 and Fig 4.10). Maximum increase in internodal length (F& S) was shown by TTL 5 in the second year and TTSS 1 in the third year. Variability of the character got reduced in relation to age of the plants.

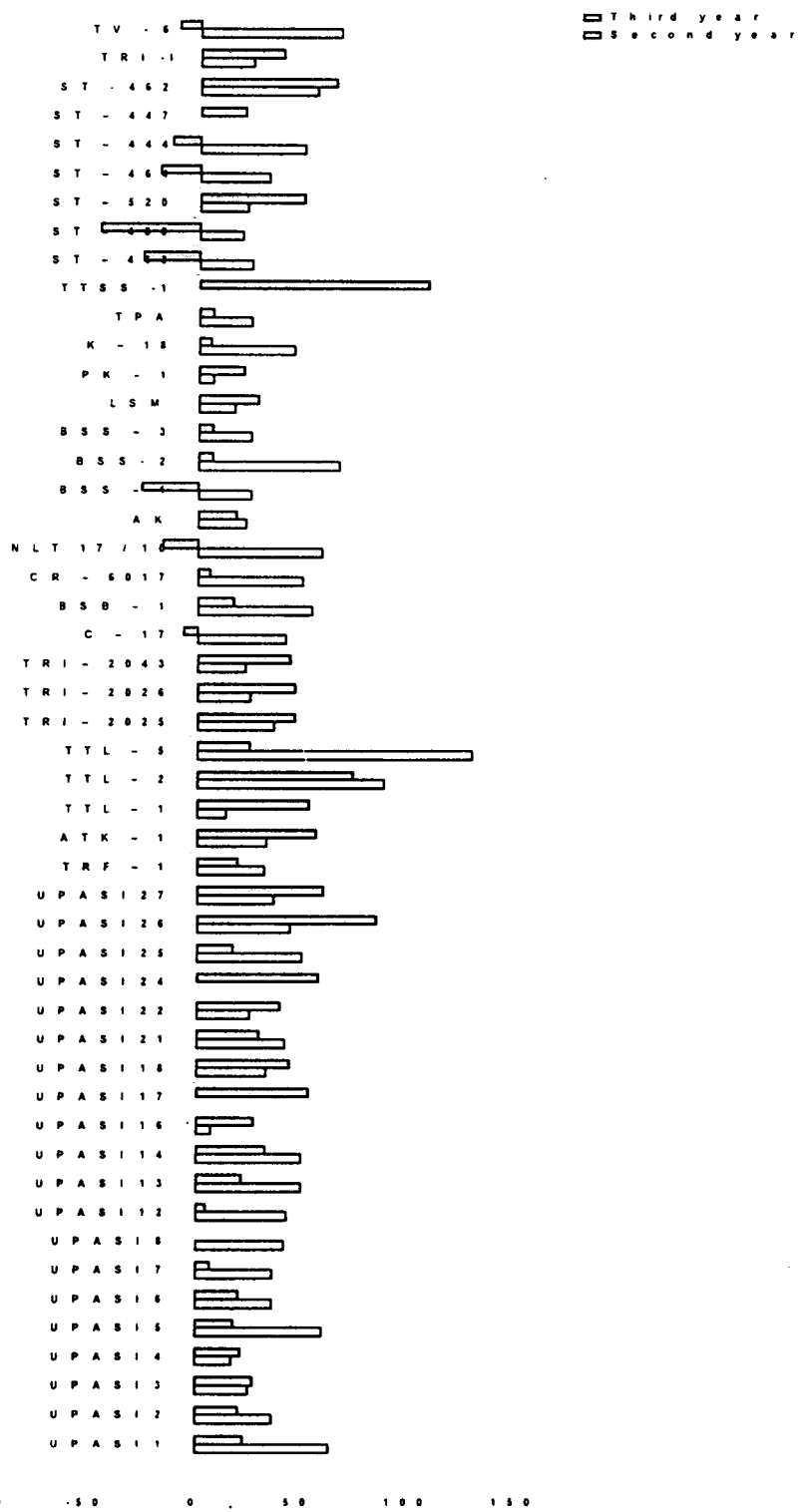
Table 4.6. Variation of internodal length between first and second leaf in juvenile plants of the fifty accessions of Assam tea studied (cm)

Sl. No.	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1.	UPASI 1	0.8	1.3	62.5	1.6	23.1
2.	UPASI 2	1.1	1.5	36.4	1.8	20.0
3.	UPASI 3	1.2	1.5	25.0	1.9	26.7
4.	UPASI 4	1.2	1.4	16.7	1.7	21.4
5.	UPASI 5	1.0	1.6	60.0	1.9	18.8
6.	UPASI 6	1.1	1.5	36.4	1.8	20.0
7.	UPASI 7	1.1	1.5	36.4	1.6	6.7
8.	UPASI 8	1.2	1.7	41.7	1.7	0.0
9.	UPASI 12	1.4	2.0	42.9	2.1	5.0
10.	UPASI 13	1.2	1.8	50.0	2.2	22.2
11.	UPASI 14	1.0	1.5	50.0	2.0	33.3
12.	UPASI 16	1.3	1.4	07.7	2.2	27.1
13.	UPASI 17	1.5	1.5	00.0	2.3	53.3
14.	UPASI 18	1.2	1.6	33.3	2.3	43.8

15.	UPASI 21	1.2	1.7	41.7	2.2	29.4
16.	UPASI 22	1.2	1.5	25.0	2.1	40.0
17.	UPASI 24	0.7	1.4	00.0	2.2	57.1
18.	UPASI 25	1.2	1.8	50.0	2.1	16.7
19.	UPASI 26	0.9	1.3	44.4	2.4	84.6
20.	UPASI 27	1.1	1.5	36.4	2.4	60.0
21.	TRF 1	1.6	2.1	31.3	2.5	19.0
22.	ATK 1	1.2	1.6	33.3	2.5	56.3
23.	TTL 1	1.5	1.7	13.3	2.6	52.9
24.	TTL 2	0.8	1.5	87.5	2.6	73.3
25.	TTL 5	0.7	1.6	128.6	2.0	25.0
26.	TRI 2025	1.1	1.5	36.4	2.2	46.7
27.	TRI 2026	1.2	1.5	25.0	2.2	46.7
28.	TRI 2043	1.3	1.6	23.1	2.3	43.8
29.	C 17	1.2	1.7	41.7	1.6	-5.9
30.	BSB 1	1.1	1.7	54.5	2.0	17.6
31.	CR 6017	1.2	1.8	50.0	1.9	5.6
32.	NLT 17/10	1.2	1.9	58.3	1.6	-15.8
33.	AK	1.3	1.6	23.1	1.9	18.8
34.	BSS 1	1.2	1.5	25.0	1.1	-26.7
35.	BSS 2	0.9	1.5	66.7	1.6	6.7
36.	BSS 3	1.2	1.5	25.0	1.6	6.7
37.	LSM	1.2	1.4	16.7	1.8	28.6

38.	PK 1	1.3	1.4	07.7	1.1	21.4
39.	K 18	1.1	1.6	45.5	1.7	6.3
40.	TPA	1.2	1.5	25.0	1.6	6.7
41.	TTSS 1	1.3	1.4	0.7	2.9	107.1
42.	ST 463	1.2	1.5	25.0	1.1	-26.7
43.	ST 450	1.2	1.5	20.8	0.8	-46.7
44.	ST 520	1.3	1.6	23.1	2.4	50.0
45.	ST 464	1.2	1.6	33.3	1.3	-18.8
46.	ST 444	1.0	1.5	50.0	1.3	-13.3
47.	ST 447	1.3	1.4	0.7	1.7	21.4
48.	ST 462	0.9	1.4	55.6	2.3	64.3
49.	TRI 1	1.2	1.5	25.0	2.1	40.0
50.	TV 6	1.2	2.0	66.7	1.8	-10.0
	Mean	1.2	1.6		1.9	
	Range	0.7- 1.6	1.3- 2.1		0.8- 2.9	
	SD	0.18	0.17		0.14	
	CV	15.0	10.6		7.4	

Fig. 4.10. Variation of internodal length (F&S) (%) during second and third years of growth in the 50 accessions of Assam tea studied



#### 4.2.1.4. Internodal length (S&T)

Internodal length between second and third leaf, which is also a yield contributing character showed a maximum in BSS 3 and TRF 1 in the first year (Table 4.7 and Fig 4.11) and in TRF 1 in the second and third years. Maximum increase in the case of this character was shown by UPASI 7 in the second year and LSM in the third year. Variability of the character was maximum in three year old plants.

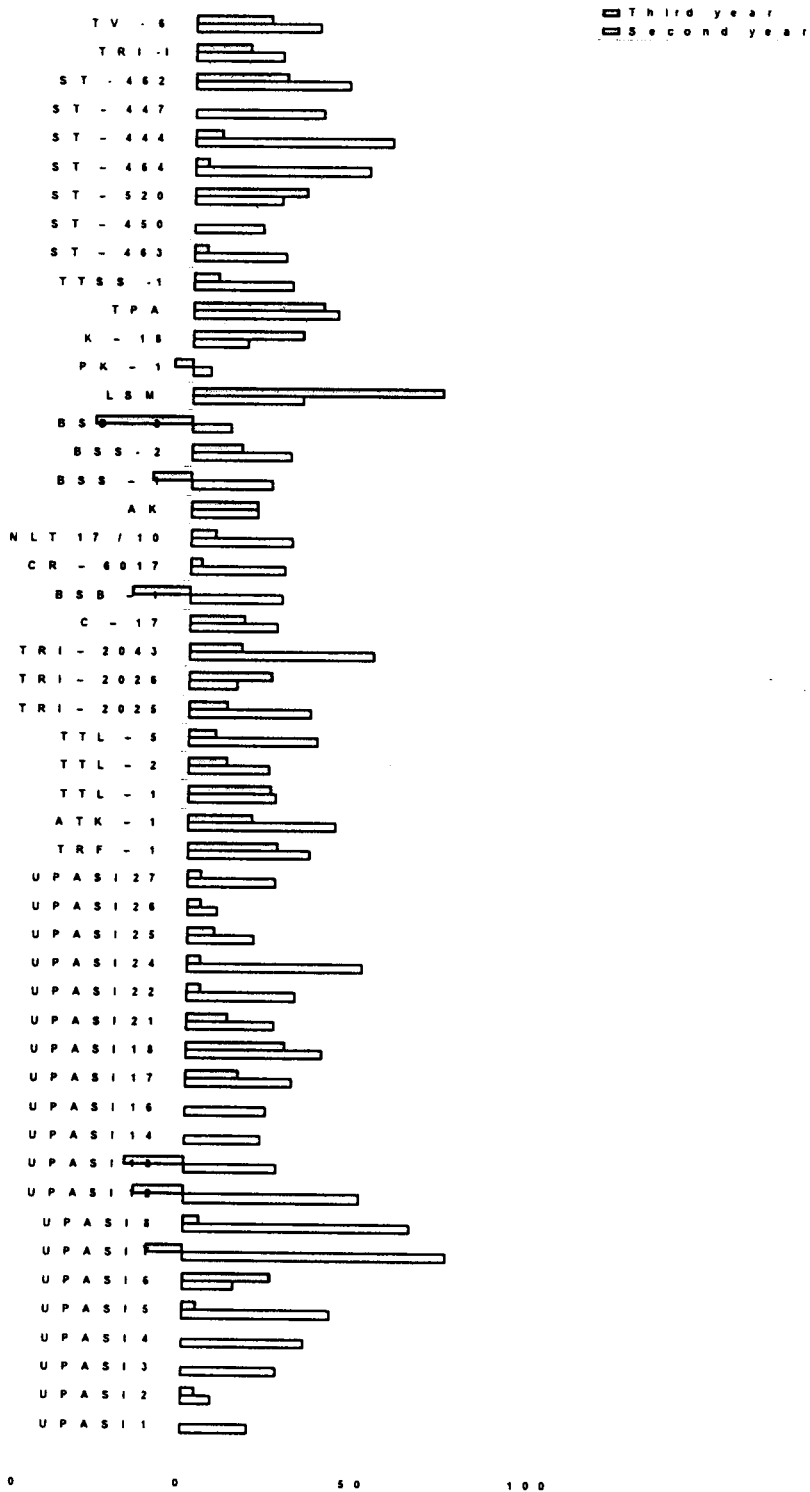
Table 4.7. Variation of internodal length between second and third leaf in juvenile plants of the fifty accessions of Assam tea studied

Sl. No.	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1.	UPASI 1	2.1	2.5	19.0	2.5	0.0
2.	UPASI 2	2.3	2.5	8.7	2.6	4.0
3.	UPASI 3	2.2	2.8	27.3	2.8	0.0
4.	UPASI 4	2.0	2.7	35.0	2.7	0.0
5.	UPASI 5	1.9	2.7	42.1	2.8	3.7
6.	UPASI 6	2.1	2.4	14.3	3.0	25.0
7.	UPASI 7	1.6	2.8	75.0	2.5	-10.7
8.	UPASI 8	1.4	2.3	64.3	2.4	4.3
9.	UPASI 12	1.8	2.7	50.3	2.3	-14.8
10.	UPASI 13	2.3	2.9	26.1	2.4	-17.2
11.	UPASI 14	2.3	2.8	21.7	2.8	0.0
12.	UPASI 16	2.2	2.7	22.7	2.7	0.0
13.	UPASI 17	2.0	2.6	30.0	3.0	15.4
14.	UPASI 18	1.8	2.5	38.9	3.1	28.6

15.	UPASI 21	2.0	2.5	25.0	2.8	12.0
16.	UPASI 22	1.9	2.5	31.2	2.6	4.0
17.	UPASI 24	1.6	2.4	50.0	2.5	4.2
18.	UPASI 25	2.1	2.5	19.0	2.7	8.0
19.	UPASI 26	2.3	2.5	8.7	2.6	4.0
20.	UPASI 27	2.0	2.5	25.0	2.6	4.0
21.	TRF 1	2.6	3.5	34.6	4.4	25.7
22.	ATK 1	1.9	2.7	42.1	3.2	18.5
23.	TTL 1	2.0	2.5	25.0	3.1	24.0
24.	TTL 2	2.2	2.7	22.7	3.0	11.1
25.	TTL 5	1.9	2.6	36.8	2.8	7.7
26.	TRI 2025	2.0	2.7	35.0	3.0	11.1
27.	TRI 2026	2.2	2.5	13.6	3.1	24.0
28.	TRI 2043	1.7	2.6	52.9	3.0	15.4
29.	C 17	2.0	2.5	25.0	2.9	16.0
30.	BSB 1	1.9	2.4	26.3	2.0	-16.7
31.	CR 6017	2.2	2.8	27.3	2.9	3.6
32.	NLT 17/10	2.1	2.7	28.8	2.9	7.4
33.	AK	2.1	2.6	19.0	3.1	19.2
34.	BSS 1	2.2	2.7	22.7	2.4	-11.1
35.	BSS 2	2.1	2.7	28.6	3.1	14.8
36.	BSS 3	2.6	2.9	11.5	2.1	-27.6
37.	LSM	1.6	2.1	31.3	3.6	71.4

38.	PK 1	1.9	2.0	5.3	1.9	-5.0
39.	K 18	1.9	2.2	15.8	2.9	31.8
40.	TPA	1.7	2.4	41.2	3.3	37.5
41.	TTSS 1	2.1	2.7	28.6	2.9	7.4
42.	ST 463	1.9	2.4	26.3	2.5	4.2
43.	ST 450	2.0	2.4	20.0	2.4	0.0
44.	ST 520	2.0	2.5	25.0	3.3	32.0
45.	ST 464	1.6	2.4	50.0	2.3	4.2
46.	ST 444	1.6	2.5	56.3	2.7	8.0
47.	ST 447	1.9	2.6	36.8	2.6	0.0
48.	ST 462	1.6	2.3	43.8	2.9	26.1
49.	TRI 1	2.0	2.5	25.0	2.9	16.0
50.	TV 6	1.7	2.3	35.3	2.8	21.7
	Mean	2.0	2.6		2.8	
	Range	1.4- 2.6	2.0- 3.5		1.9- 4.4	
	SD	0.25	0.23		0.41	
	CV	9.3	8.8		14.6	

Fig. 4.11. Variation of internodal length (S&T) (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.5. Leaf angle

Tea plants with wider leaf angle are capable of harvesting more sunlight since the leaves of such plants get better exposed to it. Though there was not so much of variation in leaf angle among the cultivars, there was a clear trend observed in this parameter. During the first, second and third years, UPASI 4 showed the minimum leaf angle and UPASI 24 showed the maximum indicating the genotypic control of the character. Leaf angle variation among the cultivars in the first year was from 31° to 61° and in the second year, from 29° to 57° and in the third year from 32° to 62° (Table 4.8 and Fig 4.12). Maximum increase in leaf angle was shown in the second year of growth by UPASI 7 and in the third year of growth by BSS 2. Coefficient of variation of the character showed slow reduction from year to year.

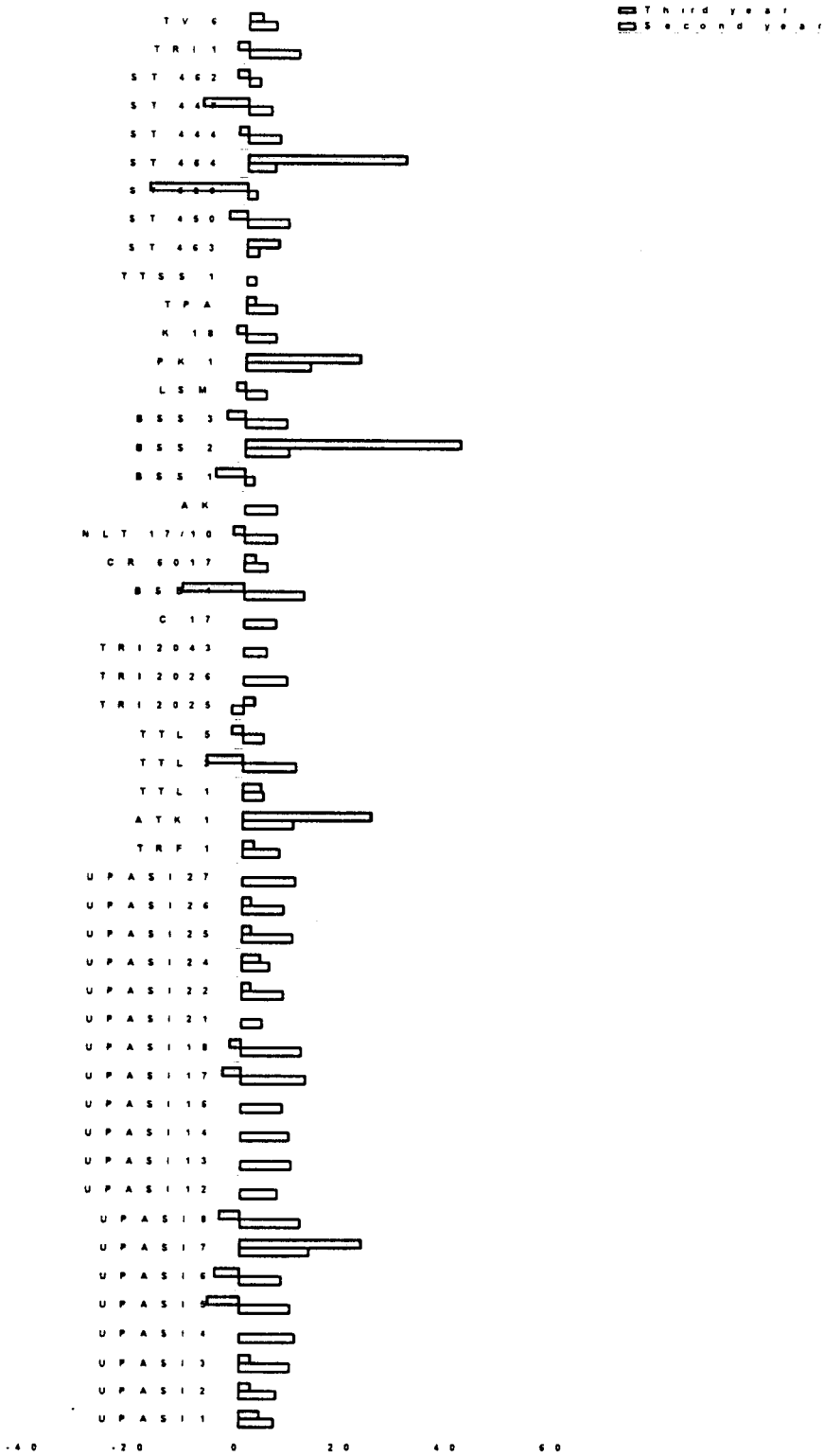
Table 4.8. Variation of leaf angle in juvenile plants of the fifty accessions of Assam tea studied (degrees)

Sl. No	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1	UPASI 1	46	49	6.52	51	4.08
2	UPASI 2	43	46	6.98	47	2.17
3	UPASI 3	42	46	9.52	47	2.17
4	UPASI 4	29	32	10.34	32	0.00
5	UPASI 5	31	34	9.68	32	-5.88
6	UPASI 6	39	42	7.69	40	-4.76
7	UPASI 7	31	35	12.90	43	22.86
8	UPASI 8	44	49	11.36	47	-4.08
9	UPASI 12	42	45	7.14	45	0.00
10	UPASI 13	42	46	9.52	46	0.00
11	UPASI 14	50	55	9.09	55	0.00
12	UPASI 16	52	56	7.69	56	0.00

13	UPASI 17	50	56	12.00	54	-3.57
14	UPASI 18	44	49	11.36	48	-2.08
15	UPASI 21	50	52	4.00	52	0.00
16	UPASI 22	52	56	7.69	57	1.79
17	UPASI 24	57	60	5.26	62	3.33
18	UPASI 25	53	58	9.43	59	1.73
19	UPASI 26	51	55	7.84	56	1.82
20	UPASI 27	40	44	10.00	44	0.00
21	TRF 1	43	46	6.98	47	2.17
22	ATK 1	41	45	9.76	56	24.44
23	TTL 1	53	55	3.77	57	3.64
24	TTL 2	51	56	9.80	51	-7.14
25	TTL 5	49	51	4.08	50	-1.96
26	TRI 2025	50	49	-2.00	50	2.04
27	TRI 2026	49	53	8.16	53	0.00
28	TRI 2043	46	48	4.35	48	0.00
29	C 17	49	52	6.12	52	0.00
30	BSB 1	53	59	11.32	52	-11.86
31	CR 6017	48	50	4.17	51	1.96
32	NLT 17/10	48	51	6.25	50	-1.96
33	AK	50	53	6.00	53	0.00
34	BSS 1	54	55	1.85	52	-5.45
35	BSS 2	36	39	8.33	55	41.03
36	BSS 3	51	55	7.84	53	-3.60
37	LSM	50	52	4.00	51	-1.92
38	PK 1	41	46	12.20	56	21.74
39	K 18	52	55	5.77	54	-1.82
40	TPA	52	55	5.77	56	1.82
41	TTSS 1	53	52	1.89	52	0.00
42	ST 463	48	49	2.08	52	6.12

43	ST 450	52	56	7.69	54	-3.57
44	ST 520	52	53	1.92	43	-18.87
45	ST 464	38	40	5.26	52	30.00
46	ST 444	51	54	5.88	53	-1.85
47	ST 447	45	47	4.44	43	-8.51
48	ST 462	44	45	2.27	44	-2.22
49	TRI 1	41	45	9.76	44	-2.22
50	TV 6	38	40	5.26	41	2.50
Grand Mean		46.3	49.4		50	
Range		29- 57	32- 60		32- 62	
SD		6.4	6.5		6.1	
CV		13.8	13.15		12.2	

Fig. 4.12. Variation of leaf angle (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.6. Leaf area

Assam tea is broad leaved. Leaves with higher leaf area are capable of producing more biomass. In the case of tea since leaves are the yield contributing parts, leaf size has got a direct relationship with yield. At the end of first year, leaf area among the cultivars varied between 2.38 cm<sup>2</sup> and 16.69 cm<sup>2</sup> (Table 4.9 and Fig 4.13). AK was found to be with minimum leaf area whereas UPASI 3 had the maximum leaf area. The same trend was observed at the end of second and third years also. However, maximum increase in leaf area at the end of the second year was shown by TTL 5 and at the end of the third year by TV 6. The character showed almost the same variability in plants of different age.

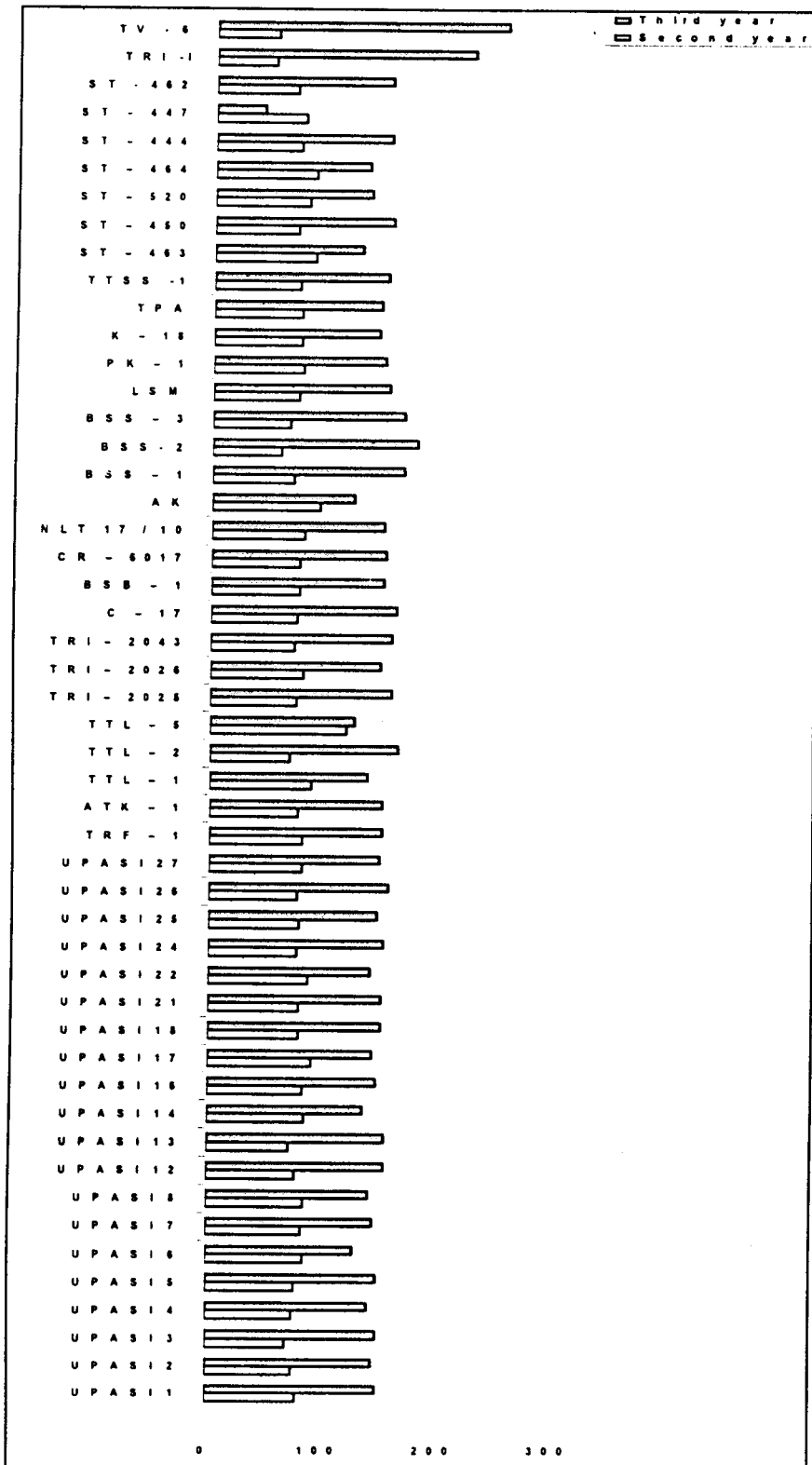
Table 4.9. Variation of leaf area (cm<sup>2</sup>) in juvenile plants of the fifty accessions of Assam tea studied.

Sl. No.	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1.	UPASI 1	9.55	17.20	80.03	42.73	148.4
2.	UPASI 2	13.71	23.96	74.77	58.86	145.7
3.	UPASI 3	16.69	28.29	69.51	71.35	149.0
4.	UPASI 4	9.08	16.00	76.19	38.56	141.0
5.	UPASI 5	7.30	12.95	77.46	32.31	149.5
6.	UPASI 6	7.93	14.62	84.38	33.46	128.9
7.	UPASI 7	8.58	15.66	82.52	38.42	145.3
8.	UPASI 8	7.73	14.22	84.07	34.21	140.6
9.	UPASI 12	8.27	14.62	76.85	37.12	153.9
10.	UPASI 13	10.24	17.66	72.53	45.13	155.5

11.	UPASI 14	8.16	15.10	85.03	35.68	136.3
12.	UPASI 16	8.02	14.63	82.53	36.14	148.0
13.	UPASI 17	7.45	14.20	90.68	34.54	143.2
14.	UPASI 18	8.17	14.66	79.37	36.72	150.5
15.	UPASI 21	8.15	14.62	79.33	36.62	150.5
16.	UPASI 22	7.63	14.23	86.54	34.32	141.2
17.	UPASI 24	7.98	14.21	78.10	35.82	152.1
18.	UPASI 25	9.08	16.21	78.43	40.00	146.8
19.	UPASI 26	9.04	16.10	78.07	41.23	156.1
20.	UPASI 27	8.09	14.62	80.73	36.32	148.4
21.	TRF 1	6.83	12.32	80.34	30.85	150.4
22.	ATK 1	11.62	20.66	77.76	51.68	150.1
23.	TTL 1	5.97	11.22	87.93	26.68	137.8
24.	TTL 2	7.27	12.36	70.05	32.76	165.0
25.	TTL 5	3.92	8.55	118.16	19.31	125.8
26.	TRI 2025	5.39	9.46	75.39	24.52	159.2
27.	TRI 2026	5.47	9.86	80.26	24.56	149.1
28.	TRI 2043	10.21	17.66	72.91	45.62	158.3
29.	C 17	5.73	10.05	75.50	26.35	162.2
30.	BSB 1	12.08	21.32	76.50	53.45	150.7
31.	CR 6017	8.86	15.66	76.85	39.72	153.6
32.	NLT 17/10	7.41	13.46	81.73	33.65	150.0
33.	AK	2.38	4.63	94.55	10.41	124.8

34.	BSS 1	6.77	11.66	72.20	31.23	167.8
35.	BSS 2	7.65	12.22	59.68	34.12	179.2
36.	BSS 3	5.63	9.41	67.25	25.26	168.4
37.	LSM	9.41	16.56	76.06	42.23	155.0
38.	PK 1	8.31	14.89	79.17	37.25	150.2
39.	K 18	13.30	23.66	77.87	58.13	145.7
40.	TPA	10.98	19.54	77.88	48.12	146.3
41.	TTSS 1	11.02	19.26	74.78	48.63	152.5
42.	ST 463	7.48	14.16	89.39	32.69	130.9
43.	ST 450	10.21	17.66	72.96	45.26	156.3
44.	ST 520	12.02	22.00	83.09	52.31	137.8
45.	ST 464	12.02	22.62	88.25	53.32	135.7
46.	ST 444	9.41	16.56	76.06	42.20	154.8
47.	ST 447	6.29	11.26	79.01	16.12	43.16
48.	ST 462	9.55	16.46	72.40	41.86	154.3
49.	TRI 1	8.65	13.25	53.18	43.23	226.3
50.	TV 6	7.32	11.32	54.64	40.21	255.2
Mean		8.6	15.3		38.2	
Range		2.38- 16.69	4.63- 28.29		10.41- 71.33	
SD		2.54	4.37		11.06	
CV		29.5	28.5		28.9	

Fig. 4.13. Variation of leaf area (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.7. Number of branches

The unique nature of the plucking table of tea is made possible by the system of branching and number of branches produced. Moreover, profuse branching results in the production of more number of yielding tips. A range between 3 and 4 branches was recorded in the accessions studied presently at the end of the first year, between 7 and 8 at the end of second year and between 8 and 14 at the end of the third year. Number of branches increased along with increasing age. Maximum increase in branch number was shown by UPASI 13 at the end of the second year and TV 6 at the end of the third year (Table 4.10 and Fig 4.14). The coefficients of variation of the character showed no particular trend of variation.

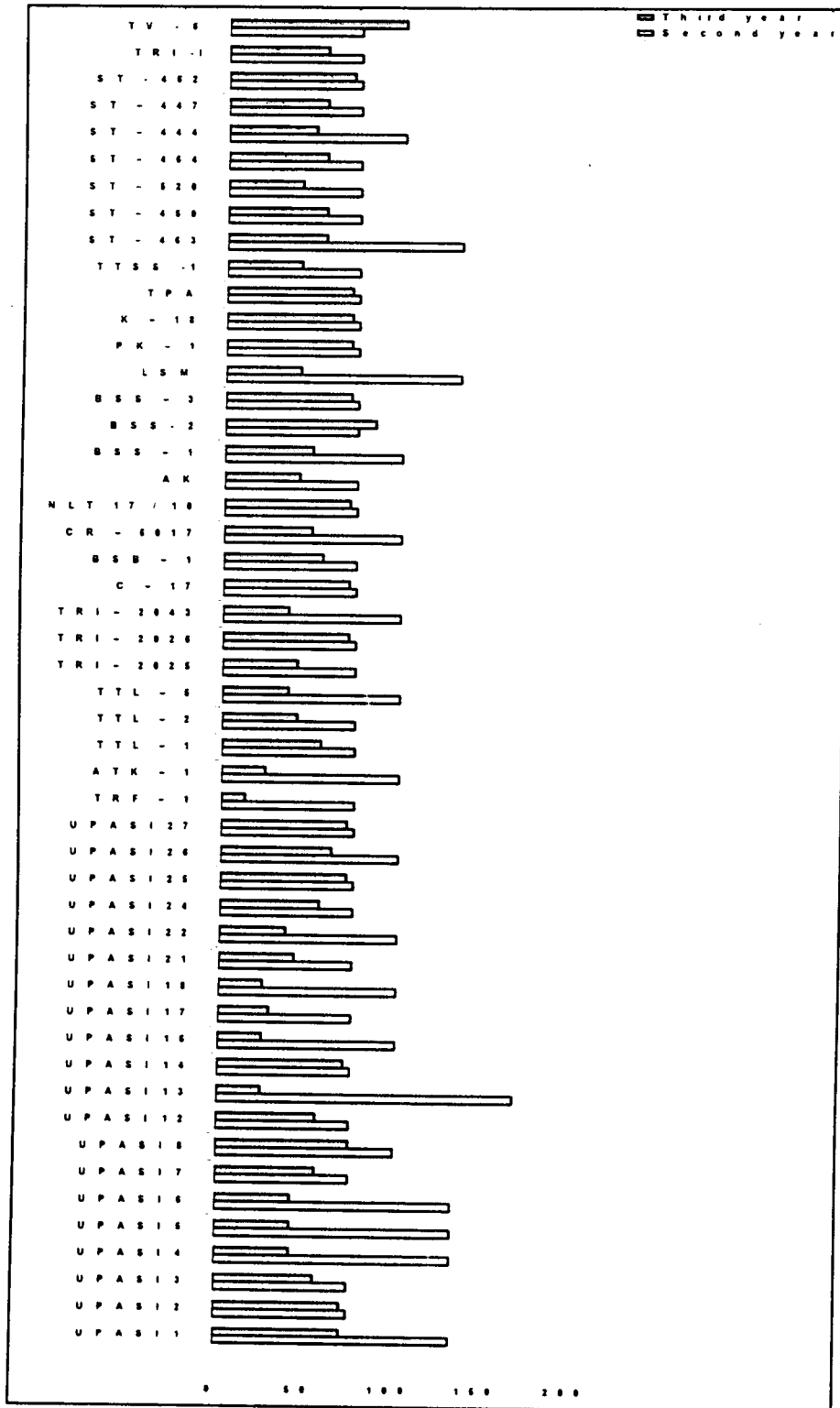
Table 4.10. Variation of number of branches in juvenile plants of the fifty accessions of Assam tea studied

Sl. No.	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1.	UPASI 1	3	7	133.3	12	71.4
2.	UPASI 2	4	7	75.0	12	71.4
3.	UPASI 3	4	7	75.0	11	57.1
4.	UPASI 4	3	7	133.3	10	42.9
5.	UPASI 5	3	7	133.3	10	42.9
6.	UPASI 6	3	7	133.3	10	42.9
7.	UPASI 7	4	7	75.0	11	57.1
8.	UPASI 8	4	8	100.0	14	75.0
9.	UPASI 12	4	7	75.0	11	57.1
10.	UPASI 13	3	8	166.7	10	25.0

11.	UPASI 14	4	7	75.0	12	71.4
12.	UPASI 16	4	8	100.0	10	25.0
13.	UPASI 17	4	7	75.0	9	28.6
14.	UPASI 18	4	8	100.0	10	25.0
15.	UPASI 21	4	7	75.0	10	42.9
16.	UPASI 22	4	8	100.0	11	37.5
17.	UPASI 24	4	7	75.0	11	57.1
18.	UPASI 25	4	7	75.0	12	71.4
19.	UPASI 26	4	8	100.0	13	62.5
20.	UPASI 27	4	7	75.0	12	71.4
21.	TRF 1	4	7	75.0	8	14.3
22.	ATK 1	4	8	100.0	10	25.0
23.	TTL 1	4	7	75.0	11	57.1
24.	TTL 2	4	7	75.0	10	42.9
25.	TTL 5	4	8	100.0	11	37.5
26.	TRI 2025	4	7	75.0	10	42.9
27.	TRI 2026	4	7	75.0	12	71.4
28.	TRI 2043	4	8	100.0	11	37.5
29.	C 17	4	7	75.0	12	71.4
30.	BSB 1	4	7	75.0	11	57.1
31.	CR 6017	4	8	100.0	12	50.0
32.	NLT 17/10	4	7	75.0	12	71.4
33.	AK	4	7	75.0	10	42.9

34.	BSS 1	4	8	100.0	12	50.0
35.	BSS 2	4	7	75.0	13	85.7
36.	BSS 3	4	7	75.0	12	71.4
37.	LSM	3	7	133.3	10	42.9
38.	PK 1	4	7	75.0	12	71.4
39.	K 18	4	7	75.0	12	71.4
40.	TPA	4	7	75.0	12	71.4
41.	TTSS 1	4	7	75.0	10	42.9
42.	ST 463	3	7	133.3	11	57.1
43.	ST 450	4	7	75.0	11	57.1
44.	ST 520	4	7	75.0	10	42.9
45.	ST 464	4	7	75.0	11	57.1
46.	ST 444	4	8	100.0	12	50.0
47.	ST 447	4	7	75.0	11	57.1
48.	ST 462	4	7	75.0	12	71.4
49.	TRI 1	4	7	75.0	11	57.1
50.	TV 6	4	7	75.0	14	100
Mean		3.9	7.2		11.1	
Range		3-4	7-8		8-14	
SD		0.33	0.43		1.18	
CV		8.5	6.0		10.6	

Fig. 4.14. Variation of number of branches (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.8. Branch length

Branch length is also a yield contributing character in tea since it can contribute towards the appearance and spread of bush. During the first and second years of growth, UPASI 3 showed the minimum branch length whereas ST 462 showed the maximum branch length (Table 4.11 and Fig 4.15). At the end of the third year UPASI 16 showed the minimum branch length and CR 6017 showed the maximum. TPA showed the maximum increase in branch length at the end of the second year and UPASI 13 showed the maximum increase in branch length at the end of the third year. Variability of the character got reduced in relation to age.

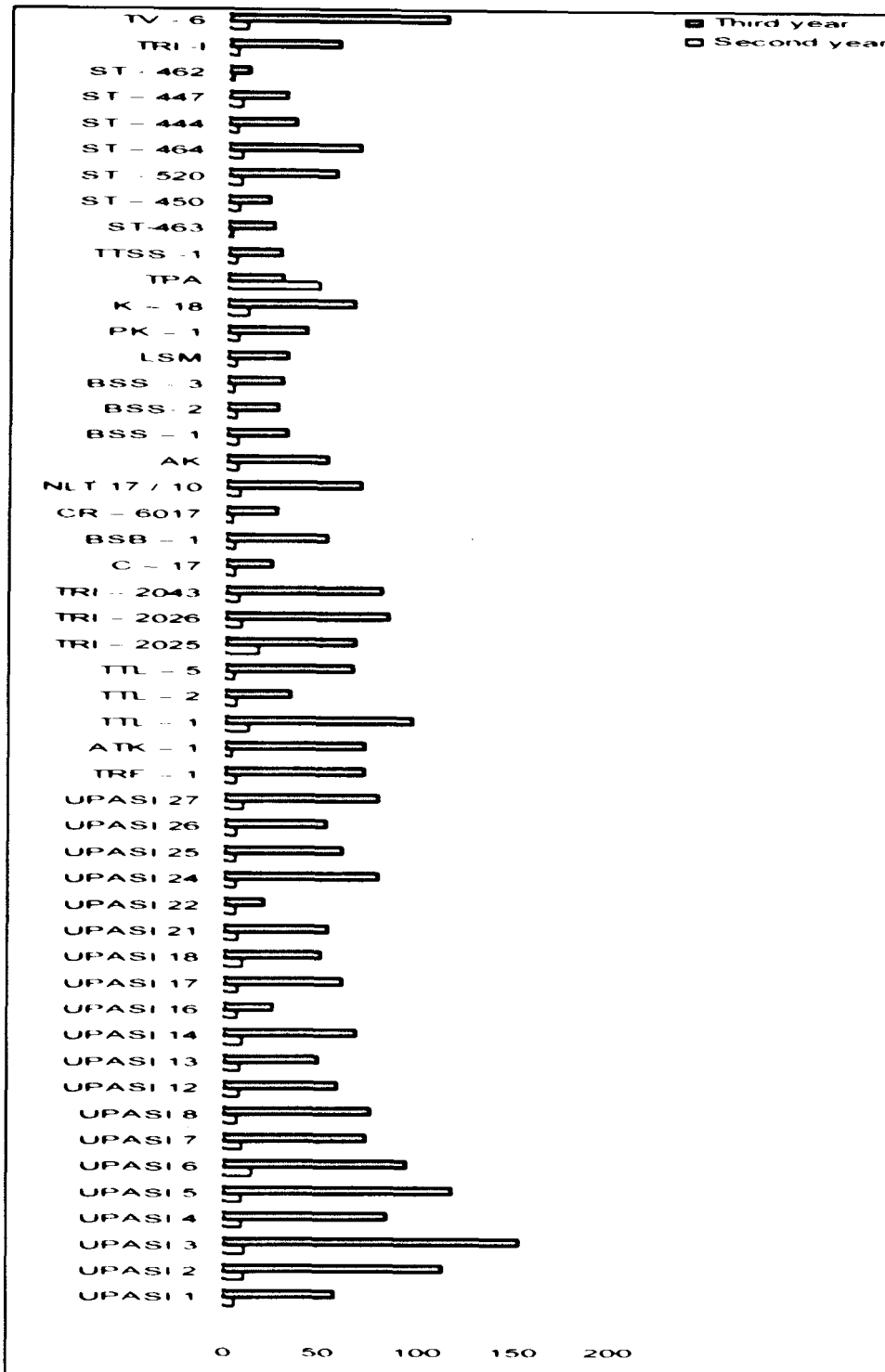
Table 4.11. Variation of branch length in juvenile plants of the fifty accessions of Assam tea studied (cm)

Sl. No.	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1.	UPASI 1	27.3	29.0	6.2	46.0	58.6
2.	UPASI 2	20.6	22.9	11.2	49.0	114.0
3.	UPASI 3	19.2	21.3	10.9	54.0	153.5
4.	UPASI 4	22.5	24.8	10.2	46.0	85.5
5.	UPASI 5	23.3	25.5	9.4	56.0	119.6
6.	UPASI 6	22.3	25.6	14.8	50.0	95.3
7.	UPASI 7	24.7	27.1	9.7	47.0	74.3
8.	UPASI 8	28.8	31.0	7.6	54.8	76.8
9.	UPASI 12	31.4	34.3	9.2	54.9	60.1
10.	UPASI 13	28.5	30.9	8.4	46.1	49.2
11.	UPASI 14	25.3	27.9	10.3	47.4	69.9

12.	UPASI 16	30.1	32.2	7.0	40.8	26.7
13.	UPASI 17	24.8	26.6	7.3	43.0	61.7
14.	UPASI 18	27.6	30.5	10.5	46.0	50.8
15.	UPASI 21	27.6	29.7	7.6	46.1	55.2
16.	UPASI 22	31.5	33.6	6.7	40.8	21.4
17.	UPASI 24	23.6	25.2	6.8	45.7	81.3
18.	UPASI 25	30.3	32.2	6.3	52.4	62.7
19.	UPASI 26	33.5	35.5	6.0	54.3	53.0
20.	UPASI 27	25.6	28.1	9.8	50.7	80.4
21.	TRF 1	30.3	32.3	6.6	55.8	72.8
22.	ATK 1	31.5	32.8	4.1	56.9	73.5
23.	TTL 1	24.4	27.5	12.7	54.5	98.2
24.	TTL 2	35.5	37.8	6.5	50.8	34.4
25.	TTL 5	28.6	30.0	4.9	50.2	67.3
26.	TRI 2025	26.3	30.8	17.1	51.7	67.9
27.	TRI 2026	28.2	30.8	9.2	57.3	86.0
28.	TRI 2043	29.6	31.9	7.8	58.2	82.4
29.	C 17	40.2	42.2	5.0	52.7	24.9
30.	BSB 1	35.4	37.2	5.1	57.1	53.5
31.	CR 6017	31.5	32.6	3.5	59.7	27.1
32.	NLT 17/10	29.6	31.7	7.1	54.2	71.0
33.	AK	33.6	35.9	6.8	55.2	53.8
34.	BSS 1	39.2	41.5	5.9	54.8	32.0

35.	BSS 2	43.3	45.2	4.4	57.8	27.9
36.	BSS 3	43.4	45.0	3.7	58.3	29.6
37.	LSM	40.2	42.4	5.5	56.3	32.8
38.	PK 1	30.5	32.3	5.9	56.3	42.6
39.	K 18	29.4	32.7	11.2	54.5	66.7
40.	TPA	29.1	43.1	48.1	55.7	29.2
41.	TTSS 1	41.4	43.3	4.6	55.8	28.9
42.	ST 463	40.4	41.5	2.7	51.7	24.6
43.	ST 450	32.4	34.5	6.5	56.7	22.2
44.	ST 520	33.2	35.7	7.5	56.2	57.4
45.	ST 464	32.2	34.5	7.1	58.7	70.1
46.	ST 444	38.4	40.5	5.5	54.9	35.6
47.	ST 447	33.3	35.6	6.9	46.8	31.5
48.	ST 462	45.6	47.0	3.1	52.1	10.9
49.	TRI 1	33.5	35.3	5.4	56.1	58.9
50.	TV 6	20.4	22.4	9.8	48.1	114.7
Mean		30.8	33.2		52.3	
Range		19.2- 45.6	21.3- 47.0		40.8- 59.7	
SD		6.35	6.33		4.88	
CV		20.6	19.0		9.3	

Fig. 4.15. Variation of branch length (%) during second and third years of growth in the fifty accessions of Assam tea studied





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#### 4.2.1.9. Branch angle

Branch angle is a major factor in determining bush spread and also the degree of exposure of leaves to sunlight, thus influencing biomass production. Wider branch angle helps to increase the spread of bush and light harvesting. Branch angle varied from  $37^{\circ}$  to  $58.7^{\circ}$  in the first year,  $38.2^{\circ}$  to  $61.9^{\circ}$  in the second year and  $41.2^{\circ}$  to  $67.3^{\circ}$  in the third year. Minimum branch angle was shown by UPASI 3 in all the three years of growth studied where as maximum branch angle was shown by UPASI 1 (Table 4.12 and Fig 4.16). BSS 1 showed the maximum increase in branch angle in the second year of growth and UPASI 22 showed the maximum increase in branch angle in the third year. No deviation in variability of the character was observed in relation to age.

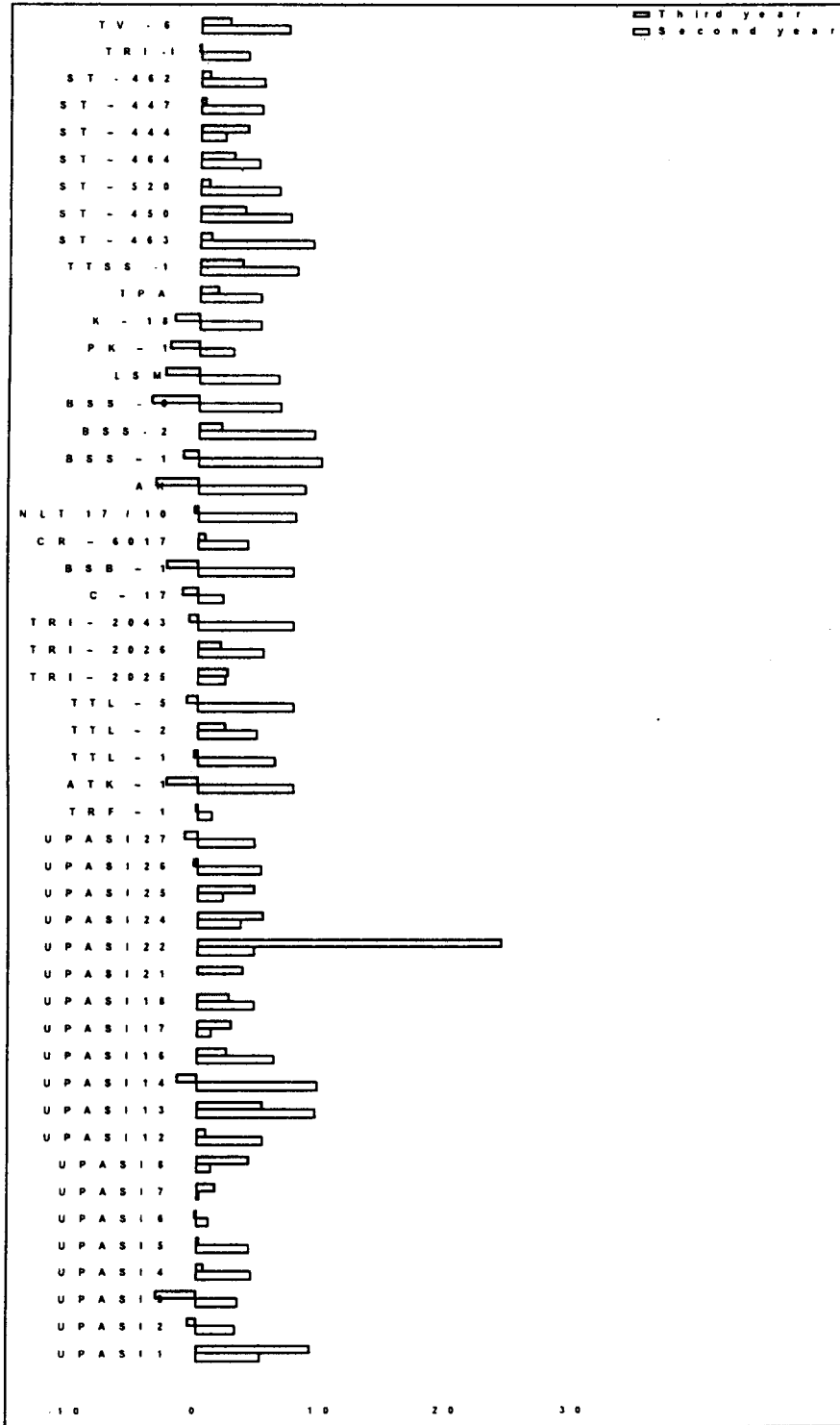
Table 4.12. Variation of branch angle in juvenile plants of the fifty accessions of Assam tea studied (degree)

Sl. No.	Accessions	First year	Second year	Percent variation	Third year	Percent variation
1.	UPASI 1	58.7	61.7	5.1	67.3	9.1
2.	UPASI 2	55.7	57.4	3.1	57.0	-0.7
3.	UPASI 3	37.0	38.2	3.2	37.0	-3.1
4.	UPASI 4	39.3	41.0	4.3	41.2	0.5
5.	UPASI 5	59.3	61.8	4.2	62.0	0.3
6.	UPASI 6	57.3	57.8	0.9	57.7	-0.2
7.	UPASI 7	51.0	51.1	0.2	51.8	1.4
8.	UPASI 8	50.3	50.9	1.2	53.0	4.1
9.	UPASI 12	54.7	57.6	5.3	58.0	0.7
10.	UPASI 13	52.3	57.2	9.4	60.2	5.2

11.	UPASI 14	51.7	56.6	9.5	55.7	-1.6
12.	UPASI 16	53.7	57.0	6.1	58.3	2.3
13.	UPASI 17	57.7	58.4	1.2	60.0	2.7
14.	UPASI 18	52.0	54.4	4.6	55.8	2.6
15.	UPASI 21	47.0	47.0	0.0	48.7	3.6
16.	UPASI 22	45.3	47.4	4.6	58.8	24.1
17.	UPASI 24	56.0	57.9	3.4	59.0	5.2
18.	UPASI 25	52.7	53.8	2.1	56.3	4.6
19.	UPASI 26	58.3	61.2	5.0	61.0	-0.3
20.	UPASI 27	56.0	58.6	4.6	58.0	-1.0
21.	TRF 1	57.7	58.4	1.2	58.3	-0.2
22.	ATK 1	55.0	59.1	7.5	57.7	-2.4
23.	TTL 1	58.3	61.9	6.2	61.7	-0.3
24.	TTL 2	47.0	49.2	4.7	50.3	2.2
25.	TTL 5	52.3	56.2	7.5	55.7	-0.9
26.	TRI 2025	50.7	51.8	2.2	53.0	2.3
27.	TRI 2026	55.3	58.2	5.2	59.3	1.9
28.	TRI 2043	54.0	58.1	7.6	57.7	-0.7
29.	C 17	52.3	53.4	2.1	52.7	-1.3
30.	BSB 1	47.7	51.3	7.5	50.0	-2.5
31.	CR 6017	52.3	54.4	4.0	54.7	0.6
32.	NLT 17/10	47.3	51.0	7.8	50.8	-0.4
33.	AK	51.3	55.6	8.4	53.7	-3.4

34.	BSS 1	51.7	56.7	9.7	56.0	-1.2
35.	BSS 2	51.0	55.7	9.2	56.7	1.8
36.	BSS 3	55.3	58.9	6.5	56.7	-3.7
37.	LSM	56.7	60.3	6.3	58.7	-2.7
38.	PK 1	57.0	58.6	2.8	57.3	-2.2
39.	K 18	56.7	59.4	4.8	58.2	-2.0
40.	TPA	50.7	53.2	4.9	54.0	1.5
41.	TTSS 1	46.7	50.3	7.7	53.0	3.4
42.	ST 463	49.3	53.8	9.1	54.3	0.9
43.	ST 450	48.3	51.8	7.2	53.7	3.7
44.	ST 520	52.3	55.6	6.3	56.0	0.7
45.	ST 464	53.3	55.8	4.7	57.3	2.7
46.	ST 444	56.0	57.1	2.0	59.3	3.9
47.	ST 447	48.7	51.1	4.9	51.3	0.4
48.	ST 462	50.7	53.3	5.1	53.7	0.8
49.	TRI 1	53.7	55.8	3.9	55.7	-0.2
50.	TV 6	48.7	52.1	7.0	53.3	2.3
Mean		52.3	54.0		55.6	
Range		37.0- 58.7	38.2- 61.9		37.0- 67.3	
SD		4.63	4.77		4.88	
CV		8.9	8.8		8.8	

Fig. 4.16. Variation of branch angle (%) during second and third years of growth in the fifty accessions of Assam tea studied



#### 4.2.1.10. Chlorophyll content

Chloroplasts constitute the photosynthetic machinery and chlorophyll is the chemical molecule fixing the energy of sunlight and making it available to the living world in the form of carbohydrates and hence chlorophyll content of leaves is directly related to biomass production in plants. Chlorophyll content among the accessions of Assam tea studied varied between 1.85 mg and 3.93 mg per gm weight of leaf at the end of the second year of growth and between 0.93 mg and 1.99 mg at the end of third year of growth (Table 4.13 and Fig 4.17). All the fifty cultivars studied showed a decreasing trend in chlorophyll content in relation to age. The reduction was maximum in NLT 17 /10 and minimum in TRI 2026. Variability of the character among the accessions did not show considerable deviation in relation to age.

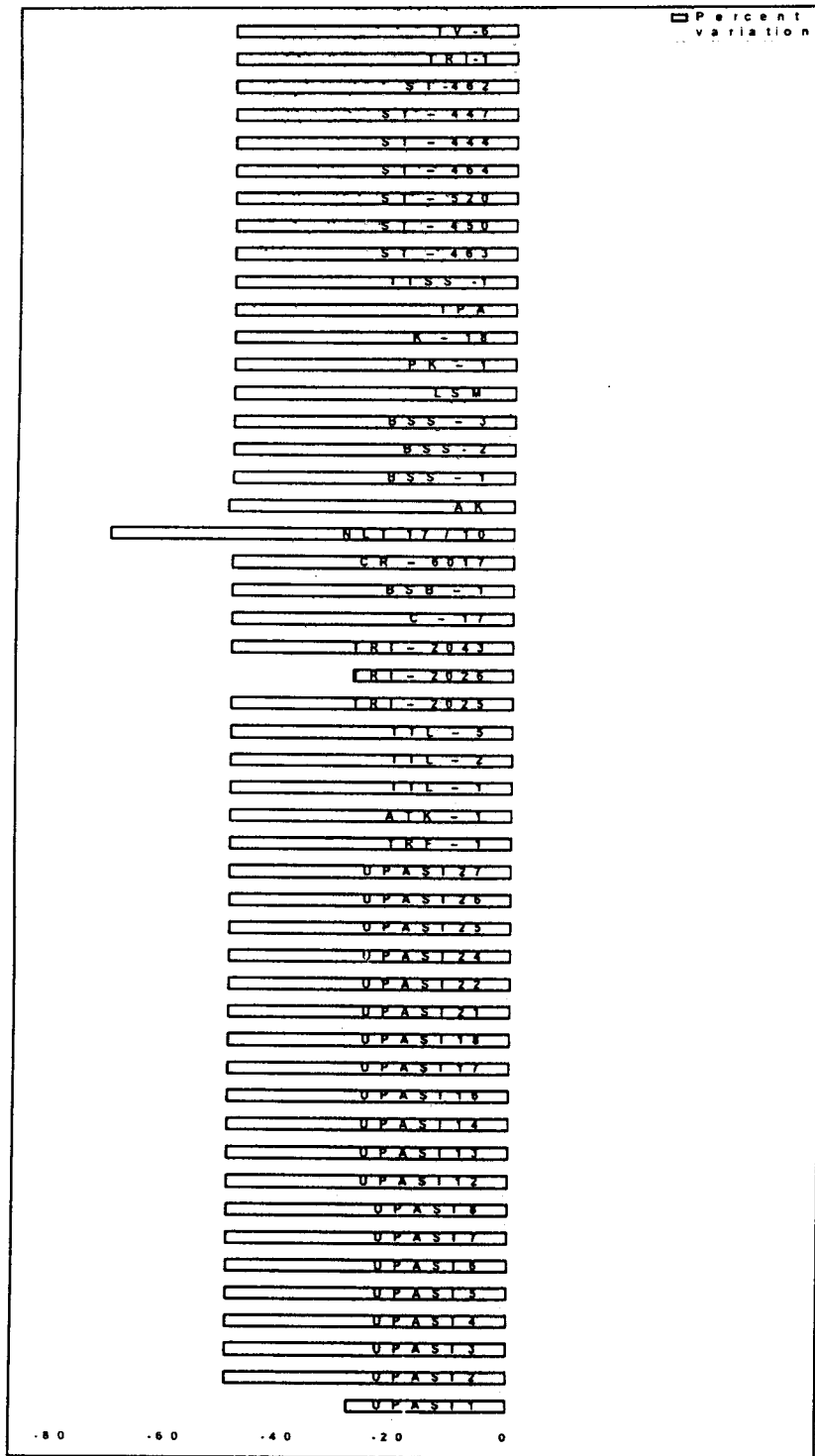
Table 4.13. Variation of total chlorophyll content in juvenile plants of the fifty accessions of Assam tea studied (mg/g weight of leaf)

Sl. No.	Accessions	Second year	Third year	Percent variation
1.	UPASI 1	2.78	1.99	-28.4
2	UPASI 2	3.11	1.56	-49.8
3	UPASI 3	2.68	1.34	-50.0
4.	UPASI 4	2.94	1.47	-50.0
5.	UPASI 5	3.65	1.83	-49.9
6.	UPASI 6	3.17	1.59	-49.8
7.	UPASI 7	3.67	1.84	-49.9
8.	UPASI 8	2.79	1.40	-49.8

9.	UPASI 12	2.12	1.06	-50.0
10.	UPASI 13	1.85	0.93	-49.7
11.	UPASI 14	2.07	1.04	-49.8
12.	UPASI 16	2.61	1.31	-49.8
13.	UPASI 17	2.81	1.41	-49.8
14.	UPASI 18	2.32	1.16	-50.0
15.	UPASI 21	2.73	1.37	-49.8
16.	UPASI 22	2.53	1.27	-49.8
17.	UPASI 24	3.73	1.87	-49.9
18.	UPASI 25	2.23	1.12	-49.8
19.	UPASI 26	2.60	1.30	-50.0
20.	UPASI 27	2.47	1.24	-49.8
21.	TRF 1	3.60	1.80	-50.0
22.	ATK 1	2.38	1.19	-50.0
23.	TTL 1	3.26	1.63	-50.0
24.	TTL 2	3.19	1.60	-49.8
25.	TTL 5	2.96	1.48	-50.0
26.	TRI 2025	3.48	1.74	-50.0
27.	TRI 2026	2.76	1.98	-28.3
28.	TRI 2043	3.12	1.56	-50.0
29.	C 17	3.33	1.67	-49.8
30.	BSB 1	3.54	1.77	-50.0
31.	CR 6017	2.57	1.29	-49.8

32.	NLT 17 / 10	3.51	1.00	-71.5
33.	AK	3.56	1.76	-50.6
34.	BSS 1	2.70	1.35	-50.0
35.	BSS 2	2.84	1.42	-50.0
36.	BSS 3	2.88	1.44	-50.0
37.	LSM	3.53	1.77	-49.9
38.	PK 1	3.93	1.97	-49.9
39.	K 18	3.72	1.86	-50.0
40.	TPA	2.60	1.30	-50.0
41.	TTSS 1	3.67	1.84	-49.9
42.	ST 463	3.70	1.85	-50.0
43.	ST 450	2.68	1.34	-50.0
44.	ST 520	3.03	1.52	-49.8
45.	ST 464	2.81	1.41	-49.8
46.	ST 444	2.87	1.44	-49.8
47.	ST 447	3.21	1.61	-49.8
48.	ST 462	2.88	1.44	-50.0
49.	TRI 1	2.76	1.38	-50.0
50	TV 6	2.84	1.42	-50.0
Mean		2.98	1.50	
Range		1.85-- 3.93	0.93- 1.99	
SD		0.50	0.27	
CV		16.78	18.00	

Fig. 4.17. Variation of total chlorophyll content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied



#### 4.2.1.11. Proline content

Proline is a chemical imparting stress resistance to plants. Proline content among the cultivars studied varied between 0.18% and 1.61% of dry weight at the end of the second year. UPASI 17 recorded the lowest proline content and UPASI 22 recorded the highest proline content. UPASI 12 had the lowest proline content whereas UPASI 21 had the highest proline content at the end of the third year. The range was from 0.12% to 1.57%. Proline content increased in relation to age in some cultivars and decreased in relation to age in some other cultivars (Table 4.14 and Fig 4.18).

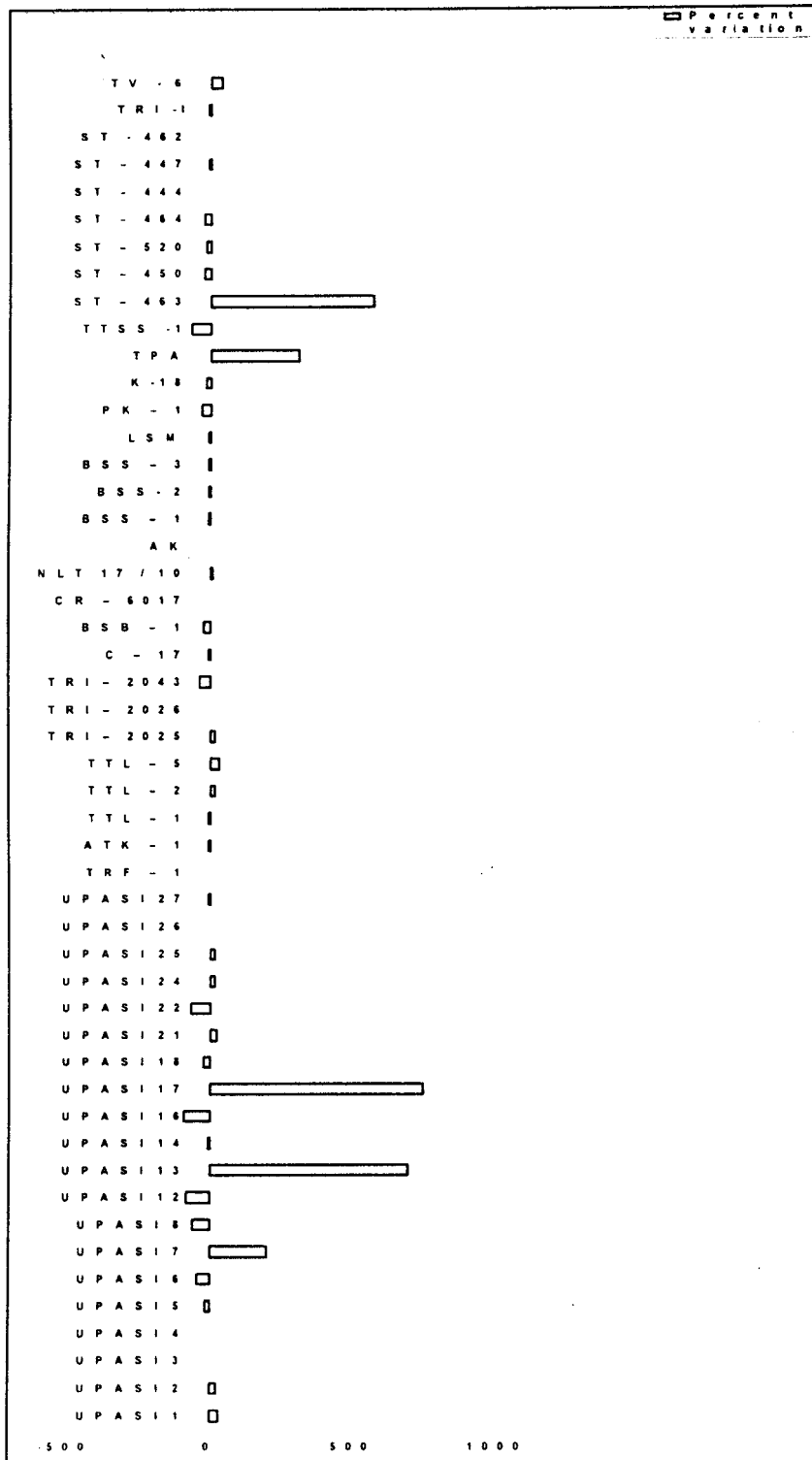
Table 4.14. Variation of proline content in juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)

Sl. No.	Accessions	Second Year	Third year	Percent variation
1.	UPASI 1	0.36	0.48	33.3
2.	UPASI 2	0.51	0.63	23.5
3.	UPASI 3	0.61	0.62	1.6
4.	UPASI 4	0.65	0.65	0
5.	UPASI 5	0.66	0.59	-10.6
6.	UPASI 6	0.62	0.35	-43.5
7.	UPASI 7	0.39	1.18	202.6
8.	UPASI 8	1.11	0.43	-61.2
9.	UPASI 12	0.78	0.12	-84.6
10.	UPASI 13	0.15	1.18	686.7
11.	UPASI 14	1.12	1.03	-8.0
12.	UPASI 16	1.07	0.13	-87.6

13.	UPASI 17	0.18	1.51	738.9
14.	UPASI 18	1.58	1.23	-22.2
15.	UPASI 21	1.27	1.57	23.6
16.	UPASI 22	1.61	0.55	-65.8
17.	UPASI 24	0.59	0.69	16.9
18.	UPASI 25	0.61	0.73	19.7
19.	UPASI 26	0.72	0.75	4.2
20.	UPASI 27	0.53	0.49	-7.5
21.	TRF 1	0.71	0.74	4.2
22.	ATK 1	0.81	0.79	-2.5
23.	TTL 1	0.72	0.69	-4.2
24.	TTL 2	0.61	0.74	21.3
25.	TTL 5	0.71	0.95	33.8
26.	TRI 2025	0.92	1.10	19.6
27.	TRI 2026	1.13	1.13	0
28.	TRI 2043	1.12	0.71	-36.6
29.	C 17	0.74	0.69	-6.8
30.	BSB 1	0.71	0.55	-22.5
31.	CR 6017	0.59	0.59	0
32.	NLT 17 / 10	0.61	0.65	6.6
33.	AK	0.62	0.65	4.8
34.	BSS 1	0.64	0.61	-4.7
35.	BSS 2	0.52	0.49	-5.8

36.	BSS 3	1.12	1.10	-1.8
37.	LSM	1.08	1.03	-4.6
38.	PK 1	1.01	0.71	-29.7
39	K 18	0.78	0.66	-15.4
40	TPA	0.12	0.49	308.3
41.	TTSS 1	0.47	0.15	-68.1
42.	ST 463	0.18	1.20	566.7
43.	ST 450	1.21	0.95	-21.5
44.	ST 520	0.92	0.80	-13.0
45.	ST 464	0.85	0.69	-18.8
46.	ST 444	0.72	0.75	4.2
47.	ST 447	0.68	0.65	-4.4
48.	ST 462	0.72	0.75	4.2
49.	TRI 1	0.58	0.53	-8.6
50.	TV 6	0.47	0.65	38.3
Mean		0.74	0.74	
Range		0.18- 1.61	0.12- 1.57	
SD		0.33	0.31	
CV		44.59	41.89	

Fig. 4.18. Variation of proline content (%) in three year old plants in relation to two year old plants of the 50 accessions of Assam tea studied



#### 4.2.1.12. Protein content

Protein content indicates the strength of the plants. Among the accessions protein content varied between 4.34% and 6.56% of dry weight at the end of the second year and 4.55% to 6.32% at the end of the third year. UPASI 17 recorded the highest protein content at the end of the second year and TTL 5 was found to be the highest in protein content at the end of the third year (Table 4.15 and Fig 4.19). The coefficient of variation of the character showed slight reduction in relation to age of the plants.

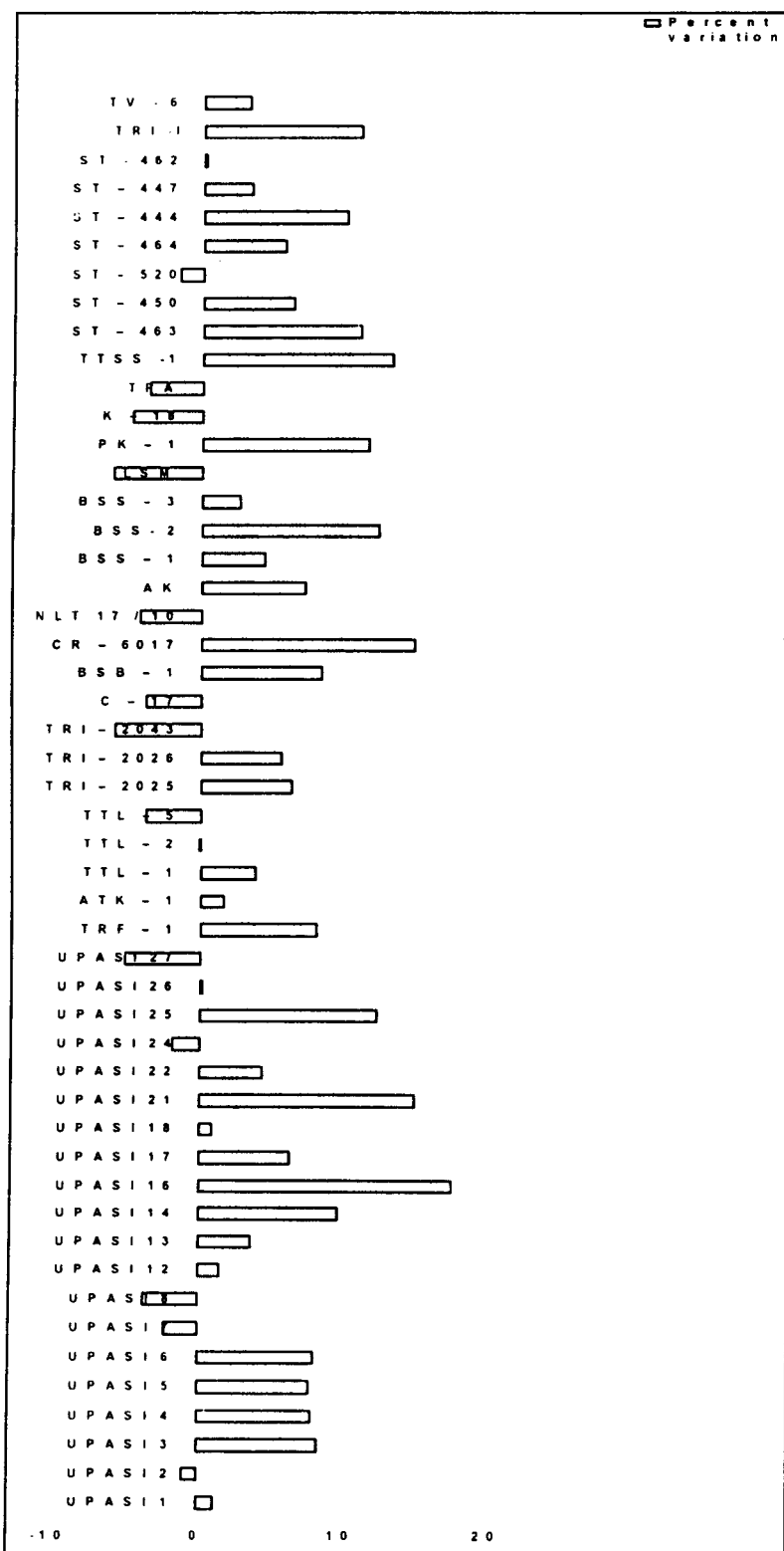
Table 4.15. Variation of protein content in the juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)

Sl. No.	Accessions	Second year	Third year	Percent variation
1.	UPASI 1	5.02	5.08	1.2
2.	UPASI 2	5.18	5.13	-1
3.	UPASI 3	4.69	5.08	8.3
4.	UPASI 4	4.64	5.00	7.8
5.	UPASI 5	4.91	5.29	7.7
6.	UPASI 6	5.39	5.82	8.0
7.	UPASI 7	5.72	5.59	-2.3
8.	UPASI 8	5.84	5.62	-3.8
9.	UPASI 12	4.64	4.71	1.5
10.	UPASI 13	4.39	4.55	3.6
11.	UPASI 14	4.80	5.26	9.6
12.	UPASI 16	4.49	5.27	17.4
13.	UPASI 17	4.34	4.61	6.2

14.	UPASI 18	4.55	4.59	0.9
15.	UPASI 21	4.66	5.35	14.8
16.	UPASI 22	4.98	5.20	4.4
17.	UPASI 24	5.27	5.17	-1.9
18.	UPASI 25	5.17	5.80	12.2
19.	UPASI 26	5.21	5.22	0.2
20.	UPASI 27	5.59	5.30	-5.2
21.	TRF 1	5.41	5.84	7.9
22.	ATK 1	5.79	5.88	1.6
23.	TTL 1	5.97	6.19	3.7
24.	TTL 2	6.16	6.15	-0.2
25.	TTL 5	6.56	6.32	-3.7
26.	TRI 2025	5.68	6.03	6.2
27.	TRI 2026	4.94	5.21	5.5
28.	TRI 2043	5.61	5.28	-5.9
29.	C 17	5.48	5.27	-3.8
30.	BSB 1	4.60	4.98	8.3
31.	CR 6017	4.96	5.69	14.7
32.	NLT 17 / 10	5.66	5.42	-4.2
33.	AK	5.21	5.58	7.1
34.	BSS 1	5.23	5.46	4.4
35.	BSS 2	5.08	5.70	12.2
36.	BSS 3	4.99	5.12	2.6

37.	LSM	5.61	5.27	-6.1
38.	PK 1	4.96	5.53	11.5
39.	K 18	5.68	5.41	-4.8
40.	TPA	5.34	5.15	-3.6
41.	TTSS 1	4.89	5.53	13.1
42.	ST 463	4.74	5.25	10.8
43.	ST 450	5.36	5.69	6.2
44.	ST 520	5.61	5.52	-1.6
45.	ST 464	5.56	5.87	5.6
46.	ST 444	5.26	5.78	9.9
47.	ST 447	5.86	6.06	3.4
48.	ST 462	5.56	5.57	0.2
49.	TRI 1	5.22	5.79	10.9
50.	TV 6	5.94	6.13	3.2
Mean		5.25	5.45	
Range		4.34–6.56	4.55–6.32	
SD		0.49	0.42	
CV		9.33	7.71	

Fig. 4.19. Variation of protein content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied



#### 4.2.1.13. Polyphenol content

All plant species synthesise phenolic compounds but tea species are unique in terms of propensity and variety of phenolics such as flavanols, flavanol glucosides, acids and depsides. The flavanols are oxidized to theaflavin and thearubigin during black tea processing by the enzyme polyphenol oxidase (Ramaswamy and Raju, 1993). Total polyphenols among the cultivars ranged from 16.71% to 25.56% of dry weight at the end of the second year and 18.73% to 27.45% at the end of the third year. ST 463 was found to be the lowest in polyphenol content whereas TRI 2025 was found to be the highest in polyphenol content in the second year. In the third year TPA had the lowest polyphenol content and TTL 5 had the highest polyphenol content (Table 4.16 and Fig. 4.20). Polyphenol content showed an increase in relation to age in juvenile plants.

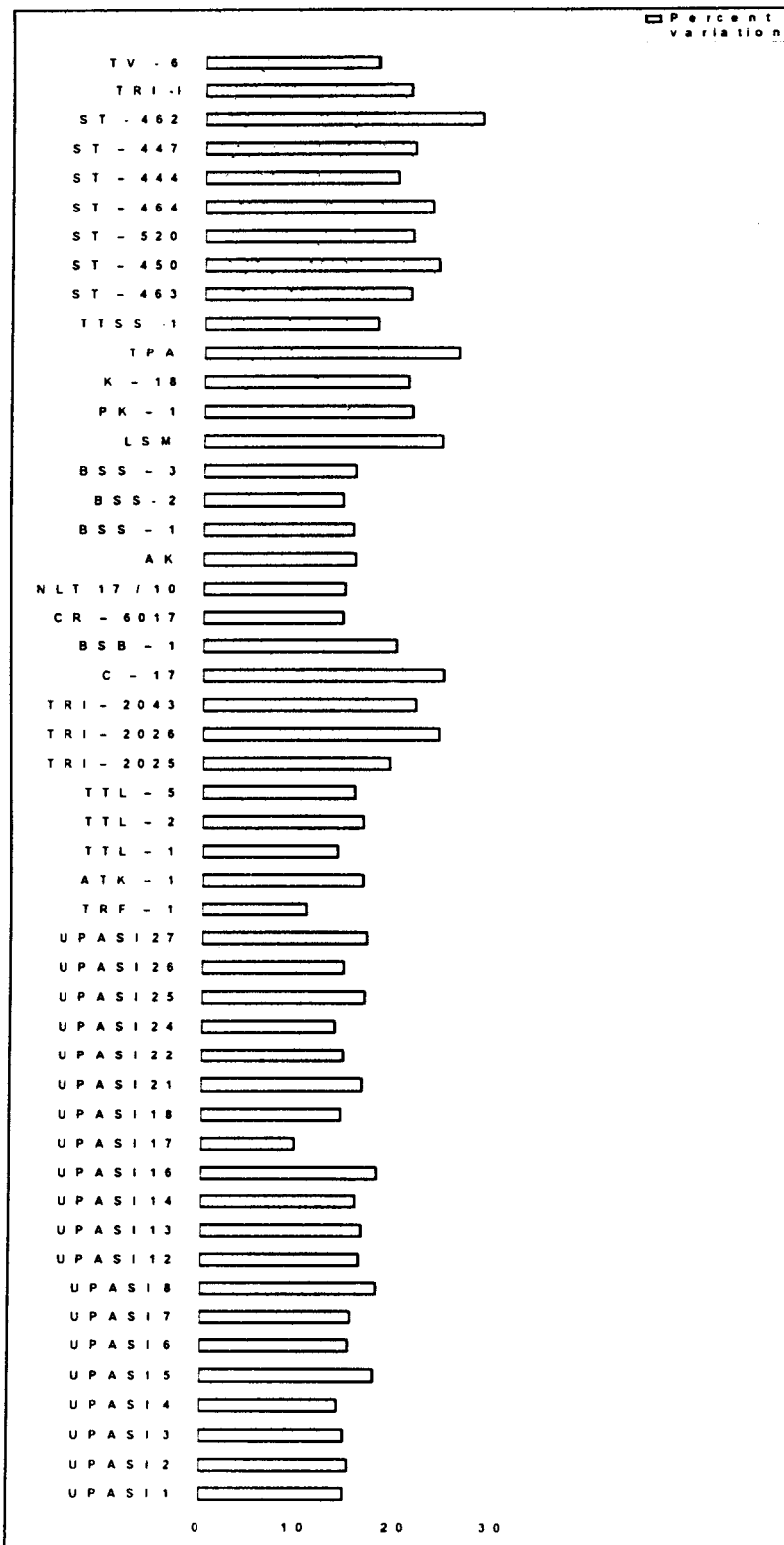
Table 4.16. Variation of polyphenol content in the juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)

Sl. No.	Accessions	Second Year	Third year	Percent variation
1.	UPASI 1	23.42	25.55	9.1
2.	UPASI 2	22.74	25.51	12.2
3.	UPASI 3	24.73	27.00	9.2
4.	UPASI 4	22.08	27.13	22.9
5.	UPASI 5	23.44	25.55	9.0
6.	UPASI 6	24.55	26.54	8.1
7.	UPASI 7	19.55	21.19	8.4

8.	UPASI 8	23.10	25.62	10.9
9.	UPASI 12	24.51	26.99	10.1
10.	UPASI 13	21.69	23.89	10.1
11.	UPASI 14	24.09	26.44	9.8
12.	UPASI 16	21.70	24.00	10.6
13.	UPASI 17	27.20	29.92	10
14.	UPASI 18	22.54	24.95	10.7
15.	UPASI 21	24.55	27.08	10.3
16.	UPASI 22	21.24	23.89	12.5
17.	UPASI 24	24.11	27.17	12.7
18.	UPASI 25	22.53	24.88	10.4
19.	UPASI 26	21.19	23.97	13.1
20.	UPASI 27	23.73	26.01	9.6
21.	TRF 1	24.26	27.05	11.5
22.	ATK 1	23.43	25.97	10.8
23.	TTL 1	21.45	24.22	12.9
24.	TTL 2	19.39	21.85	12.7
25.	TTL 5	25.43	27.45	7.9
26.	TRI 2025	25.56	27.40	7.2
27.	TRI 2026	22.63	24.99	10.4
28.	TRI 2043	17.70	20.02	13.1
29.	C 17	17.09	19.51	14.2
30.	BSB 1	21.07	23.78	12.9

31.	CR 6017	24.47	26.78	9.4
32.	NLT 17 / 10	20.08	22.15	10.3
33.	AK	21.08	23.38	10.9
34.	BSS 1	23.42	25.39	8.4
35.	BSS 2	23.59	25.90	9.8
36.	BSS 3	23.29	25.26	8.5
37.	LSM	23.61	25.81	9.3
38.	PK 1	17.71	19.56	10.4
39.	K 18	19.67	21.88	11.2
40.	TPA	16.88	18.73	11.0
41.	TTSS 1	18.58	20.84	12.2
42.	ST 463	16.71	18.74	12.1
43.	ST 450	18.38	20.62	12.2
44.	ST 520	21.57	22.74	5.4
45.	ST 464	18.32	21.12	15.3
46.	ST 444	22.71	24.61	8.4
47.	ST 447	17.84	19.52	9.4
48.	ST 462	17.44	19.60	12.4
49.	TRI 1	22.05	24.23	9.9
50.	TV 6	22.42	24.59	9.7
Mean		21.81	24.14	
Range		16.71-25.56	18.73-27.45	
SD		2.61	2.74	
CV		11.96	11.35	

Fig. 4.20. Variation of polyphenol content in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied



#### 4.2.1.14. Catechin content

Catechins are flavanols that get oxidized into theaflavin and thearubigin determining the quality of tea (Jain, 1999; Ramaswamy, 1999). Catechin content among the cultivars varied from 8.45% to 25.04% at the end of the second year and 10.83% to 27.42% at the end of the third year. UPASI 17 had the maximum catechin content and ST 462 had the minimum catechin content at the end of the third year (Table 4.17 and Fig 4.21).

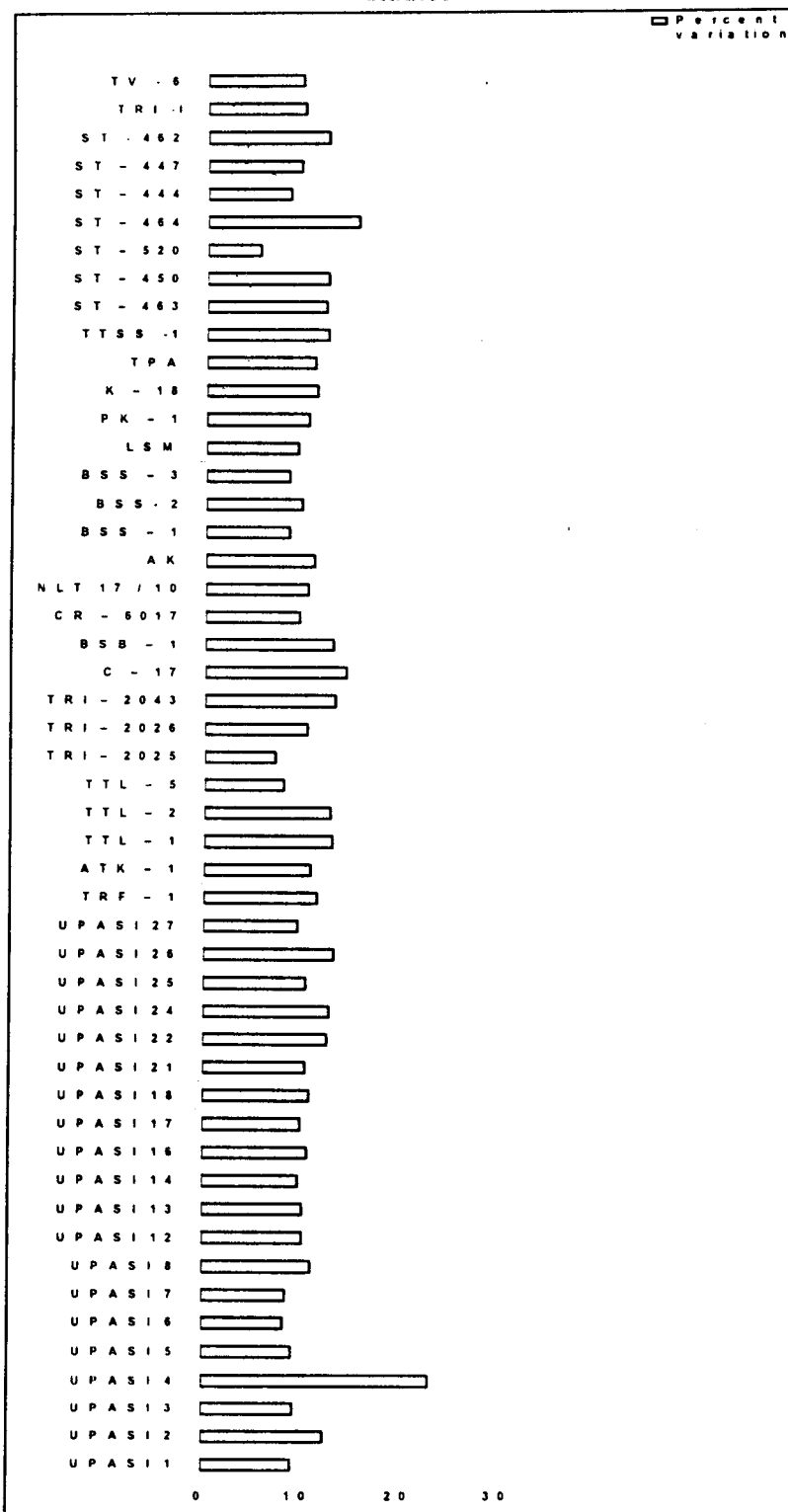
Table 4.17. Variation of catechin content in the juvenile plants of the fifty accessions of Assam tea studied (% of dry weight)

S. No.	Accessions	Second year	Third year	Percent variation
1.	UPASI 1	16.32	18.70	14.6
2.	UPASI 2	15.83	18.21	15.0
3.	UPASI 3	16.32	18.70	14.6
4.	UPASI 4	17.04	19.42	14.0
5.	UPASI 5	13.40	15.78	17.8
6.	UPASI 6	15.64	18.02	15.2
7.	UPASI 7	15.50	17.88	15.4
8.	UPASI 8	13.33	15.71	17.9
9.	UPASI 12	14.74	17.12	16.1
10.	UPASI 13	14.63	17.01	16.3
11.	UPASI 14	15.13	17.51	15.7
12.	UPASI 16	13.29	15.67	17.9
13.	UPASI 17	25.04	27.42	9.5

14.	UPASI 18	16.64	19.02	14.3
15.	UPASI 21	14.49	16.87	16.4
16.	UPASI 22	16.54	18.92	14.4
17.	UPASI 24	17.55	19.93	13.6
18.	UPASI 25	14.35	16.73	16.6
19.	UPASI 26	16.54	18.92	14.4
20.	UPASI 27	14.05	16.43	16.9
21.	TRF 1	22.54	24.92	10.6
22.	ATK 1	14.60	16.98	16.3
23.	TTL 1	17.23	19.61	13.8
24.	TTL 2	14.55	16.93	16.4
25.	TTL 5	15.35	17.73	15.5
26.	TRI 2025	12.45	14.83	19.1
27.	TRI 2026	9.95	12.33	23.9
28.	TRI 2043	11.09	13.47	21.5
29.	C 17	9.77	12.15	24.4
30.	BSB 1	12.09	14.47	19.7
31.	CR 6017	16.77	19.15	14.2
32.	NLT 17 / 10	16.37	18.75	14.5
33.	AK	15.35	17.73	15.5
34.	BSS 1	15.43	17.81	15.4
35.	BSS 2	16.59	18.97	14.3
36.	BSS 3	15.33	17.71	15.5

37.	LSM	9.89	12.27	24.1
38.	PK 1	11.23	13.61	21.2
39.	K 18	11.45	13.83	20.8
40.	TPA	9.23	11.61	25.8
41.	TTSS 1	13.45	15.83	17.7
42.	ST 463	11.31	13.69	21.0
43.	ST 450	9.98	12.36	23.8
44.	ST 520	11.26	13.64	21.1
45.	ST 464	10.29	12.67	23.1
46.	ST 444	12.06	14.44	19.7
47.	ST 447	11.19	13.57	21.3
48.	ST 462	8.45	10.83	28.2
49.	TRI 1	11.40	13.78	20.9
50.	TV 6	13.52	15.90	17.6
Mean		14.13	16.51	
Range		8.45 – 25.04	10.83 – 27.42	
SD		3.18	3.95	
CV		22.50	23.92	

Fig. 4.21. Variation of catechin content (%) in three year old plants in relation to two year old plants of the fifty accessions of Assam tea studied



#### **4.2.2. Juvenile growth index in Assam tea**

Juvenile growth index in the case of the fifty accessions of Assam tea under study has been analyzed presently based on juvenile growth pattern and rank of performance. Nine biometric parameters observed at the end of the first, second and third years of growth and five phytochemical characters observed at the end of the second and third years of growth have been used for the purpose. Value points were attributed to the accessions based on their comparative growth vigour in the case of each character and overall growth index calculated based on the relative vigour shown in the case of the fourteen characters studied as presented in tables 4.18 and 4.19.

TRI 2025 showed the best performance in terms of relative growth during the second and third years, based on the nine morphometric characters and five phytochemical characters studied, followed by TTSS 1. The first five promising accessions based on juvenile growth vigour are TRI 2025, TTSS 1, ST 520, UPASI 14 and BSS 1 in the order of performance. Juvenile behaviour of perennial crop plants has been considered as indicator of their future performance by earlier workers (Abraham, 2000).

Table 4.18. Juvenile growth index in the case of the fifty accessions of Assam tea studied (value points attributed to the accessions in relation to characters)

Accessions	Value points/Characters													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
UPASI 1	29	6	20	8	26	13	9	23	37	6	37	16	8	9
UPASI 2	44	11	17	11	21	10	9	44	13	4	36	12	27	10
UPASI 3	15	6	22	8	21	19	7	47	3	2	28	32	9	9
UPASI 4	31	6	18	8	16	6	5	40	18	2	27	29	35	5
UPASI 5	23	12	9	10	5	15	5	46	16	3	15	28	7	22
UPASI 6	4	4	17	25	7	3	5	42	15	4	6	31	4	11
UPASI 7	9	13	72	6	29	9	7	35	24	3	40	9	5	12
UPASI 8	12	3	8	12	8	7	10	36	34	4	5	7	23	23
UPASI 12	13	6	9	4	16	24	7	24	20	2	2	17	17	15
UPASI 13	6	10	19	2	16	27	2	16	36	5	43	22	17	16
UPASI 14	46	4	26	8	16	5	9	30	8	4	17	33	14	14
UPASI 16	21	6	23	8	16	12	2	4	27	4	1	42	20	23
UPASI 17	43	6	32	19	9	9	3	25	29	4	44	27	16	1
UPASI 18	40	4	28	28	11	19	2	17	28	2	10	15	21	6
UPASI 21	19	6	25	17	16	19	5	21	31	4	37	41	18	17
UPASI 22	38	6	27	10	18	8	4	2	38	4	3	24	29	7
UPASI 24	27	7	34	11	24	22	7	37	36	3	32	10	30	3
UPASI 25	30	8	13	15	17	12	9	27	35	4	34	40	19	18
UPASI 26	8	4	38	10	19	28	8	18	14	2	29	14	32	7

UPASI 27	24	1	35	10	16	13	9	38	11	4	18	2	12	19
TRF 1	32	2	16	26	24	18	1	33	15	2	29	30	26	2
ATK 1	36	4	33	21	30	16	2	34	5	2	25	18	22	16
TTL 1	34	9	31	24	25	7	7	43	14	2	24	23	3	4
TTL 2	18	4	37	16	4	33	5	13	26	4	35	13	30	17
TTL 5	11	4	21	14	12	3	4	28	12	2	38	7	3	13
TRI 2025	20	4	29	16	22	31	5	29	27	2	33	27	2	24
TRI 2026	7	3	29	24	16	14	9	4	25	6	27	25	19	35
TRI 2043	35	4	28	19	16	36	4	39	13	2	7	3	32	32
C 17	35	4	7	20	6	32	9	5	9	4	19	6	33	37
BSB 1	39	6	14	3	2	21	7	19	4	2	9	32	31	25
CR 6017	40	4	10	9	20	23	6	5	19	4	27	40	11	5
NLT 17/10	28	4	4	13	12	16	9	32	13	1	31	5	18	8
AK	37	4	15	22	16	2	5	20	2	5	30	28	23	13
BSS 1	16	5	2	5	6	33	6	11	10	2	21	24	5	12
BSS 2	1	4	12	18	32	35	4	6	24	2	20	38	14	7
BSS 3	42	8	12	1	8	34	9	9	1	2	26	19	6	13
LSM	26	4	24	32	13	26	5	12	8	3	22	1	10	36
PK 1	25	4	18	7	28	17	9	15	6	3	8	37	19	30
K 18	3	3	11	29	15	16	9	26	7	2	13	4	25	26
TPA	33	3	12	31	19	11	9	8	23	2	41	8	24	38
TTSS 1	36	4	39	13	16	23	5	7	30	3	4	39	27	21
ST 463	22	4	2	11	27	6	7	4	22	2	42	35	27	28

ST 450	41	6	1	8	9	29	7	3	32	2	11	27	27	34
ST 520	17	8	30	30	1	7	5	22	20	4	14	11	1	29
ST 464	14	6	3	11	31	4	7	31	29	4	12	26	34	33
ST 444	2	6	5	15	14	26	6	14	33	4	29	34	5	25
ST 447	17	6	18	8	3	1	7	10	17	4	23	21	25	31
ST 462	10	6	36	27	10	25	9	1	21	2	29	15	28	39
TRI 1	5	4	27	20	10	36	7	23	15	2	16	36	15	27
TV 6	19	6	6	23	23	37	12	45	27	2	39	20	13	20

Characters: 1. Shoot weight (3L&B); 2. Internodal length (B&F); 3. Internodal length (F&S); 4. Internodal length (S&T); 5. Leaf angle; 6. Leaf area; 7. Number of branches; 8. Branch length; 9. Branch angle; 10. Chlorophyll content; 11. Proline content; 12. Protein content; 13. Polyphenol content; 14. Catechin content.

Table 4.19. Juvenile growth index in the case of the fifty accessions of Assam tea studied (growth indices in relation to each character and total growth indices of the accessions)

Accessions	Growth indices in relation to characters															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	Rank
UPASI 1	0.66	0.46	0.51	0.45	0.81	0.35	0.75	0.49	0.97	1.0	0.84	0.38	0.23	0.23	8.13	13
UPASI 2	1.0	0.85	0.44	0.34	0.66	0.27	0.75	0.94	0.34	0.67	0.82	0.29	0.77	0.26	8.4	9
UPASI 3	0.34	0.46	0.56	0.25	0.66	0.51	0.58	1.0	0.08	0.33	0.64	0.76	0.83	0.23	7.23	22
UPASI 4	0.70	0.46	0.46	0.25	0.5	0.16	0.42	0.85	0.47	0.33	0.61	0.69	1.0	0.13	7.03	26
UPASI 5	0.52	0.92	0.23	0.31	0.16	0.41	0.42	0.98	0.42	0.15	0.34	0.67	0.2	0.56	6.29	37
UPASI 6	0.09	0.31	0.44	0.78	0.22	0.08	0.42	0.89	0.39	0.67	0.14	0.74	0.11	0.28	5.56	43
UPASI 7	0.20	1.0	0.31	0.19	0.91	0.24	0.58	0.74	0.63	0.5	0.91	0.21	0.14	0.31	6.87	29
UPASI 8	0.27	0.23	0.21	0.38	0.25	0.19	0.83	0.77	0.89	0.67	0.11	0.17	0.66	0.59	6.22	38
UPASI 12	0.30	0.46	0.23	0.13	0.5	0.65	0.58	0.51	0.53	0.33	0.05	0.40	0.49	0.38	5.54	44
UPASI 13	0.14	0.77	0.49	0.06	0.5	0.73	0.17	0.34	0.95	0.83	0.98	0.57	0.49	0.41	7.43	20
UPASI 14	0.91	0.31	0.67	0.25	0.5	0.14	0.75	0.64	0.21	0.67	0.39	0.79	0.4	0.36	9.85	4
UPASI 16	0.48	0.46	0.59	0.25	0.5	0.32	0.17	0.09	0.71	0.67	0.02	1.0	0.59	0.59	6.44	35

UPASI 17	0.98	0.46	0.82	0.59	0.28	0.24	0.75	0.53	0.76	0.67	1.0	0.64	0.46	0.03	8.21	11
UPASI 18	0.91	0.31	0.72	0.88	0.34	0.51	0.17	0.36	0.74	0.33	0.23	0.38	0.6	0.15	6.63	33
UPASI 21	0.43	0.46	0.64	0.53	0.5	0.51	0.42	0.45	0.81	0.67	0.84	0.98	0.51	0.44	8.19	12
UPASI 22	0.86	0.46	0.69	0.31	0.56	0.22	0.33	0.02	1.0	0.67	0.07	0.57	0.83	0.18	6.77	31
UPASI 24	0.61	0.54	0.57	0.34	0.75	0.59	0.58	0.79	0.95	0.5	0.73	0.24	0.86	0.08	8.13	13
UPASI 25	0.68	0.62	0.33	0.47	0.53	0.32	0.75	0.57	0.92	0.67	0.77	0.95	0.54	0.46	8.58	8
UPASI 26	0.18	0.31	0.97	0.31	0.59	0.76	0.67	0.38	0.37	0.33	0.66	0.33	0.91	0.18	6.95	28
UPASI 27	0.55	0.08	0.90	0.31	0.53	0.35	0.75	0.80	0.29	0.67	0.41	0.05	0.34	0.49	6.52	34
TRF 1	0.73	0.15	0.41	0.81	0.75	0.49	0.08	0.70	0.39	0.33	0.66	0.71	0.74	0.05	7.0	27
ATK 1	0.82	0.31	0.84	0.66	0.94	0.43	0.17	0.72	0.13	0.33	0.57	0.43	0.63	0.41	7.39	21
TTL 1	0.77	0.69	0.79	0.75	0.78	0.19	0.58	0.91	0.37	0.33	0.55	0.55	0.89	0.10	8.25	10
TTL 2	0.41	0.31	0.95	0.5	0.13	0.89	0.42	0.28	0.68	0.67	0.80	0.31	0.86	0.44	7.65	17
TTL 5	0.25	0.31	0.54	0.44	0.38	0.08	0.33	0.60	0.32	0.33	0.86	0.17	0.09	0.33	5.03	45
TRI 2025	0.45	0.31	0.74	0.5	0.69	0.84	0.42	0.62	0.71	0.33	0.75	0.64	0.06	0.62	12.06	1
TRI 2026	0.16	0.23	0.74	0.75	0.5	0.38	0.75	0.87	0.66	1.0	0.61	0.59	0.54	0.90	8.68	7

TRI 2043	0.80	0.31	0.72	0.59	0.5	0.81	0.33	0.83	0.34	0.33	0.16	0.07	0.91	0.82	7.52	19
C 17	0.80	0.31	0.18	0.63	0.19	0.86	0.75	0.11	0.24	0.67	0.43	0.14	0.94	0.95	7.2	23
BSB 1	0.89	0.46	0.36	0.09	0.06	0.57	0.58	0.40	0.11	0.33	0.20	0.76	0.89	0.64	6.34	36
CR 6017	0.91	0.31	0.26	0.28	0.63	0.62	0.5	0.11	0.5	0.83	0.61	0.95	0.31	0.13	6.95	28
NLT 17 / 10	0.64	0.31	0.10	0.41	0.38	0.43	0.75	0.68	0.34	0.17	0.76	0.12	0.51	0.21	5.81	41
AK	0.84	0.31	0.38	0.69	0.5	0.05	0.42	0.43	0.05	0.83	0.68	0.64	0.66	0.33	6.81	30
BSS 1	0.36	0.38	0.05	0.16	0.19	0.89	0.5	0.23	0.26	0.33	0.48	0.57	0.14	0.31	9.05	5
BSS 2	0.02	0.31	0.31	0.56	1.0	0.95	0.92	0.13	0.63	0.33	0.45	0.90	0.4	0.18	7.09	24
BSS 3	0.95	0.62	0.31	0.03	0.25	0.92	0.75	0.19	0.03	0.33	0.59	0.45	0.17	0.33	5.92	40
LSM	0.59	0.31	0.62	1.0	0.41	0.70	0.42	0.26	0.21	0.5	0.5	0.02	0.29	0.92	6.75	32
PK 1	0.57	0.31	0.46	0.22	0.88	0.46	0.75	0.32	0.16	0.5	0.18	0.88	0.54	0.77	7.0	27
K 18	0.07	0.23	0.28	0.91	0.47	0.43	0.75	0.55	0.18	0.33	0.30	0.10	0.71	0.67	5.98	39
TPA	0.75	0.23	0.31	0.97	0.59	0.30	0.75	0.17	0.61	0.33	0.93	0.19	0.69	0.97	7.79	15
TTSS 1	0.82	0.31	1.0	0.41	0.5	0.62	0.42	0.15	0.79	0.5	0.09	0.93	0.77	0.54	10.7	2
ST 463	0.5	0.31	0.05	0.34	0.84	0.16	0.56	0.09	0.58	0.33	0.95	0.83	0.77	0.72	7.03	26

ST 450	0.93	0.46	0.03	0.25	0.28	0.78	0.58	0.06	0.84	0.33	0.25	0.64	0.77	0.87	7.07	25
ST 520	0.37	0.62	0.77	0.94	0.03	0.19	0.42	0.47	0.53	0.67	0.32	0.26	0.03	0.74	9.88	3
ST 464	0.32	0.46	0.08	0.34	0.97	0.11	0.58	0.66	0.76	0.67	0.27	0.62	0.97	0.85	7.66	16
ST 444	0.16	0.46	0.13	0.47	0.44	0.70	0.5	0.30	0.87	0.67	0.66	0.81	0.14	0.64	6.95	28
ST 447	0.39	0.46	0.46	0.25	0.09	0.03	0.58	0.21	0.45	0.67	0.52	0.5	0.31	0.79	5.71	42
ST 462	0.23	0.46	0.92	0.84	0.31	0.68	0.75	0.02	0.55	0.33	0.66	0.36	0.8	1.0	7.91	14
TRI 1	0.11	0.31	0.69	0.63	0.31	0.97	0.98	0.49	0.39	0.33	0.36	0.86	0.43	0.69	7.55	18
TV 6	0.43	0.46	0.15	0.72	0.72	1.0	1.0	0.96	0.71	0.52	0.89	0.48	0.37	0.51	8.92	6

Characters: 1. Shoot weight (31.&B); 2. Internodal length between bud and first leaf; 3. Internodal length between first and second leaf; 4. Internodal length between second and third leaf; 5. Leaf angle; 6. Leaf area; 7. Number of branches; 8. Branch length; 9. Branch angle; 10. Chlorophyll content; 11. Proline content; 12. Protein content; 13. Polyphenol content; 14. Catechin content.

### 4.2.3. Genetic control of characters in Assam tea

Gregor Johann Mendel, the father of genetics established in 1865 that biological characters are controlled by hereditary factors (Mohanani, 1993). The characters were later categorized into oligogenic, polygenic and plasmagenic based on the nature of the genes involved. Most of the agronomic characters of crop plants are polygenic in nature. The nature of the genetic control of nine growth characters and five phytochemical characters of the fifty accessions of Assam tea studied presently has been analyzed based on frequency distribution of the characters.

#### 4.2.3.1. Growth characters

Nine growth characters of Assam tea namely shoot weight (three leaves and a bud), internodal length (B&F), internodal length (F&S), internodal length (S&T), leaf angle, leaf area, number of branches, branch length and branch angle have been analyzed presently (Table 4.20 and Fig 4.22).

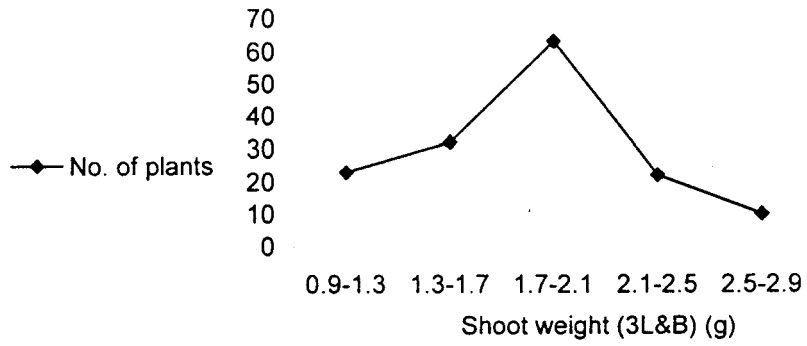
Table 4.20. Frequency distributions of growth characters of Assam tea studied

Character/ Distribution	Number of plants
<b>1. Shoot weight (3 L &amp; B) (gm)</b>	
0.9-1.3	23
1.3-1.7	32
1.7-2.1	63
2.1-2.5	22
2.5-2.9	10
Total	150
<b>2. Internodal length (B&amp;F) (cm)</b>	
0.4-0.9	125
0.9-1.4	23
1.4-1.9	2
Total	150
<b>3. Internodal length (F&amp;S) (cm)</b>	
0.5-0.9	16

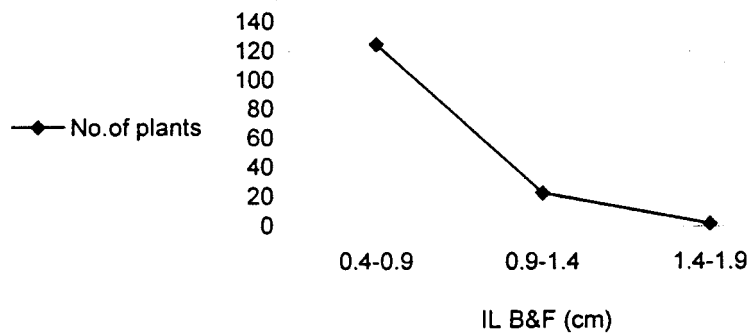
0.9-1.3	13
1.3-1.7	17
1.7-2.1	27
2.1-2.5	49
2.5-2.9	25
2.9-3.3	3
Total	150
<b>4. Internodal length (S&amp;T) (cm)</b>	
1.9-2.3	6
2.3-2.7	15
2.7-3.1	45
3.1-3.5	23
3.5-3.9	44
3.9-4.3	12
4.3-4.7	2
4.7-5.1	3
Total	150
<b>5. Leaf angle (degree)</b>	
32-47	44
47-62	103
62-77	3
Total	150
<b>6. Leaf area (cm<sup>2</sup>)</b>	
4.18-14.18	69
14.18-24.18	78
24.18-34.18	3
Total	150
<b>7. Number of branches</b>	
8.-11	46
11.- 14	94
14.-17	10
Total	150
<b>8. Branch length (cm)</b>	
40.5-45.5	9
45.5-50.5	35
50.5-55.5	49
55.5-60.5	56
60.5-66.5	1
Total	150
<b>9. Branch angle (degree)</b>	
37-47	7
47-57	60
57-67	83
Total	150

Fig. 4.22. Frequency curves of the growth characters of Assam tea studied

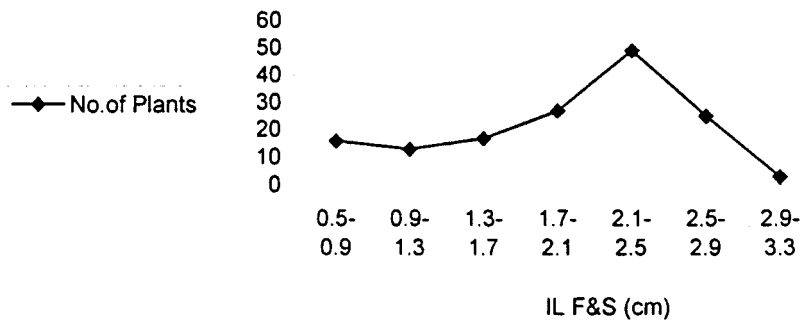
1. Shoot weight (3L&B)



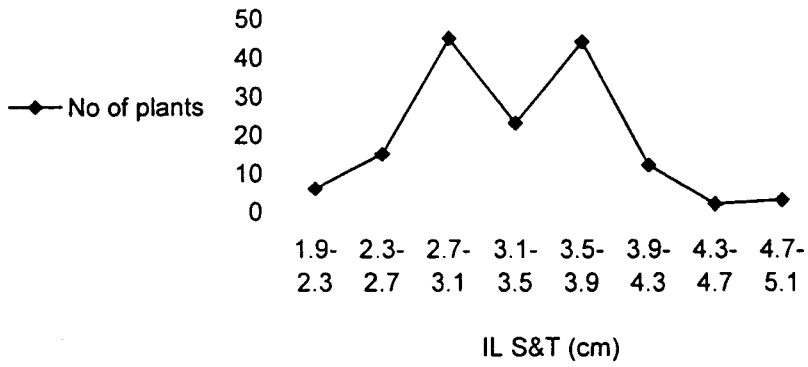
2. Internodal length (B&F)



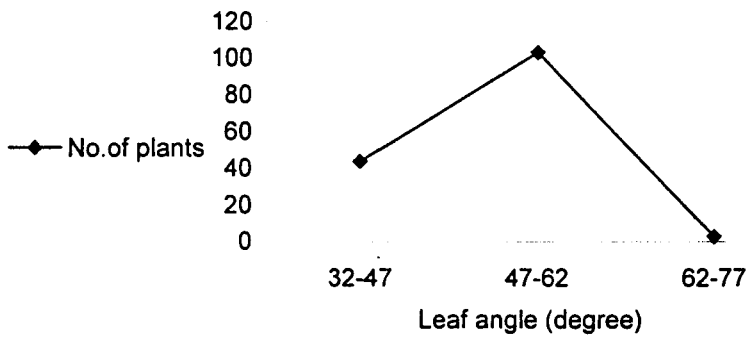
3. Internodal length (F&S)



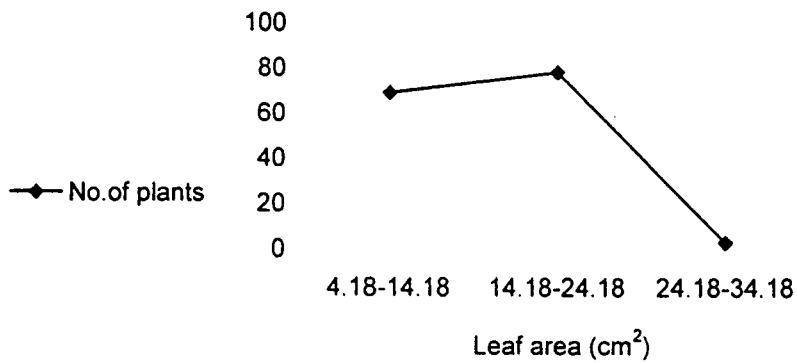
#### 4. Internodal length (S&T)



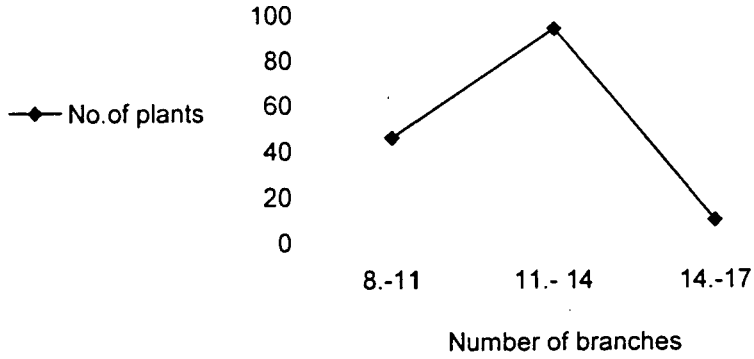
#### 5. Leaf angle



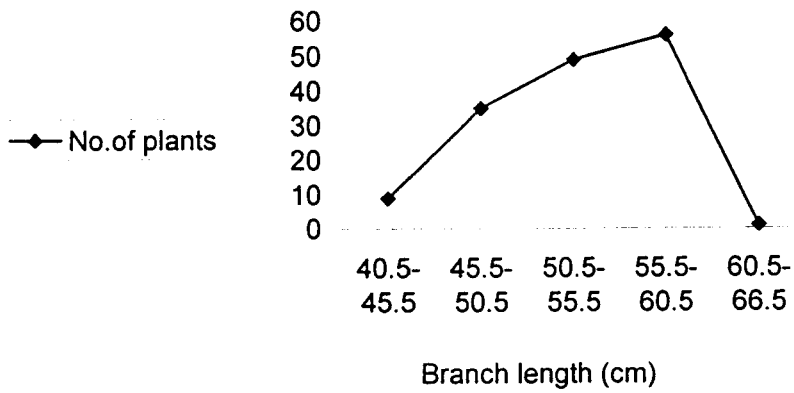
#### 6. Leaf area



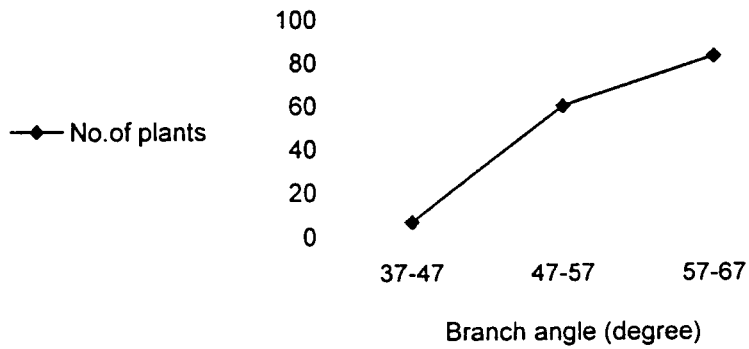
### 7. Number of branches



### 8. Branch length



### 9. Branch angle



**Shoot weight of three leaves and a bud** is an important character directly related to yield in tea since three leaves and a bud constitute the economically important crop part. The present study indicated continuous distribution of the character with maximum frequency of plants towards the arithmetic mean of the character. The frequency distribution of the character shows that most of the plants have got medium shoot weight as compared to those with lower and higher shoot weights. The distribution of the different phenotypes of the character indicates continuous and normal distribution of alleles controlling the character showing polygenic control. Moreover, the fact that only a few genotypes have got higher shoot weight among the plants studied when compared to the arithmetic mean indicates the possibility of selection for the character from among the accessions studied.

**Length of the internode** is a yield contributing character in tea since it directly influences the quantity of biomass produced. The present study indicated higher frequency of plants with smaller internodes between bud and first leaf. Study of internodal length between the first and second leaves showed continuous frequency distribution. Internodal length (S&T) appears to be normally distributed but bimodal with two peaks interrupted by a class with lower frequency. Higher frequency of plants with lower internode length shows the accumulation of negative factors for the character in such plants. Plants with desirable internode length are to be selected so that genotypes with improvement in the character under study are obtained.

**Leaf angle** shows a variation between  $32^{\circ}$  and  $77^{\circ}$  with a peak in the centre. However, plants with wider leaf angle are found to be rare. Continuous distribution of the character indicates its polygenic control. Wider leaf angle is a desirable character since it helps to harvest more sunlight. Plants with wide leaf angle are rare in the present population under study thus indicating the rarity of the alleles contributing for the same in the gene pool of the crop.

Assam type tea is broad leaved. However, **leaf area** showed continuous frequency distribution indicating polygenic control of the character, but with a very few number of plants with larger leaves.

**Number of branches** has been found to be distributed normally in the population indicating its polygenic control. However, the number of plants with lower branch number was high. Higher number of branches is a desirable character since it contributes directly towards the production of more number of growing tips.

**Branch length** was found to be normally distributed with gradual increase in frequency of plants up to the mode value but with a sudden decrease in frequency beyond the mode value. Continuous and normal frequency distribution indicates polygenic control of the character.

**Branch angle** has been found to be increasing gradually from lower to higher values and the mode class is the upper most

class of the distribution. This shows that the number of plants with wider branch angle is higher in the population studied. Wider branch angle is a desirable character. The distribution is continuous showing the polygenic control of the character.

Among the nine growth characters of Assam tea studied, only shoot weight (3L&B) showed a balanced distribution of the frequency of plants in the population towards both the sides of the mode value of the distribution indicating the balanced distribution of the alleles for the character in the gene pool. Leaf angle, leaf area and number of branches showed accumulation of higher frequency of plants towards the bottom of the distribution indicating the accumulation of recessive factors for the characters in the distribution, thus highlighting the necessity for selection of favourable types. Characters like shoot weight, internodal length and branch length showed a broader distribution, indicating the involvement of more number of factors in the distribution of the character. However, characters like leaf angle, leaf area, number of branches and branch angle showed only limited range of distribution indicating the involvement of only a few number of factors in the control of the character. Characters with wide variation provide very good scope for selection of desirable genotypes. Characters with narrow variation require more careful handling so that maximum of the available potential of such characters is identified and exploited.

Polygenic control of growth characters of crop plants has been established already by different workers like Dharmaraj and Sreenivasan, 1992; Sreenivasan and Santharam, 1993; Nikhila *et*

*al.*, 2002; Reghu *et al.*, 2003 and Radhakrishnan, 2003. They have further suggested the usefulness of variability of such characters in improving such crops.

#### 4.2.3.2. Phytochemical characters

Phytochemical characters are the most important in the quality point of view especially in the case of spices and beverage crops. Five phytochemical characters namely chlorophyll content, proline content, protein content, polyphenol content and catechin content in Assam tea were analyzed for their genetic control presently based on the nature of their frequency distributions (Table 4.21 and Fig. 4.23).

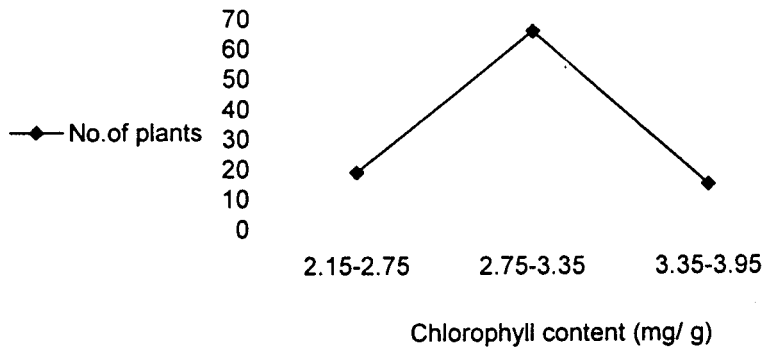
Table 4.21. Frequency distributions of phytochemical characters of Assam tea studied

Character/ Distribution	Number of plants
<b>1. Chlorophyll content (% mg/ g)</b>	
2.15-2.75	19
2.75-3.35	66
3.35-3.95	15
Total	100
<b>2. Proline content (% of dry weight)</b>	
0.12-0.62	30
0.62-1.12	56
1.12-1.62	14
Total	100
<b>3. Protein content (% of dry weight)</b>	
4.26-5.26	34
5.26-6.26	62
6.26-7.26	4
Total	100
<b>4. Polyphenol content (% of dry weight)</b>	
18.53-23.53	31
23.53-28.53	66
28.53-33.353	3
Total	100

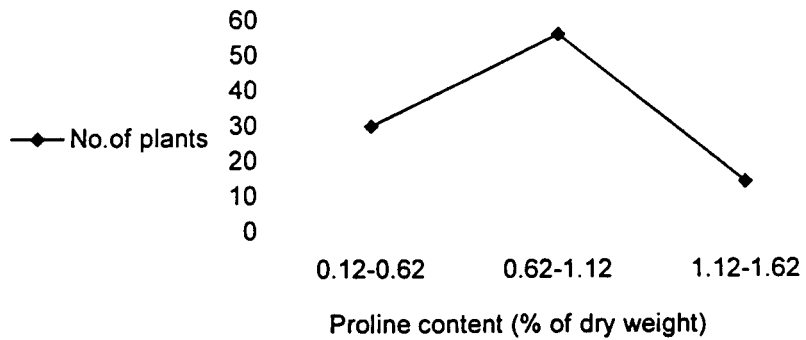
5. Catechin content (% of dry weight)	
10.83-17.83	44
17.83-24.83	52
24.83-31.83	4
Total	100

Fig. 4.23. Frequency curves of the phytochemical characters of Assam tea studied.

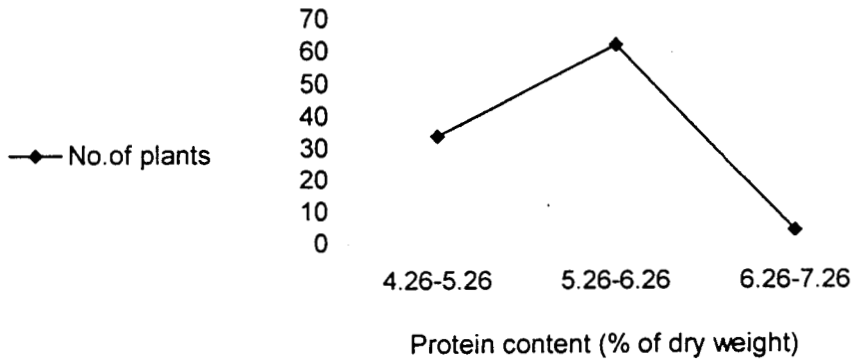
1. Chlorophyll content



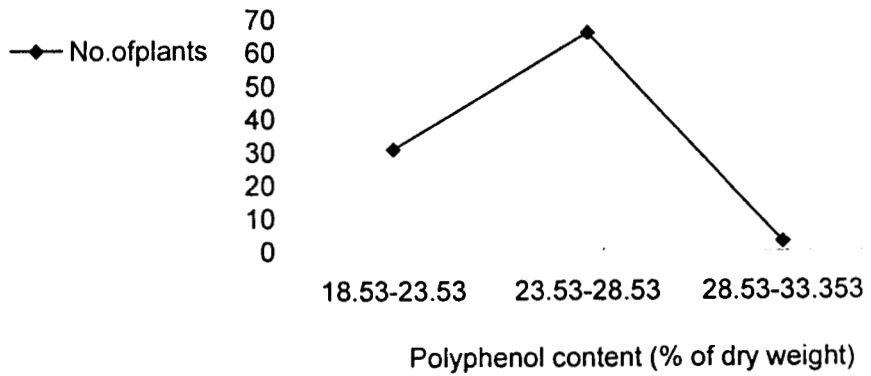
2. Proline content



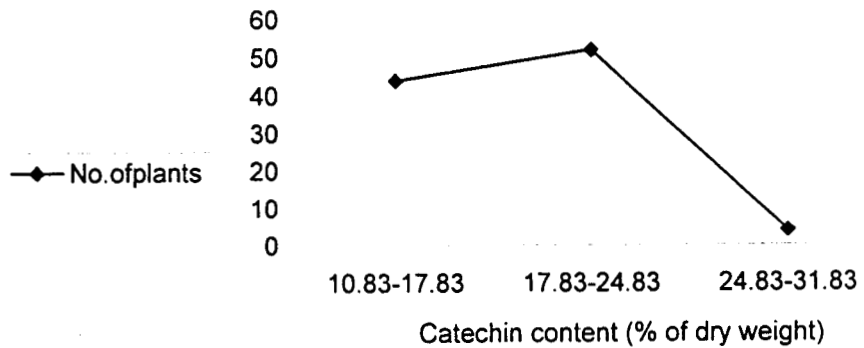
### 3. Protein content



### 4. Polyphenol content



### 5. Catechin content



**Chlorophyll content** of a leaf determines the efficiency of it to trap light energy. In Assam tea, the character showed continuous frequency distribution indicating varietal difference in chlorophyll content and continuous distribution of the character. However, the extent of variation is narrow thus indicating that only limited number of factors are involved in the control of the character.

**Proline content** indicates the response pattern of the plant towards water stress. The character showed continuous frequency distribution with higher number of plants towards the lower side of the distribution. Here also the extent of variability is limited showing the involvement of only a few alleles in the control of the character.

**Protein content** also showed continuous distribution showing the contributory nature of the alleles involved. The gene pool of the present population shows accumulation of recessive factors in higher numbers as evidenced by the non symmetrical nature of the distribution.

Polyphenols are very important in tea because their quantity and diversity directly influence the quality of tea. **Polyphenol content** showed a trend of distribution in which genotypes with higher polyphenol content were lower in number. Continuous distribution of the genotypes indicated contributory nature of the alleles involved.

**Catechin content** is the most important phytochemical character in tea since catechins are the group of polyphenols that are directly responsible in determining the quality of tea. Plants with high catechin content were found to be lower in number when compared to plants with medium and lower catechin content showing the scope of selection for the character. The distribution was continuous indicating contributory nature of the alleles involved.

All the five phytochemical characters studied presently showed comparatively narrow distribution of phenotypes, even though the distributions appear to be continuous in nature. This indicates that phytochemical characters are not as diversely distributed in Assam tea as in the case of morphometric growth characters. However, the variation in such characters is useful in exercising selection for quality in Assam tea as in the case of other beverage crops and spices. Continuous distribution of quality contributing phytochemical characters and their differential variation has already been reported in crops like cardamom (Radhakrishnan, 2003).

#### **4.2.4. Genetic variability in Assam tea**

Genetic variability of a crop species is the most important raw material for the selection of the most favourable genotypes for propagation and breeding programmes. Assam tea, widely distributed in the Indian subcontinent is very rich in its diversity. Variability of Assam tea has been analyzed presently based on nine growth characters and five phytochemical characters. Fifty accessions have been studied for the purpose with the help of

ANOVA, genotypic and phenotypic variance, coefficient of variation, heritability (broad sense) and genetic advance under selection.

#### 4.2.4.1. ANOVA (Analysis of variance)

Analysis of variance has been carried out to compare the extent of variability of characters between accessions with variability within the accessions. Out of the nine growth characters studied eight showed statistically significant variation between accessions indicating genotypic differences between them. However, the difference in the case of leaf area was not significant between accessions (Table 4.22). Out of the five phytochemical characters studied, four, excluding proline content showed significant inter accessional variation, indicating significant difference between accessions at phytochemical level (Table 4.23). Statistically significant variation in the case of morphometric and phytochemical characters that are agronomically important in nature confirms the significance of the variability available for different breeding programmes. However, interestingly, leaf area showed no statistical significance in variation between the accessions eventhough considerable variability is present in the case of the character at phenotypic level. The reason is the lack of difference between interaccessional variability and intraaccessional variability. Assessment of the statistical significance of the variations in the case of agronomic characters has been used as a tool to identify genotypes with significantly favourable character variations (Sobha, 1993; Misra *et al.*, 1998; Nikhila *et al.*, 2002; Reghu *et al.*, 2003; Radhakarishnan, 2003).

Table 4.22. Variability of growth characters in the case of the fifty accessions of Assam tea studied

Cultivars	Shoot weight (3L&B) (gm) **	Inter nodal length (B&F) (cm) **	Inter nodal length (F&S) (cm) **	Inter nodal length (S&T) (cm) **	Leaf angle (degree) **	Leaf area (cm <sup>2</sup> )	Number of branches **	Branch length (cm) **	Branch angle (degree) **
UPASI 1	1.2	0.7	2.0	2.87	51	16.77	12.7	46.4	65.3
UPASI 2	1.5	0.8	2.1	2.87	48	24.06	13.7	48.9	57.8
UPASI 3	1.7	0.6	2.1	3.07	45	29.29	11.0	55.2	39.4
UPASI 4	1.4	0.6	2.3	3.17	33	15.94	9.5	46.3	43.6
UPASI 5	1.3	1.4	2.1	3.07	34	12.81	10.4	56.0	61.1
UPASI 6	1.0	0.5	2.1	3.87	43	13.92	10.0	50.3	58.4
UPASI 7	1.0	1.6	2.4	2.77	36	15.06	10.3	47.3	51.6
UPASI 8	1.2	0.5	1.5	2.77	49	13.56	14.2	54.8	53.0
UPASI 12	1.1	0.6	1.7	2.47	46	14.51	10.6	55.4	58.8
UPASI 13	1.5	0.6	1.7	2.63	46	17.96	9.6	46.5	59.9
UPASI 14	1.7	0.6	2.0	2.93	56	14.32	11.3	47.5	57.0
UPASI 16	1.7	0.6	2.1	2.93	58	14.07	9.6	40.8	58.1
UPASI 17	1.7	0.6	2.1	3.43	56	13.07	9.8	43.1	61.2
UPASI 18	1.7	0.6	2.1	3.43	48	14.34	12.0	46.4	56.6
UPASI 21	1.7	0.5	2.1	3.13	53	14.31	9.8	47.3	50.9
UPASI 22	1.8	0.6	2.2	2.93	57	13.39	10.2	41.3	49.9
UPASI 24	1.9	0.5	2.3	2.83	63	14.00	11.3	46.2	59.0
UPASI 25	2.1	0.8	2.2	2.87	59	15.94	12.0	53.3	57.9
UPASI 26	1.5	0.5	2.5	2.77	55	15.87	12.1	55.1	62.6
UPASI 27	2.2	0.5	2.5	2.67	44	14.20	12.7	51.2	59.0
TRF 1	2.2	0.5	2.6	5.10	47	11.99	8.8	56.0	60.2
ATK 1	2.2	0.5	2.6	4.00	47	20.40	9.0	56.9	58.3
TTL 1	2.2	0.6	2.5	3.80	58	10.48	10.3	55.1	62.6
TTL 2	2.1	0.6	2.6	3.60	53	12.76	11.1	51.3	51.5
TTL 5	1.9	0.6	2.4	3.00	53	6.88	10.3	51.1	56.1
TRI 2025	2.0	0.5	2.4	3.60	52	9.47	11.2	53.4	53.7
TRI 2026	1.7	0.5	2.6	3.70	54	9.60	12.1	58.6	58.2
TRI 2043	2.0	0.5	2.4	3.70	50	17.93	10.7	58.5	58.1
C 17	1.8	0.6	1.5	3.00	53	10.05	12.0	53.1	54.3
BSB 1	2.6	0.6	2.4	3.50	51	21.20	11.3	57.6	51.4
CR 6017	2.0	0.6	2.1	3.50	53	15.54	11.8	60.2	57.2
NLT 17/10	1.8	0.5	1.9	3.60	50	13.00	12.2	55.4	52.2
AK	1.9	0.5	1.5	3.70	53	4.18	11.1	55.5	55.7
BSS 1	1.8	0.5	1.1	2.50	54	11.88	12.6	55.3	56.7
BSS 2	1.1	1.1	2.2	3.60	48	13.43	13.2	58.6	56.8

BSS 3	2.6	1.0	2.1	2.00	54	9.87	12.1	58.7	59.3
LSM	1.8	0.6	2.1	4.60	54	16.51	10.1	56.3	60.4
PK 1	1.6	0.7	1.5	2.10	49	14.59	11.2	55.9	59.3
K 18	1.0	0.6	1.5	3.00	54	23.35	12.3	55.3	59.7
TPA	1.8	0.6	2.0	3.60	56	19.28	12.4	56.7	53.4
TTSS 1	2.1	0.6	3.0	3.70	54	19.34	10.7	55.8	52.7
ST 463	1.9	0.6	1.2	2.60	51	13.12	10.4	52.2	54.0
ST 450	2.5	0.6	0.6	2.60	55	17.92	11.3	57.4	55.2
ST 520	2.0	1.0	2.5	4.10	49	21.09	10.4	56.4	58.2
ST 464	2.1	0.5	1.1	2.60	43	21.09	12.0	59.0	59.8
ST 444	1.5	0.6	1.0	3.10	54	16.51	12.0	55.2	60.0
ST 447	1.5	0.5	1.4	3.00	43	11.26	12.4	47.1	52.9
ST 462	1.7	0.7	2.4	3.53	47	16.76	12.3	52.6	54.3
TRI 1	2.4	0.7	1.7	3.63	46	12.56	12.2	56.6	56.6
TV 6	2.0	0.6	2.1	2.97	41	11.34	14.8	49.1	54.0
<b>Mean</b>	<b>1.8</b>	<b>0.4</b>	<b>2.0</b>	<b>3.2</b>	<b>50</b>	<b>15.1</b>	<b>11.3</b>	<b>52.8</b>	<b>56.2</b>
<b>Range</b>	<b>1.0- 2.6</b>	<b>0.5- 1.6</b>	<b>0.6- 3.0</b>	<b>2.0- 5.1</b>	<b>33- 63</b>	<b>4.18- 29.29</b>	<b>8.8- 14.8</b>	<b>41.3- 60.2</b>	<b>39.4- 65.3</b>
<b>Genotypic variance</b>	<b>0.16</b>	<b>0.05</b>	<b>0.72</b>	<b>0.36</b>	<b>36.39</b>	<b>-52.18</b>	<b>1.55</b>	<b>24.12</b>	<b>20.24</b>
<b>Phenotypic variance</b>	<b>0.17</b>	<b>0.06</b>	<b>0.74</b>	<b>0.37</b>	<b>37.46</b>	<b>213.99</b>	<b>1.97</b>	<b>24.21</b>	<b>22.53</b>
<b>GCV (%)</b>	<b>22.22</b>	<b>55.90</b>	<b>42.43</b>	<b>18.75</b>	<b>12.06</b>	<b>47.84</b>	<b>11.02</b>	<b>9.30</b>	<b>8.01</b>
<b>PCV (%)</b>	<b>22.91</b>	<b>61.24</b>	<b>43.01</b>	<b>19.01</b>	<b>12.24</b>	<b>96.87</b>	<b>12.42</b>	<b>9.32</b>	<b>8.46</b>
<b>Heritability (%)</b>	<b>94.00</b>	<b>83.33</b>	<b>97.30</b>	<b>97.30</b>	<b>97.14</b>	<b>-24.38</b>	<b>78.68</b>	<b>99.63</b>	<b>89.84</b>
<b>Genetic advance under selection (%)</b>	<b>44.36</b>	<b>105.12</b>	<b>86.21</b>	<b>38.10</b>	<b>24.50</b>	<b>-1.33</b>	<b>20.13</b>	<b>19.13</b>	<b>15.63</b>

\*\* : Significant at 1% and 5% levels

Table 4.23. Variability of phytochemical characters in the case of the fifty accessions of Assam tea studied

Cultivars	Chlorophyll content (mg/g) **	Proline content (% of dry weight)	Protein content (% of dry weight) **	Polyphenol content (% of dry weight) **	Catechin content (% of dry weight) **
UPASI 1	1.99	0.48	5.08	25.55	18.70
UPASI 2	1.56	0.63	5.13	25.51	18.21
UPASI 3	1.34	0.62	5.08	27.00	18.70
UPASI 4	1.47	0.65	5.00	27.13	19.42
UPASI 5	1.83	0.59	5.29	25.55	15.78
UPASI 6	1.59	0.35	5.82	26.54	18.02
UPASI 7	1.84	1.18	5.59	21.19	17.88
UPASI 8	1.40	0.43	5.62	25.62	15.71
UPASI 12	1.06	0.12	4.71	26.99	17.12
UPASI 13	0.93	1.18	4.55	23.89	17.01
UPASI 14	1.04	1.03	5.26	26.44	17.51
UPASI 16	1.31	0.13	5.27	24.00	15.67
UPASI 17	1.41	1.51	4.61	29.92	27.42
UPASI 18	1.16	1.23	4.59	24.95	19.02
UPASI 21	1.37	1.57	5.35	27.08	16.87
UPASI 22	1.27	0.55	5.20	23.89	18.92
UPASI 24	1.87	0.69	5.17	27.17	19.93
UPASI 25	1.12	0.73	5.80	24.88	16.73
UPASI 26	1.30	0.75	5.22	23.97	18.92
UPASI 27	1.24	0.49	5.30	26.01	16.43
TRF 1	1.80	0.74	5.84	27.05	24.92
ATK 1	1.19	0.79	5.88	25.97	16.98
TTL 1	1.63	0.69	6.19	24.22	19.61
TTL 2	1.60	0.74	6.15	21.85	16.93
TTL 5	1.48	0.95	6.32	27.45	17.73
TRI 2025	1.74	1.10	6.03	27.40	14.83
TRI 2026	1.98	1.13	5.21	24.99	12.33
TRI 2043	1.56	0.71	5.28	20.02	13.47
C 17	1.67	0.69	5.27	19.51	12.15
BSB 1	1.77	0.55	4.98	23.78	14.47
CR 6017	1.29	0.59	5.69	26.78	19.15
NLT 17/10	1.00	0.65	5.42	22.15	18.75
AK	1.76	0.65	5.58	23.38	17.73
BSS 1	1.35	0.61	5.46	25.39	17.81
BSS 2	1.42	0.49	5.70	25.90	18.97
BSS 3	1.44	1.10	5.12	25.26	17.71
LSM	1.77	1.03	5.27	25.81	12.27

PK 1	1.97	0.71	5.53	19.56	13.61
K 18	1.86	0.66	5.41	21.88	13.83
TPA	1.30	0.49	5.15	18.73	11.61
TTSS 1	1.84	0.15	5.53	20.84	15.83
ST 463	1.85	1.20	5.25	18.74	13.69
ST 450	1.34	0.95	5.69	20.62	12.36
ST 520	1.52	0.80	5.52	22.74	13.64
ST 464	1.41	0.69	5.87	21.12	12.67
ST 444	1.44	0.75	5.78	24.61	14.44
ST 447	1.61	0.65	6.06	19.52	13.57
ST 462	1.44	0.75	5.57	19.60	10.83
TRI 1	1.38	0.53	5.79	24.23	13.78
TV 6	1.42	0.65	6.13	24.59	15.90
<b>Mean</b>	<b>1.49</b>	<b>0.742</b>	<b>5.44</b>	<b>24.13</b>	<b>16.51</b>
<b>Range</b>	<b>0.93 – 1.99</b>	<b>0.12- 1.57</b>	<b>4.55- 6.32</b>	<b>18.73- 29.92</b>	<b>10.83- 27.42</b>
<b>Genotypic Variance</b>	<b>0.08</b>	<b>0.01</b>	<b>0.08</b>	<b>4.83</b>	<b>5.78</b>
<b>Phenotypic Variance</b>	<b>0.10</b>	<b>0.10</b>	<b>0.18</b>	<b>5.03</b>	<b>8.62</b>
<b>GCV (%)</b>	<b>18.98</b>	<b>13.48</b>	<b>5.20</b>	<b>9.11</b>	<b>14.56</b>
<b>PCV (%)</b>	<b>21.22</b>	<b>42.62</b>	<b>7.80</b>	<b>9.29</b>	<b>17.78</b>
<b>Heritability (%)</b>	<b>80.00</b>	<b>10.00</b>	<b>44.44</b>	<b>96.02</b>	<b>67.05</b>
<b>Genetic advance under selection (%)</b>	<b>34.98</b>	<b>8.72</b>	<b>7.14</b>	<b>18.38</b>	<b>24.56</b>

\*\* : Significant at 1% and 5% levels

#### 4.2.4.2. Phenotypic and genotypic variation

Phenotypic and genotypic variation in the case of each character has been calculated based on phenotypic and genotypic variance and phenotypic and genotypic coefficients of variation (Tables 4.22 and 4.23). Phenotypic variance is the measure of total variability of a character at phenotypic level in the case of a population: whereas genotypic variance is its heritable component. Among the nine growth characters studied, maximum phenotypic variance was shown by leaf area, where as it was

minimum in the case of internodal length (B&F). Maximum genotypic variance was shown by leaf angle (Table 4.22). In the case of phytochemical characters, phenotypic variance and genotypic variance were the maximum for catechin content (Table 4.23).

PCV is the measure of total phenotypic percentage of variability of a character and GCV, the percentage of variability that is genetically contributed. Among the nine morphometric characters studied, maximum GCV was shown by internodal length (B&F) and maximum PCV by leaf area. Among the phytochemical characters, maximum GCV was shown by chlorophyll content and maximum PCV by proline content (Table 4.23). High GCV in the case of internodal length (B&F) indicates the genotypic base of the variation of the character and the usefulness of the character in selection.

#### **4.2.4.3. Heritability (broad sense)**

Polygenic characters show different levels of heritability in organisms based on the influence of environment on the character concerned. Among the growth characters of Assam tea studied presently, maximum heritability was shown by branch length followed by internodal length (F&S) and internodal length (S&T). All the growth characters except leaf area were found to show heritability above 79%. Among the phytochemical characters, polyphenol content was found to be maximum heritable and proline content, the minimum. Similar studies have been undertaken by earlier workers in different crops (Tripathi *et al.*, 2000; Radhakrishnan, 2003).

#### **4.2.4.4. Genetic advance under selection**

The percentage of genetic advance possible under selection was calculated presently so as to find out the utility of the characters studied in crop improvement programmes. Genetic advance was found to be maximum in the case of internodal length (B&F) followed by internodal length (F&S) in the case of growth characters and chlorophyll content followed by catechin content and polyphenol content in the case of phytochemical characters (Tables 4.22 & 4.23). This shows that internodal length and chlorophyll content can be considered lead characters in the case of crop production and catechin content and polyphenol content lead characters in the case of crop quality for the selection of superior genotypes based on genetic advance. Similar studies have already been carried out in crops like coriander (Tripathi *et al.* (2000) and cardamom (Radhakrishnan, 2003).

#### **4.2.5. Correlation of characters in Assam tea**

Success of any plant breeding programme depends upon the efficiency of selection. Most of the agronomic characters in crop plants are polygenic in nature; they are interrelated and also influenced by environment. Correlation studies have been carried out presently in the case of the growth characters and phytochemical characters of Assam tea so as to identify the most suited characters that can be targeted for in selection and other crop improvement programmes.

The present study showed that shoot weight ((3L&B) and internodal length (B&F) were positively correlated with eleven characters. internodal length (F&S) with nine characters.

internodal length (S&T) with ten characters, Leaf angle with eight characters, leaf area with four characters, number of branches with six characters, branch length with seven characters, branch angle with eight characters, chlorophyll content with six characters, proline content with seven characters, protein content with seven characters, polyphenol content with seven characters and catechin content with eight characters (Table 4.24).

Shoot weight (3L&B) is a character directly related to the quantity of made tea produced. The character shows 38% correlation with branch length, 26% correlation with internodal length (B&F), 17% correlation with internodal length (S&T) and 12% correlation with internodal length (F&S) showing the relationship between tea production and internodal length of the crop yielding part. However, the correlations are not statistically significant. Among the phytochemical characters, chlorophyll content is negatively correlated with polyphenol content and catechin content. This may be an indication of the inverse relationship between biomass production and tea quality. The inverse relationship between quality and production of tea has been established by earlier workers (Cox, 2002).

However, correlation between characters is significant only in the case of polyphenol content and catechin content, which are closely related characters. Characters that show strong positive correlation may usually show covariation and hence selection of better genotypes for such traits becomes easy. Such an approach has already been employed in other crops by earlier workers (Radhakrishnan, 2003).

Table 4.24. Correlation coefficients of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied.

	Shoot weight (S1.&B)	Inter nodal length (B&F)	Inter nodal length (F&S)	Inter nodal length (S&T)	Leaf angle	Leaf area	No. of branches	Branch length	Branch angle	Chlorophyll content	Proline content	Protein content	Polyphenol content	Catechin content
Shoot weight (S1.&B)		0.26	0.12	0.17	0.32	0.08	0.08	0.38	-0.04	-0.08	0.12	0.22	0.09	0.10
Internodal length (B&F)	0.26		0.14	0.14	0.39	0.05	-0.01	0.03	0.05	0.19	0.08	0.03	-0.07	0.01
Internodal length (F&S)	0.12	0.14		0.48	-0.01	0.02	-0.26	-0.09	-0.05	0.11	-0.03	0.02	0.29	0.31
Internodal length (S&T)	0.17	0.14	0.48		0.02	-0.01	-0.33	0.22	0.02	0.18	-0.01	0.24	0.13	0.12
Leaf angle	0.32	0.39	-0.01	0.02		-0.12	0.02	-0.004	0.26	-0.03	0.09	-0.02	0.01	0.03
Leaf area	0.08	0.05	0.02	-0.01	-0.12		0.004	0.12	-0.19	-0.12	-0.16	-0.28	-0.12	-0.16
Number of branches	0.08	-0.01	-0.26	-0.33	0.02	0.004		0.19	0.03	-0.05	-0.23	0.12	-0.17	-0.27
Branch length	0.38	0.03	-0.09	0.22	-0.004	0.12	0.19		0.13	0.13	-0.17	0.27	-0.21	-0.37
Branch angle	-0.04	0.05	-0.05	0.02	0.26	-0.19	0.03	0.13		0.12	0.02	-0.004	0.10	0.08
Chlorophyll content	-0.08	0.19	0.11	0.18	-0.03	-0.12	-0.05	0.13	0.12		0.01	0.18	-0.20	-0.15
Proline content	0.12	0.08	-0.03	-0.01	0.09	-0.16	-0.23	-0.17	0.02	0.01		-0.15	0.12	0.12
Protein content	0.22	0.03	0.02	0.24	-0.02	-0.28	0.12	0.27	-0.004	0.18	-0.15		-0.14	-0.18
Polyphenol content	0.09	-0.07	0.29	0.13	0.01	-0.12	-0.17	-0.21	0.10	-0.20	0.12	-0.14		0.66*
Catechin content	0.10	0.01	0.31	0.12	0.03	-0.16	-0.27	-0.37	0.08	-0.15	0.12	-0.18	0.66*	

\*: Significant at 5% level.

#### **4.2.6. Character association in Assam tea**

Most of the agronomic characters of crop plants are polygenic in nature and they show different levels of interrelationships. Character association has been studied presently so as to find out lead variables and to reduce the complexity of recording, analyzing and interpreting a host of multivariate data in field experiments. Factor analysis has been carried out for the purpose, using the statistical software STATISTICA, in the case of nine growth characters and five phytochemical characters of Assam tea (Table 3.6). The study enabled to get a set of reduced number of new orthogonal variables. The above said variables identified five factors that accounted for 62.16% of the variability produced by the 14 variables (Table 4.25). This finding estimates only the mathematical association among the variables and hence the result should be supplemented with biological interpretations based on logics. The variables were grouped with respect to the five factors identified and lead variables identified based on the factor loading for each character. Among the five groups, catechin content was found to be the lead variable in the first group followed by polyphenol content, internodal length (F&S) and proline content. In the second group, internodal length (S&T) was the lead variable followed by shoot weight, protein content, branch length and leaf angle. The third group of variables was lead by internodal length (B&F) followed by chlorophyll content and leaf area. The fourth group consisted of branch angle and the fifth group consisted of number of branches (Tables 4.26 & 4.27).

Table 4.25. Factor analysis of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied (percentage of variance contributed by each factor and cumulative percentage of variance)

Factor	Eigen value	Percentage of variance	Cumulative Eigen value	Cumulative percentage of variance
1	2.435773	17.39838	2.435773	17.39838
2	2.001561	14.29687	4.437334	31.69525
3	1.684623	12.03302	6.121957	43.72827
4	1.396518	9.97513	7.518475	53.70339
5	1.183286	8.45204	8.701761	62.15544

Table 4.26. Factor analysis of growth characters and phytochemical characters in the case of the 50 accessions of Assam tea studied- factor loadings

Sl. No.	Characters	F1	F2	F3	F4	F5
1	Shoot weight (3L&B)	-.012627	<b>.642915</b>	-.310516	-.256348	-.236873
2	Internodal length (B&F)	-.012627	-.315874	<b>.622901</b>	.338224	-.141927
3	Internodal length (F&S)	<b>.516757</b>	.374801	.435146	-.188719	.091502
4	Internodal length (S&T)	.275195	<b>.680819</b>	.370696	-.206991	.050109
5	Leaf angle	.048103	<b>.389247</b>	-.670767	.055969	-.075732
6	Leaf area	-.170931	-.268477	<b>.198448</b>	-.667063	-.040007
7	Number of branches	-.538639	-.204552	-.198134	.150759	<b>.463611</b>
8	Branch length	-.525218	<b>.460056</b>	.153304	-.078725	.139998
9	Branch angle	.052270	.181977	-.200300	<b>.585473</b>	.183324
10	Chlorophyll content	-.158606	.270378	<b>.456629</b>	.453987	-.213403
11	Proline content	<b>.319362</b>	.005352	-.175708	.231101	-.715545

12	Protein content	-.301975	<b>.545628</b>	.172025	.226729	.245831
13	Polyphenol content	<b>.757131</b>	-.008613	-.092594	.035869	.373257
14	Catechin content	<b>.830700</b>	-.057752	-.060743	.077023	.251741

Table 4.27. Factor analysis of growth characters and phytochemical characters in the case of the fifty accessions of Assam tea studied- character association

Factor	Characters associated
1	Catechin content, Polyphenol content, Internodal length (F&S), Proline content
2	Internodal length (S&T), Shoot weight (3L&B), Protein content, Branch length, Leaf angle
3	Internodal length (B&F), Chlorophyll content, Leaf area
4	Branch angle
5	Number of branches

The above analysis shows that growth characters and phytochemical characters of Assam tea can be classified in to five groups based on factor analysis and in each group, certain characters can be considered as lead characters based on factor loadings. In the present study, catechin content was found to be the lead character in the first group of characters, internodal length (S&T) and shoot weight (3L&B) the lead character in group two and internodal length (B&F) the lead character in group three. Such characters can be considered as key characters for selection so that other characters may also get selected along with them. Since the characters under study are polygenic in nature with

contributory nature of alleles, pleiotropic effect may also be involved in the case of such characters resulting in interrelationship of characters.

Factor analysis has been used for the study of interrelationship of variables and grouping of characters by earlier workers (Rao *et al.*, 1981; Saji *et al.*, 2002; Radhakrishnan, 2003).

#### **4.2.7 Genetic divergence in Assam tea**

The study of genetic divergence in Assam tea was carried out so as to group the genotypes under study into different clusters based on the genetic distance between them since they showed significant differences in relation to the characters studied (Tables 4.22 & 4.23).

Cluster analysis was carried out based on the nine morphological and five phytochemical characters studied (Table 3.6), with the help of the statistical software STATISTICA following UPGMA procedure. The 50 genotypes studied could be grouped into four major clusters, the first cluster consisting of 2 genotypes, the second cluster consisting of 16 genotypes, the third cluster consisting of 28 genotypes and the fourth cluster consisting of 4 genotypes (Table 4.28 and Fig 4.24).

UPASI 17 and UPASI 18 formed one of the closest groups and TRF 1 and ATK 1 formed another similar group with a linkage distance of 0.71 (Fig. 4.24). UPASI 13, UPASI 16 and UPASI 18 formed a cluster with 79% linkage distance and CR 6017 and TV 6, UPASI 14 and TPA, TTL 5 and C 17, LSM and

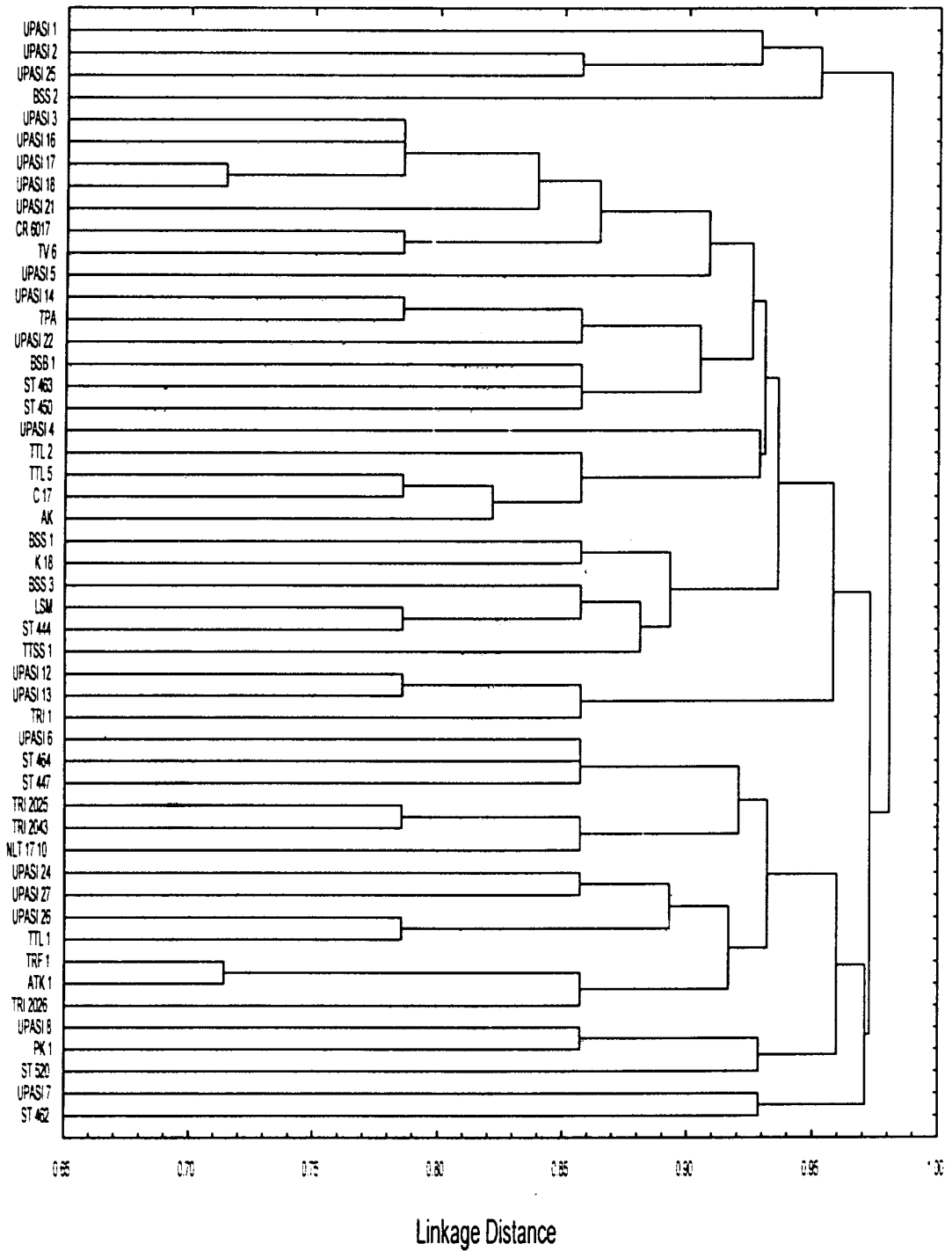
ST 444, UPASI 12 and UPASI 13, TRI 2025 and TRI 2043 and UPASI 26 and TTL 1 formed similar groups.

Among the four clusters obtained, the fourth cluster with four genotypes was found to be the most distant from others with a linkage distance of 0.98 (Fig. 4.24). All the other 46 accessions could be included in a single group at a linkage distance of 0.97 and could be divided in to two groups at a linkage distance of 0.965. One of these groups could further be classified in to two groups at a linkage distance of 0.96, thus forming four clusters at the linkage distance of 0.96 as given in Table 4.28.

Table 4.28. Cluster analysis in the case of the fifty accessions of Assam tea studied

Cluster No.	Accessions
I	ST 462, UPASI 7
II	ST 520, PK 1, UPASI 8, TRI 2026, ATK 1, TRF 1, TTL 1, UPASI 26, UPASI 27, UPASI 24, NLT 17/10, TRI 2043, TRI 2025, ST 447, ST 464, UPASI 6.
III	TRI 1, UPASI 13, UPASI 12, TTSS 1, ST 444, LSM, BSS 3, K 18, BSS 1, AK, C 17, TTL 5, TTL 2, UPASI 4, ST 450, ST 463, BSB 1, UPASI 22, TPA, UPASI 14, UPASI 5, TV 6, CR 6017, UPASI 21, UPASI 18, UPASI 17, UPASI 16, UPASI 3.
IV	BSS 2, UPASI 25, UPASI 2, UPASI 1.

Fig. 4.24. Cluster analysis in the case of the fifty accessions of Assam tea studied- dendrogram



Genotypes belonging to the most distant clusters can be utilized for hybridization programmes so as to bring out the combination of superior alleles belonging to distant gene pools. Such combinations may result in the production of the best hybrids possible from interaccessional crosses in the genotypes studied.

Earlier workers have undertaken similar studies in different crops including dahlia (Misra *et al.*, 1990), capsicum (Indira, 1994), coriander (Srivastava *et al.*, 2000) and cardamom (Radhakrishnan, 2003).

#### **4.2.8. Performance analysis in Assam tea**

Performance analysis has been carried out in the case of 50 accessions of Assam tea studied presently based on the performance index calculated as detailed elsewhere. TRF 1 proved to be the best performer scoring 9.35/14 (66.79%) (Tables 29, 30 and 31) followed by TTL 1 (65.43%). TRF 1 is a selection released by UPASI Tea Research Foundation, Valparai, Tamil Nadu and TTL 1 is a selection released by the R&D Division of Tata Tea Ltd. The remaining eight accessions among the best ten performers are CR 6017 (Valparai, Tamil Nadu), ATK 1 (Valparai, Tamil Nadu), BSS 2 (Valparai, Tamil Nadu), TTSS 1 (Tocklai, Assam), UPASI 25 (Valparai, Tamil Nadu), BSS 3 (Valparai, Tamil Nadu), AK (Valparai, Tamil Nadu) and ST 520 (Tocklai, Assam) in that order.

Among the best performers, TRF 1 showed very good performance in terms of both yield and quality parameters, thus projecting its potential as a good yielder and yielder of good quality tea. TTL 1 also showed good performance in terms of yield and quality.

Table 4.29. Performance analysis in the case of the fifty accessions of Assam tea studied (value points attributed to accessions in relation to characters)

Cultivars	Characters/ Value points													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
UPASI 1	3	4	9	8	13	12	6	3	17	12	3	1	7	8
UPASI 2	6	5	10	8	10	18	7	6	11	8	5	1	7	7
UPASI 3	8	3	10	11	7	19	4	12	1	5	5	1	8	8
UPASI 4	5	3	12	12	1	11	3	3	2	7	6	1	8	9
UPASI 5	4	11	10	11	2	8	3	13	14	10	4	1	7	5
UPASI 6	1	2	10	18	5	9	3	7	11	8	2	2	8	7
UPASI 7	1	13	13	6	3	11	3	4	5	10	11	2	3	7
UPASI 8	3	2	6	6	11	9	7	12	6	6	2	2	7	5
UPASI 12	2	3	7	3	8	10	4	11	12	3	1	1	8	6
UPASI 13	6	3	7	4	8	13	3	4	13	1	11	1	5	6
UPASI 14	8	3	9	9	19	10	4	5	10	2	9	1	7	7
UPASI 16	8	3	10	9	21	10	3	1	11	5	1	1	5	5
UPASI 17	8	3	10	13	19	9	3	2	14	6	12	1	9	10
UPASI 18	8	3	10	13	10	10	5	3	10	3	11	1	6	8
UPASI 21	8	2	10	11	15	10	3	4	4	6	13	1	8	6
UPASI 22	9	3	10	9	20	9	3	1	3	5	5	1	5	8
UPASI 24	10	2	12	7	23	10	4	3	12	11	6	1	8	9
UPASI 25	12	5	11	8	22	11	5	10	11	3	6	2	6	6
UPASI 26	6	2	14	6	18	11	5	12	16	5	7	1	5	8
UPASI 27	13	2	14	5	6	10	6	8	12	4	3	1	7	5
TRF 1	13	2	15	22	9	7	1	13	13	10	6	2	8	10
ATK 1	13	2	15	19	9	15	2	14	11	4	7	2	7	6
TTL 1	13	3	14	17	21	6	3	8	16	8	6	2	5	9

TTL 2	12	3	15	15	15	8	4	8	5	8	6	2	4	6
TTL 5	10	3	13	10	15	2	3	8	9	7	9	2	8	7
TRI 2025	11	2	13	15	14	3	4	10	7	9	10	2	8	4
TRI 2026	8	2	15	16	16	4	5	15	11	12	10	1	6	2
TRI 2043	11	2	13	16	12	13	4	15	11	8	6	1	2	3
C 17	9	3	6	10	15	6	5	10	7	9	6	1	2	2
BSB 1	17	3	13	14	13	16	4	15	4	10	5	1	5	4
CR 6017	11	3	10	14	15	11	5	16	10	5	5	2	8	8
NLT 17/10	9	2	8	15	12	9	5	12	5	2	6	1	4	8
AK	10	2	6	16	15	1	4	13	9	16	6	2	5	7
BSS 1	9	2	3	3	16	7	6	12	10	6	5	1	6	7
BSS 2	2	8	11	15	10	9	6	15	11	6	4	2	7	8
BSS 3	17	7	10	1	16	5	5	15	12	6	10	1	6	7
LSM	9	3	10	21	16	12	3	13	11	10	9	1	8	2
PK 1	7	4	6	2	11	10	4	13	12	12	6	2	2	4
K 18	1	3	6	10	16	17	5	12	6	11	6	1	4	4
TPA	9	3	9	15	18	14	5	14	6	5	4	1	1	2
TTSS 1	12	3	15	16	16	14	4	13	6	10	2	2	3	5
ST 463	10	3	4	4	13	9	3	9	7	11	11	1	1	4
ST 450	15	3	1	4	17	13	4	14	8	5	10	2	3	2
ST 520	11	7	14	20	11	16	3	13	10	7	7	2	4	4
ST 464	12	2	3	4	5	16	5	15	12	6	6	2	3	3
ST 444	6	3	2	11	16	12	5	14	12	6	7	2	6	4
ST 447	6	2	5	10	5	7	5	4	6	8	6	2	2	4
ST 462	8	4	13	14	9	12	5	10	7	6	7	2	2	1
TRI 1	14	4	7	15	8	8	5	15	10	6	4	2	5	4
TV 6	11	3	10	10	4	7	8	6	7	6	6	2	6	5

Characters: 1. Shoot weight (3L&B): 2. Internodal length between bud and first leaf: 3. Internodal length between first and second leaf: 4. Internodal length between second and third leaf: 5. Leaf angle: 6. Leaf area: 7. Number of branches: 8. Branch length: 9. Branch angle: 10. Chlorophyll content: 11. Proline content: 12. Protein content: 13. Polyphenol content: 14. Catechin content.

Table 4.30. Performance analysis in the case of the fifty accessions of Assam tea studied (performance index in relation to characters and overall performance index)

Cultivars	Performance index in relation to characters															Index
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	
UPASI 1	0.18	0.31	0.6	0.36	0.57	0.63	0.75	0.19	1.0	0.75	0.23	0.5	0.78	0.8	7.65	19
UPASI 2	0.35	0.38	0.67	0.36	0.43	0.94	0.88	0.38	0.68	0.5	0.38	0.5	0.78	0.7	7.93	18
UPASI 3	0.47	0.23	0.67	0.56	0.30	1	0.5	0.75	0.06	0.31	0.38	0.5	0.89	0.8	7.42	23
UPASI 4	0.29	0.23	0.8	0.55	0.04	0.58	0.38	0.19	0.12	0.44	0.46	0.5	0.39	0.9	5.87	46
UPASI 5	0.24	0.84	0.67	0.5	0.09	0.42	0.38	0.81	0.82	0.63	0.31	0.5	0.78	0.5	7.49	22
UPASI 6	0.06	0.15	0.67	0.82	0.22	0.47	0.38	0.44	0.65	0.5	0.15	1	0.89	0.7	7.1	28
UPASI 7	0.06	1.0	0.87	0.27	0.13	0.58	0.38	0.25	0.29	0.63	0.85	1.0	0.33	0.7	7.34	24
UPASI 8	0.18	0.15	0.40	0.27	0.48	0.47	0.88	0.75	0.35	0.38	0.15	1.0	0.78	0.5	6.74	37
UPASI 12	0.12	0.23	0.47	0.14	0.35	0.53	0.5	0.69	0.71	0.19	0.08	0.5	0.89	0.6	6.0	45
UPASI 13	0.35	0.23	0.47	0.18	0.35	0.57	0.38	0.25	0.76	0.06	0.85	0.5	0.56	0.6	6.11	44
UPASI 14	0.47	0.23	0.60	0.41	0.83	0.53	0.5	0.31	0.59	0.13	0.69	0.5	0.78	0.7	7.27	25
UPASI 16	0.47	0.23	0.67	0.41	0.91	0.53	0.36	0.06	0.65	0.31	0.08	0.5	0.56	0.5	6.24	42
UPASI 17	0.47	0.23	0.67	0.59	0.83	0.47	0.38	0.13	0.82	0.38	0.92	0.5	1.0	1.0	8.39	11
UPASI 18	0.47	0.23	0.67	0.59	0.43	0.53	0.63	0.19	0.59	0.19	0.55	0.5	0.67	0.8	7.04	31
UPASI 21	0.47	0.45	0.67	0.5	0.65	0.53	0.38	0.25	0.24	0.38	1.0	0.5	0.89	0.6	7.51	21
UPASI 22	0.53	0.23	0.67	0.41	0.87	0.47	0.38	0.06	0.18	0.31	0.38	0.5	0.56	0.8	6.35	41

UPASI 24	0.59	0.15	0.8	0.32	1.0	0.53	0.5	0.19	0.71	0.69	0.46	0.5	0.89	0.9	8.23	14
UPASI 25	0.71	0.38	0.73	0.36	0.96	0.58	0.63	0.63	0.65	0.19	0.46	1.0	0.67	0.6	8.55	7
UPASI 26	0.35	0.15	0.93	0.27	0.78	0.58	0.63	0.75	0.94	0.31	0.54	0.5	0.56	0.8	8.09	15
UPASI 27	0.76	0.15	0.93	0.23	0.26	0.53	0.75	0.5	0.71	0.25	0.23	0.5	0.78	0.5	7.08	29
TRF 1	0.76	0.15	1.0	1.0	0.39	0.37	0.13	0.81	0.76	0.63	0.46	1.0	0.89	1.0	9.35	1
ATK	0.76	0.15	1.0	0.86	0.39	0.79	0.25	0.83	0.65	0.25	0.54	1.0	0.78	0.6	8.85	4
TTL 1	0.76	0.23	0.93	0.77	0.91	0.32	0.38	0.5	0.94	0.5	0.46	1.0	0.56	0.9	9.16	2
TTL 2	0.71	0.23	1.0	0.68	0.65	0.42	0.5	0.5	0.29	0.5	0.46	1.0	0.44	0.6	7.98	17
TTL 5	0.59	0.23	0.87	0.45	0.65	0.11	0.38	0.5	0.53	0.44	0.69	1.0	0.89	0.7	8.03	16
TRI 2025	0.65	0.15	0.87	0.68	0.61	0.16	0.5	0.63	0.41	0.56	0.77	1.0	0.89	0.4	8.28	13
TRI 2026	0.47	0.15	1.0	0.73	0.70	0.21	0.63	0.94	0.65	0.75	0.77	0.5	0.67	0.2	8.37	12
TRI 2043	0.65	0.15	0.87	0.73	0.52	0.57	0.5	0.94	0.65	0.5	0.46	0.5	0.22	0.3	7.56	20
C 17	0.53	0.23	0.4	0.45	0.65	0.32	0.63	0.63	0.41	0.56	0.46	0.5	0.22	0.2	6.19	43
BSB 1	1.0	0.23	0.87	0.64	0.57	0.84	0.5	0.94	0.24	0.63	0.38	0.5	0.56	0.4	8.3	12
CR 6017	0.65	0.23	0.67	0.64	0.65	0.58	0.63	1.0	0.59	0.31	0.38	1.0	0.89	0.8	9.02	3
NLT 17/10	0.53	0.15	0.53	0.68	0.52	0.47	0.63	0.75	0.29	0.10	0.46	0.5	0.44	0.8	6.85	35
AK	0.59	0.15	0.4	0.73	0.65	0.05	0.5	0.81	0.53	1.0	0.46	1.0	0.89	0.7	8.46	9
BSS 1	0.53	0.15	0.2	0.14	0.70	0.37	0.75	0.75	0.59	0.38	0.38	0.5	0.67	0.7	6.81	36
BSS 2	0.12	0.62	0.73	0.68	0.43	0.47	0.75	0.94	0.65	0.38	0.31	1.0	0.78	0.8	8.66	5
BSS 3	1.0	0.54	0.67	0.05	0.70	0.26	0.63	0.94	0.71	0.38	0.77	0.5	0.67	0.7	8.52	8

LSM	0.53	0.23	0.67	0.95	0.70	0.63	0.38	0.81	0.65	0.63	0.69	0.5	0.89	0.2	0.46	48
PK 1	0.41	0.31	0.4	0.09	0.48	0.53	0.5	0.81	0.71	0.75	0.46	1.0	0.22	0.4	7.07	30
K 18	0.06	0.23	0.4	0.45	0.70	0.89	0.63	0.75	0.35	0.69	0.46	0.5	0.44	0.4	6.95	33
TPA	0.53	0.23	0.6	0.68	0.78	0.74	0.63	0.83	0.35	0.31	0.31	0.5	0.44	0.2	7.13	27
TISS 1	0.71	0.23	1.0	0.73	0.70	0.74	0.5	0.81	0.35	0.63	0.15	1.0	0.56	0.5	8.61	6
ST 463	0.59	0.23	0.27	0.18	0.57	0.47	0.38	0.56	0.41	0.69	0.85	0.5	0.44	0.4	6.54	40
ST 450	0.88	0.23	0.07	0.18	0.74	0.57	0.5	0.83	0.47	0.31	0.77	0.5	0.22	0.2	6.87	34
ST 520	0.65	0.54	0.93	0.91	0.48	0.84	0.38	0.81	0.59	0.44	0.54	0.5	0.44	0.4	8.45	10
ST 464	0.71	0.15	0.12	0.18	0.22	0.84	0.63	0.94	0.71	0.38	0.46	0.5	0.33	0.3	6.87	34
ST 444	0.35	0.23	0.13	0.5	0.70	0.63	0.63	0.83	0.71	0.38	0.54	0.5	0.44	0.4	6.97	32
ST 447	0.35	0.15	0.33	0.45	0.22	0.37	0.63	0.25	0.35	0.5	0.46	0.5	0.44	0.4	5.4	47
ST 462	0.47	0.31	0.87	0.64	0.39	0.63	0.63	0.63	0.41	0.38	0.54	0.5	0.11	0.1	6.61	39
TRI 1	0.82	0.31	0.47	0.68	0.35	0.42	0.63	0.94	0.59	0.38	0.31	0.5	0.44	0.4	7.24	26
TV 6	0.65	0.23	0.67	0.45	0.17	0.37	1.0	0.38	0.41	0.38	0.46	0.5	0.56	0.5	6.73	38

Characters: 1. Shoot weight (3I.&B); 2. Internodal length between bud and first leaf; 3. Internodal length between first and second leaf; 4. Internodal length between second and third leaf; 5. Leaf angle; 6. Leaf area; 7. Number of branches; 8. Branch length; 9. Branch angle; 10. Chlorophyll content; 11. Proline content; 12. Protein content; 13. Polyphenol content; 14. Catechin content.

Table 4.31. Performance analysis in the case of the fifty accessions of Assam tea studied- the best ten performers

Rank of performance	Accession	Percentage of weightage
1	TRF 1	66.79
2	TTL 1	65.43
3	CR 6017	64.43
4	ATK 1	63.21
5	BSS 2	61.86
6	TTSS 1	61.50
7	UPASI 25	61.07
8	BSS 3	60.86
9	AK	60.43
10	ST 520	60.36

# RESULTS AND DISCUSSION

B. Ramasubramanian “Studies on variability, genetic divergence and crop improvement in tea (*Camellia assamica* (Masters) Wight ) Thesis. Department of Botany, University of Calicut, 2005

## Chapter V

### SUMMARY AND CONCLUSION

The present study on variability, genetic divergence and crop improvement in tea (*Camellia assamica* (Masters) Wight) has been carried out so as to analyze the genetic control of agronomic characters, variability of the crop and the nature and distribution of characters in Assam tea on a plant breeding perspective. The field work was carried out in the experimental farm of UPASI Tea Research Foundation, Valparai, Tamil Nadu, India during 2001-2004. Fifty accessions collected from different parts of the Indian subcontinent were used for the purpose. Observations on nine growth characters and five phytochemical characters were analyzed for nursery performance, juvenile growth pattern, genetic control of characters, genetic variability, correlation of characters, character association and genetic divergence and also for overall performance of the accessions studied.

Percentage of survival of seedlings ranged from 75.0% to 98.6% among the different accessions of the study population.

Root growth of nursery plants was studied based on root length, fresh root weight and dry root weight. The characters showed significant variation among the accessions studied, indicating the influence of genotypic differences on root growth in Assam tea.

Shoot growth of nursery plants was studied based on shoot length, fresh shoot weight and dry shoot weight. The characters showed significant variation among the accessions studied, indicating the influence of genotypic differences on shoot growth in Assam tea.

Juvenile growth performance of plants can be considered as an indicator of their future vigour. Nine growth parameters were recorded at the end of the first, second and third years of growth in the case of the fifty accessions under study and five phytochemical characters were recorded at the end of the second and third years of growth and analyzed comparatively to study the juvenile growth pattern of Assam tea. Some of the characters showed a trend of change in relation to age of the plants. However, some other characters showed no such relationship.

Juvenile growth index in the case of the fifty accessions of Assam tea under study has been analyzed presently based on juvenile growth pattern and rank of performance. TRI 2025 showed the best performance in terms of relative growth during the second and third years, based on nine morphometric characters and five phytochemical characters, followed by TTSS 1.

A preliminary attempt has been carried out presently to study the nature of genetic control of agronomic characters in Assam tea. Among the nine growth characters studied, only shoot weight (3L&B) showed a balanced distribution of the frequency of plants in the population towards both the sides of the mode value of the distribution indicating the balanced distribution of the

alleles for the character in the gene pool. Leaf angle, leaf area and number of branches showed accumulation of higher frequency of plants towards the bottom of distribution indicating the accumulation of recessive factors for the character in the distribution, thus highlighting the necessity of selection for favourable genotypes. Characters like shoot weight, internodal length and branch length showed a broader distribution indicating the involvement of more number of factors in the distribution of the characters.

However characters like leaf angle, leaf area, number of branches and branch angle showed only limited range of distribution indicating the involvement of only a few number of factors in the control of the character. Characters with wide variations provide very good scope for selection of desirable genotypes for breeding programmes. Characters with narrow variation require more careful handling so that maximum of the available potential of such characters is identified and exploited.

The five phytochemical characters studied presently showed comparatively narrow distribution, even though the distribution appeared to be continuous in nature.

Genetic variability of a crop species is the most valuable raw material for the selection of the most favourable genotypes for propagation and other breeding programmes. Variability of Assam tea has been analyzed presently based on nine growth characters and five phytochemical characters. All growth characters, except leaf area showed statistically significant variation between accessions providing the opportunity of

selecting superior genotypes for propagation and breeding programmes.

Partitioning of the variability available at population level in to its phenotypic and genotypic components is important since only the genotypic component is heritable. The heritable and nonheritable components of variability have been partitioned presently as phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). Among the morphometric characters, internodal length (B&F) showed the maximum heritable component and among the phytochemical characters, chlorophyll content showed the maximum heritable component. Higher GCV further indicates the lower level of the influence of environment on the characters concerned.

Polygenic characters show different levels of heritability in organisms based on the influence of environment on the character concerned. Among the growth characters of Assam tea studied presently, maximum heritability was shown by branch length. All the growth characters except leaf area showed above 79% of heritability. Among the phytochemical characters polyphenol content showed maximum heritability, indicating the heritable nature of tea quality.

The percentage of genetic advance possible under selection was calculated presently so as to find out the utility of the characters studied in crop improvement programmes. Genetic advance was found to be the maximum in the case of internodal length (B&F) among growth characters and chlorophyll content

followed by catechin content and polyphenol content in the case of phytochemical characters.

Most of the agronomic characters in crop plants are polygenic in nature: they are interrelated and also influenced by environment. Correlation studies have been carried out presently in the case of the growth characters and phytochemical characters of Assam tea so as to identify the most suited characters that can be targeted for in selection. Shoot weight (3L&B) and internodal length (B&F) were correlated positively with eleven other characters, thus showing the importance of these characters in selection.

Agronomic characters of crop plants show interrelationships due to their polygenic and pleiotropic nature. Character association has been studied presently so as to find out lead variables and to reduce the complexity of handling data. The fourteen variables under study identified five factors under factor analysis with catechin content, internodal length (S&T), internodal length (B&F), branch angle and number of branches as lead variables.

Cluster analysis was carried out in the case of the fifty accessions of Assam tea studied, based on nine morphometric and five phytochemical characters. The accessions could be grouped in to four major clusters, the first cluster consisting of two genotypes, second cluster consisting of sixteen genotypes, third cluster consisting of twenty eight genotypes and the fourth cluster consisting of four genotypes.

Performance analysis has been carried out presently in the case of the fifty accessions of Assam tea studied. TRF 1, a selection released by UPASI Tea Research Foundation, Valparai, Tamil Nadu, India proved to be the best performer based on fourteen characters and TTL 1, a selection released by Tata Tea Ltd., performed the next. Both of them showed good performance in terms of yield and quality parameters.

The present experiments utilizing fifty accessions of Assam tea generated considerable quantum of information on different aspects of the genetics and diversity of the crop in the Indian subcontinent. It has further helped to compare the above genotypes based on their performance. It is hoped that further investigations carried out in future may contribute more towards the knowledge on the crop thus improving tea productivity and the quality of tea produced.

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