STUDIES ON ALTITUDINAL MORPHOGENETIC DIVERSITY AMONG CERTAIN *RHODODENDRON* SPECIES OF NAGALAND

By

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DECLARATION

I, Mr N. Abenthung Kithan, bearing Ph. D. Registration No. 682/2015 dated 06 AUG 2015 hereby declare that the subject matter of my Ph. D. thesis entitled 'Studies on Altitudinal Morphogenetic Diversity among certain *Rhododendron* species of Nagaland' is the record of original work done by me, and that the contents of this thesis did not form the basis for award of any degree to me or to anybody else to the best of my knowledge. This thesis has not been submitted by me for any Research Degree in any University/ Institute.

This is further certified that the Ph. D. thesis is submitted in compliance with the University Grants Commission (Minimum Standard and Procedure for Award of M. Phil./Ph.D. Degree) (2nd amendment) Regulations, 2018 dated 16th October 2018. This thesis is being submitted to the Nagaland University for the degree of 'Doctor of Philosophy in Botany'.

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Ph. D. Course Work Mark Sheet and Certificate.

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Course No..... Research Methodology	B. Ph. D-I	100	35	54
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Course No..... Review of Literature Reports/Seminar	B. Ph.D-III	100	35	80
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Average Pass Mark - 55%				

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Abbreviations

Abbreviation	Full Form
ANOVA	Analysis of variance
CP	Cophenetic correlation coefficient
E	Environmentability
GCV	Genotypic coefficient Variance
H^2	Heritability
masl	Meter above sea level
PCA	Principal Component Analysis
PCV	Phenotypic coefficient Variance
R	Repeatability
RET	Rare, endangered and threaten
S.D.	Standard deviation
S.E.	Standard Error
UPGMA	Unweighted Pair Group Method with Arithmetic mean
V	Variance
V_E	Environmental variance
V_G	Genotypic variance
$V_{G\times E}$	Genotype and Environment Interaction Variance
V_P	Phenotypic variance

Chapter - 1

Introduction

Any life form and its taxonomic status along with geographical range of flora and fauna have important effect on the genetic variation and partitioning of genetic diversity within and among plant population. Also, reproductive strategy, gene flow and gene drift are essential in saving the genetic composition of population (Schneller and Liepst, 2007;Stocklin*et al*., 2009).

The genus *Rhododendron* (Ericaceae) was first reported in the book 'Species Plantarum' by Linnaeus (Linnaeus, 1753). Rhododendrons comprise of two Greek words *Rhodo* and *Dendron*. In Greek, *Rhodon* represents rose while *Dendron* represent tree, therefore, all together *Rhododendron* means a rose tree.

Rhododendron is a genus characterized by the shrubs and small to large trees, the smallest species growing from 10-100 cm (3.9-39.4 inch) tall, and the largest, *R. protistum* var. *giganteum*, reported to 30 m (98 ft) tall, evergreen and deciduous (Mao and Gogoi, 2012). Some species are best known for their clusters of large flowers. *Rhododendron* represents x=13 chromosome number. Peak season for flowering of Rhododendrons are March, April and May. Rhododendrons are mostly native to higher altitudes in the Sino-Himalayan region with maximum concentration in Western China. Rhododendrons are distributed mostly at higher altitudes in different regions of Nagaland.

The state of Nagaland include the former Naga hills district of Assam lies in the extreme North Eastern part of India, covering an area of 16,527 sq km between 25°6'- 27°4'N Latitude and 93°2'-97°13'E Longitude. The state is bounded by Assam in the west and north-west, flanked by Tawang district of Arunachal Pradesh in the north-east. The southern boundary is

marked by the state of Manipur, while the eastern limits are continuous with International boundary between India and Myanmar. Nagaland is mostly covered by high altitude mountains. The average height of the peaks is between 900 to 1200 masl. It consists of 11 districts with different altitudes i.e. Dimapur (260 masl), Kohima (1444 masl), Mokokchung (1325 masl), Kiphire (896 masl), Longleng (1066 masl), Mon (898 masl), Peren (1445 masl), Phek (1524 masl), Tuensang (1371 masl), Wokha (1314 masl), and Zunheboto (1874 masl) respectively. Mount Saramati (in Kiphire district) is the highest peak (3840 masl) in Nagaland.

Rhododendron includes approximately 850 species in the world with attractive and beautiful flowers (Mabberley, 2008). Most of the Rhododendrons are distributed at the higher altitude (Pradhan, 1985). Most of the species are restricted to eastern Himalaya in India. The various authors revised the genus time to time and reported their distribution, status, rare or endemic *Rhododendron* in India (Cullen, 1980; Chamberlain, 1982; Philipson and Philipson, 1956; Chamberlain and Rae, 1990; Kron, 1993; Jutt and Kron, 1995; Ghosh and Samaddar, 1989; Bhattacharya and Sanjappa, 2008; Sastry and Hajra, 1983;Mao *et al*., 2002;Pradhan and Lachungpa, 1990; Singh *et al*., 2003; Yumnam, 2008).

In India, there are about 80 species (with 10 subspecies and 14 varieties) in different regions and altitudes in the Himalayan regions in between 1500-5500 masl and it is one of the most neglected group of plants in terms of scientific enquiry in India (Bhattacharya, 2011). On record, 98% of the Indian species is found in the Himalayan region among which 72% is found in Sikkim and the species availability decreases drastically from 4500 masl upwards and 2500 masl downwards (Singh *et al*., 2003). Three species of *Rhododendron* L. (*R. arboreum*, *R. companulatum*, *R. anthopogon*) were recorded from nine districts and inhabiting temperate, sub alpine and alpine regions of Himachal Pradesh (Kharwal and Rawat, 2013). The eighteen *Rhododendron* species from Myodia district (lower Dibang valley) and a total of 47 taxa of *Rhododendron* were recorded from the West Kameng and Tawang districts of Arunachal

Pradesh (Mao *et al*., 2009). Rhododendrons were recorded from subtropical hills of Ukhrul district, Senapati district (1000-1500masl), temperate hills of Siroi, Koubru peak and Mt Esii (1600-2500masl) of Manipur (Mao, 2010). Rhododendrons are found in subtropical hills of Zunheboto district, Wokha district, temperate forest of Mt. Saramati, Mt. Japfu, Jakhama, Khonoma, Puliebadze and Dzulakei hills of Nagaland (Mao, 2010). The common species for both Manipur and Nagaland includes *R. elliotii*, *R. formosum var.formosum*, *R. formosum var.inaequale*, *R. johnstoneanum*, *R. lepidotum*, *R. macabeanum*, *R. maddenii*, *R. triflorum*, *R. vaccinioides* and *R. wattii* (Mao, 2010). Frank Kingdom-Ward (1949 and 1960) explored Japfu hills of Nagaland (1928), hills of Manipur (1939) and Nagaland bordering Myanmar (1948) and contributed to the knowledge of *Rhododendron*. *Rhododendron* species from Manipur and Nagaland was first collected by Sir George Watt (1890) who surveyed Manipur and Nagaland from 1882-1885 and described four new species (*R. macabeanum*, *R. ellioti*, *R. triflorum var. bauhiniflorum* and *R. wattii*) from Japfu hill range of Nagaland.

The Himalayan region is one of the most sophisticated hilly regions of the world which include a huge biological diversity and this biological diversity is under threat through human activity in the Himalayan region. The over exploitation, destruction or destroying the habitat, use of harmful chemicals and introduction of invasive and alien species, a number of important flora and fauna has been disappeared and some other species are standing in queue to loss from the environment. This may be the possible reason that a gap between demand and supply increases. More over efforts are made to conserve the flora and fauna especially RET species which are important component of any biological diversity.

The anthropogenic activity in the Himalayan region cause decrease in natural population of *Rhododendron*. The decrease in *Rhododendron* population in the Himalayan regions is the major threat to the natural population of *Rhododendron*. The other activity such as deforestation, extraction of fire wood and Jhum cultivation, may be possibly causing harm to

the population of *Rhododendron*. Some of the *Rhododendron* species which may be consider rare or endangered disappeared in near future if proper conservation are not made.

The distribution of Rhododendrons may be found from North western Himalayan through Nepal Sikkim, Tibet, Bhutan, Arunachal Pradesh, Burma to western China. These regions are rich in *Rhododendron* population. Approximately 50 species of *Rhododendron* are found in India and restricted to the Himalayan region but one species *Rhododendron nilagiricum* found in southern India. Rhododendrons are most neglected group of plant in term of scientific enquiry in India. According to one of the record 98% of *Rhododendron* species found in Himalayan region and out of 98% approximately 72% found in Sikkim alone (Singh *et al*., 2003). The maximum availability of *Rhododendron* in Sikkim may be considered as best location for conservation and propagation study of *Rhododendron* in India.

Besides the conservations of *Rhododendron* species there was a report on pharmacognosy where trunk, leaves, flowers, fruit and seeds are used or exploited to make useful drugs, photochemistry where bark, leaves, flower are used to extract different chemical, pharmacology where *Rhododendron* are used as anti inflammatory, hepato protective, anti diarrhoeal activity and anti oxidant activity (Srivastava,2012). It has been used for the medicinal purposes in homeopathic and ayurvedic also. In commercial uses it may be used as taste, sweet or sour, jam and jelly appetizer, chutney, charcoal and fuel (Paul *et al*., 2005).

The aesthetic values of *Rhododendron* are significant and it is the recognized regional flower in American States of Washington (*Rhododendron macrophyllum*) and West Virginia (*Rhododendron maximum*) and in Japan's Shiga Prefecture (*Rhododendron metternichii* var. *hondoense*), and *Rhododendron arboreum* is Nepal's national flower and is depicted on its coat of arms (de Milleville, 2002).

In India, *Rhododendron* is the state flower of Himachal Pradesh (*Rhododendron campanulatum*) and Nagaland (*Rhododendron arboreum*), and is the state tree of both Sikkim

(*Rhododendron niveum*) and Uttarakhand (*Rhododendron arboreum*) (Kant, 2004; Joshi and Sharma, 2005). There was report on ethno botanical study of *Rhododendron* species in Himachal Pradesh (Kharwal and Rawat, 2013). *Rhododendron* species were studied and reported from Arunachal Pradesh (Mao *et al*., 2009). A brief account of *Rhododendro*n species distributed in North East India reported (Mao, 2010). *Rhododendron* species also recorded from Manipur and Nagaland by Sir George watt (Watt, 1890). Four new *Rhododendron species* were reported from Japfu hill range from Nagaland but no detailed taxonomic account was available.

Various molecular markers are used for DNA finger printing in *Rhododendron*. The application of these markers to identify a marker assisted genotype and for the construction of genetic linkage map has been done (Wei *et al*., 2005). It was reported that a 25 kDdehydrin ametabolite is conserved when exposed to drought, cool and high salt concentration in the various species (Arora *et al*., 2003). A clonal diversity of *Rhododendron ferrugineum* obtained using AFLP markers (Taberlet *et al*., 1998). Molecular genetic diversity was analyzed for *R. arboretum* from China of Changbai mountain using ISSR and RAPD (Liu *et al*., 2010).

Molecular genetic diversity was analyzed from the population on *Rhododendron arboretum* of temperate and tropical forest of Satpura region of Indian sub continent (Seeni *et al*., 2014).There was a *Rhododendron* hybridization between *Rhododendron eriocarpum* and *Rhododendron indicum* from south west Japan (Okubo *et al*., 2008). Twenty four micro satellite loci were isolated for *Rhododendron decorum* (Long *et al*., 2009).

The asymmetric hybridization was reported in *Rhododendron agastum* in China (Sun *et al*., 2010). The asymmetric hybridization occurred possibility due to the process of speciation which involve of formation and maintenance of reproductive and isolation (Levin, 2000; Wu, 2001). There is a possibility that species may form barriers among themselves by eliminating intermitted forms or hybrids. But it is also fact that hybrids higher facts over the both parents (Campbell, 2004; Campbell *et al*., 2005). The reason of hybrids in intermediate habitat provides

a potential for germplasm to flow between inter fertile species. And also possibility arises that some species still exist inspite of continuous gene flow.

There were many authors reported for the hybridization among *Rhododendron* species from different countries (Yang *et al*., 2010; Chamberlain *et al*., 1999). Molecular diversity and relationship among *Rhododendron* species was analyzed using RFLP molecular marker (Li *et al*., 2012). The distribution of *Rhododendron* species and their economical and horticultural use with special reference to Himalayan region was suggested by Bhattacharya (2011). Molecular diversity of *Rhododendron* species were studied in different countries using molecular markers such as ISSR, AFLP, Mat k sequences, RBV2 gene sequences, PsbA-trnH marker (Xia *et al*., 2007; Sharma *et al*., 2014; Praveen *et al*., 2008; Atak *et al*., 2011; Li *et al*., 2008; Zhao *et al*., 2012; Goetsch *et al*., 2005; Liu *et al*., 2012) . A natural hybridization of *Rhododendron* was reported as *Rhododendron agastum* is a natural hybrid between female *Rhododendron delaby* and a male *Rhododendron decorum* (Li *et al*., 2008). *Rhododendron* species were clone and studied their genotypic structural dynamic by Pornon (2000).

Quantitative genetics is a sub branch of evolutionary population genetics which quantified the inheritance and evolution of continuously varying phenotypic traits (Falconer and Mackay, 1996). The quantitative trait is a specific term characterized and determined by multiple genes and environmental factors. It is measurable but varies over a range among the individuals to produce a continuous distribution of phenotypes. A phenotype is a quantitative trait controlled by many genes (multiple genes) and influenced by environmental factors or in other words, a genotype is a set of genes involved in the expression of a certain phenotype. The quantitative genetics mostly applied to the crops to check their yield and other traits for future breeding prospects and new varieties, but now it is used for all various other plants such as horticultural, fruits, trees, vegetables, etc. generally, to measure the quantitative traits measure

of central tendency (mean, standard error, standard deviation, variance, ANOVA, correlation and regression) of statistics are used.

Mean is the sum of a number of data collected and divided by the count of number of data in the collected sample. The standard error (S.E.) measures the accuracy of a sample data collected from a population. A sample mean deviates from the actual mean of a population and this deviation is the standard error. Standard deviation (S.D.) is a measure of data variability around mean of a sample of population. Variance (V) measures how far a set of random numbers of data are spread out from their mean or average value. ANOVA is a method used to test the general differences rather than specific differences between two or more means. Correlation measures the direction and strength of linear relationship between two quantitative variables and regression summarizes the relationship between explanatory (x) and response variable (y).

The estimation of genotypic and phenotypic parameter have prime role in genetic breeding program. These parameters enable the breeders to make decision about the appropriate method to handle the population and select the characteristic to be considered in initial and advance steps of the breeding program (Koniarski and Matysiak, 2013). The continuous improvement of genetic breeding of Rhododendrons depends on the information about genetic variability, genetic parameters, and their application that access the breeders in reliable selection process. Statistically, the assessment of the parameters could be obtained through the estimation of phenotypic variance (V_P), genotypic variance (V_G), environmental variance (V_E), interaction of genotype and environment ($V_{G\times E}$) (Byers, 2008; Chen *et al*., 2016; Henderson and Salt, 2017; Lawrence *et al*., 2017).

The genotypic and phenotypic coefficient of variation GCV and PCV give information about the nature and magnitude of variation. It clarifies either the variation is due to genetic

causes or environmental causes. Usually the PCV is greater than GCV, if the differences between PCV and GCV are larger than the environmental effect on the character will be more.

Heritability (H^2) gives information about the inheritance of character. Traits having high heritability are easy to improve through selection.

Repeatability (R) is defined as the consistency of a trait over time and allows an assessment of the probability of measuring heritability. Repeatability indicates the proportion of total variation in a trait that is due to differences between individuals (Falconer, 1981). It is based on repeated measures of the same individuals followed by an analysis of variance. Repeatability is directly useful as a measure of the intra-individual consistency of displays and other aspects of behaviour. Only traits that are manifested consistently within individuals as well as differing between individuals can respond to selection.

Environmentability (E) measures how much a trait is under the influence of environment of a particular place.

Phenotypic plasticity refers to changes in organisms' traits due to changes in internal or external environmental conditions (Pigliucci, 2001). When these phenotypic changes are reversible over time, the name of phenotypic flexibility is commonly used (Piersma and Drent, 2003).

The survey of literature suggested that a voluminous work has been done on the distribution and taxonomy of Rhododendrons including different molecular markers used to identify diversity among the Rhododendrons, and reported other uses of the Rhododendrons such as in ayurveda, medicine, pharmacognosy, pharmacology and anti microbial agents, but data on morphogenetic traits and their association with tree growth, development and interaction with environment are meager. The present work was taken up to study the preliminary data collection on certain quantitative traits of Rhododendrons from three different altitudes (1780, 1854, 1952 of Mt. Tiyi; 1653, 2050, 2284 of Mt. Puliebadze; and 2688, 3112,

3430 of Mt. Saramati,masl) of three districts, Wokha, Kohima and Kiphire of Nagaland (India) to observe the altitudinal effects on morphogenetic traits and their diversity. It is hoped that data may be useful for designing tree breeding programs in *Rhododendron* species.

SCOPE OF STUDY

The survey of literature suggested that a voluminous work has been done on the distribution and taxonomy of Rhododendrons but data on morphological and genetic variation in relation to tree improvement program are meager.

Also the survey on *Rhododendron* species at different altitudes and regions of Nagaland suggest that most of the species are under RET and red listed as described below which gives an important point for further study and examine to *Rhododendron*.

The five taxa (*R. formosum var.formosum*, *R. formosum var.inaequale*, *R. ellioti*, *R. macabeanum* and *R. wattii*) are red listed under different IUCN categories from the State (Gibbs *et al*., 2011). The critically endangered species from Nagaland are *R. lepidotum* (Dzukou valley), *R. wattii* (Dzukou valley) and *R. vaccinioides* (Japfo hill) and *R. wattii* is the most critical and only a single tree was located from Dzukou hill (Mao and Gogoi, 2007). The species of *Rhododendron* which are endemic to Nagaland are *R. elliottii*, *R. macabeanum*, *R. triflorum var. bauhiniflorum*, *R. wattii*, *R. johnstoneanum*,*R. formosum var. inequale* and *R. arboreum* (World Largest *Rhododendron*) is the most affected species due to jhumming or agricultural activities in the hills. The taxa found in the states of Nagaland have become rare and threatened as the species are only found in few pockets in the states (Mao, 2010). The endemic taxa of state require immediate conservation (Mao, 2010).

The present, work was taken up to study the preliminary data collection on certain quantitative traits of Rhododendrons from three different altitudes of three districts, Wokha, Kohima and Kiphire of Nagaland (India) in terms of Mean, Standard Error (S.E.), Standard deviation (S.D.), Variance, ANOVA, Correlation, Principal component analysis (PCA),

Phenotypic variance (V_P), Genotypic variance (V_G), Environmental Variance (V_E), Variance due to genotype and environment interaction ($V_{G\times E}$), Repeatability (R), Heritability (H^2) and Environmentability (E) to observe the altitudinal effects on morphogenetic traits as well as their diversity. It is hoped that data may be useful for designing tree breeding programs in *Rhododendron* species as well as taken up for further study.

OBJECTIVES

1. To study the morphological variation at different altitudes and regions among certain *Rhododendron* species of Nagaland.
2. To study the genetic variation at different altitudes and regions among certain *Rhododendron* species of Nagaland.
3. To study the morphogenetic relationship (based on morphological and genetic characters) among certain *Rhododendron* species of Nagaland.

Chapter – 2

Materials and Methods

Data collection

The collection of data has been done using simple random sample method from a quadrate method of (50X50 m^2) from three replicates at each altitude of the 3 districts. Firstly, the highest and lowest altitudes were measured using GPS equipment by walking in the jungle or forest from one end to other where *Rhododendron* populations were found. Then it has been divided into three parts of different gradation, which gave us the three altitudinal regions in each district. Three replicates were used for data collection in each altitudinal regions. Mean and standard error was calculated for each altitudinal region to get the final mean altitude. Same was repeated for all the districts.

The following data such as plant height (in meter), number of branches (count), girth of the tree (in cm), number of internodes (count), node length (cm), leaf length (cm), leaf breadth (cm), petiole length (cm) peduncle length (cm), pedicel length (cm), number of flowers per peduncle (count), petal length (cm), petal breadth (cm), stamen length (cm) and carpel length (cm) were collected which served as quantitative morphogenetic traits for the present purpose.

The collected species were identified as *Rhododendron arboreum*, *R. formosum*, *R. trifolium*, and *R. macabeanum* (Mao 2010; Mao and Gogoi 2007; 2012; Mao *et al*., 2002). Moreover, species identification was also consulted with Professor N. S. Jamir, Plant Taxonomist, in the Department by producing flowering stage of the *Rhododendron*.

Although approximately 10 species of *Rhododendron* were reported from Nagaland (Mao, 2010), but only four species were encountered in the study area of three district. The area and district was selected on the basis of that maximum population of *Rhododendron* was found in that area, but that population was dominated by only four species.

The data collection on the other species of *Rhododendron* may be covered in near future and would be analyzed and presented in the form of published article.

Morphological quantitative data

The morphological quantitative data such as plant height (ph), number of branches (nbr), girth of the tree (g), number of internodes (in), node length (nl), leaf length (ll), leaf breadth (lb), petiole length (ptl) peduncle length (pdl), pedicel length (pcl), number of flowers per peduncle (nfpp), petal length (pl), petal breadth (pb), stamen length (sl) and carpel length (cl) were collected which served as quantitative traits for the present purpose. The data collection and measurement of the traits had been done from three different altitudes of Wokha, Kohima and Kiphire districts of Nagaland (Figure 1).

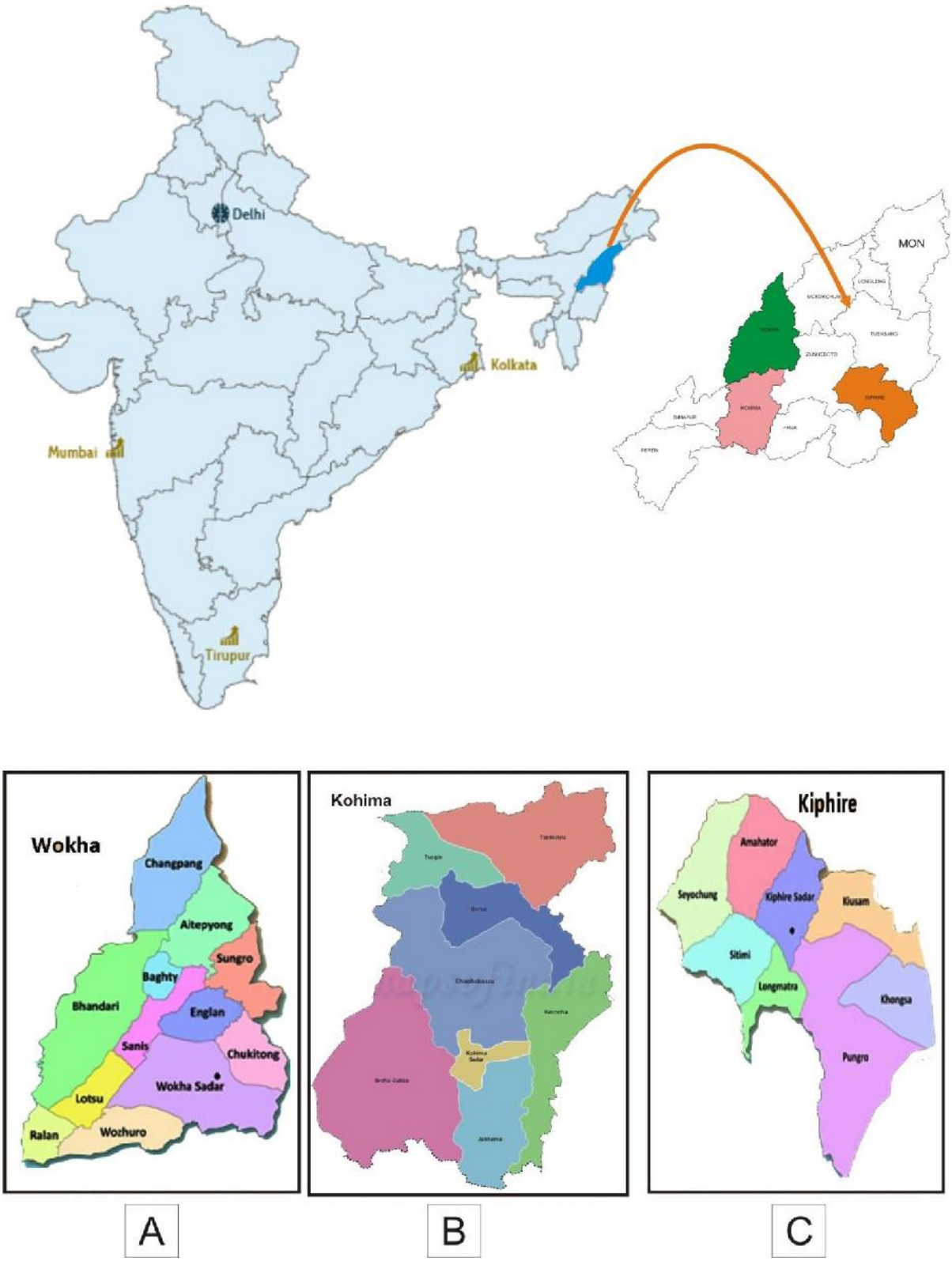


Figure 1. Data collection area and map of three districts of Nagaland. A. Wokha, B. Kohima, C. Kiphire

District and Altitudes (Mean ± S.E.) used in the present study

District(s)	Altitude (Mean ± S.E.)	Altitude (masl)
Wokha	1780.4 ± 4.17	1780
	1854.0 ± 4.10	1854
	1952.23 ± 2.10	1952
Kohima	1653.4 ± 1.36	1653
	2050.3 ± 0.71	2050
	2284.4 ± 0.39	2284
Kiphire	2688± 0.43	2688
	3112.2 ± 0.95	3112
	3430.9 ± 0.40	3430

Descriptive statistics

Mean = $\bar{x} = \Sigma\frac{xi}{N}$

Standard Error (S.E.) = $\frac{S.D.}{\sqrt{N}}$

Standard deviation (S.D.) = $\sqrt{\frac{(x-\bar{x})^2}{N}}$

Variance (V) = $\sqrt{\frac{(x-\bar{x})^2}{n-1}}$

Statistical analysis

The analysis of variance (ANOVA) was performed for the traits against the altitude as a factor for three districts. The ANOVA differentiated the variations between and within the traits as mean square value and within mean square value considered as environmental variance (V_E) present in the trait. Accordingly, other variations such as genotype variation (V_G), phenotype

variation (V_P) and variation due to genotype and environment interaction ($V_{G\times E}$) were measured and calculated exercising Burton (1952), Sharma (1988) and Shivasubramanian and Menon (1973).

$V_P = VG + VE/r$

$$V_G = \frac{\text{Mean Square (Between)} - \text{Mean Square (Group)}}{\text{Number of replications (r)}}$$

V_E = Environmental variation, within mean square value (ANOVA)

$V_{G\times E}$= Variation due to genotype and environment interaction

$$PCV = \frac{\sqrt{V_p}}{\bar{x}} \times 100$$

$$GCV = \frac{\sqrt{V_g}}{\bar{x}} \times 100$$

The other variation components such as Repeatability (R), Heritability (H^2) and Environmentability (E) were calculated using the following formulae:

$$\text{Repeatability (R)} = \frac{V_G + V_{G\times E}}{V_P} \text{ (Falconer, 1981)}$$

$$\text{Heritability } (H^2) = \frac{V_G}{V_P} \times 100 \text{ (Falconer and Mackay, 1996)}$$

Environmentability (E) = l–Heritability

Mean ±S.E., S.D., Sample variance, Pearson correlation (2 tailed), Scree plot, PCA for the selected quantitative traits were analyzed using SPSS ver. 16 for all the regions (Wokha, Kohima and Kiphire) and altitudes (3 altitudes each region).

UPGMA cluster analysis using Pearson correlation or similarity index for α and β diversity (Shannon index) based on selected quantitative traits for all the regions and altitudes was studied using Past Software.

***Altitudinal density of* Rhododendrons**

The density of *Rhododendron* species were recorded from all the altitudes of three district of Nagaland. The density may be defined as the number of trees per unit area or number of trees per meter square or the number of trees per hectare. In our experiment, we have used quadrate method 50×50 meter square to count the number of trees and converted the values into hectare.

Population density= Number of plants/unit area OR Number of plants/square meter OR number of plants / hectare.

1 hectare=2.47 acres

1 hectare= 10,000 square meter

10,000 square meter= 1 hectare

2500 square meter= 1/10,000 hectare

1 square meter= 1/10,000X 2500 hectare

1 square meter= 0.25 hectare

Chapter – 3

Results and Discussion

Morphogenetical variations and diversities of* Rhododendrons *of Wokha

Altitude 1780 masl

The morphological parameter of the Rhododendrons at an altitude of 1780 masl was statistically described for mean, standard error, standard division and variance (Table1). The highest mean was recorded for number of flower per shoot (15.66±1.364), followed by number of anthers (10.00±0.000) and leaf length (9.255±0.245) respectively. The high mean value of number of flower per shoot indicates that the environmental condition at an altitude of 1780 masl is favorable to the phenotypic trait followed by number of anthers and leaf length. The other parameters were also favored by altitude 1780 masl but less as compared to number of flowers, number of anther and leaf length.

Analysis of variance (ANOVA) was performed for the morphological traits and observed that all the morphological traits are significantly varied more than 5% and 1% probability level (Table 2). None of the morphological traits showed significance variation at probability level 5 or 1 %.

All the morphological parameters were correlated for their association with each other using bivariate Pearson correlation (2 tailed) and it was observed that number of trees showed a good correlation with altitude (0.908*) at P≤0.05 (Table 3). Number of branches 100% correlated with number of nodes (1.000**) at P≤0.01. Leaf breadth showed association with petal length (0.720*) at P≤0.05, length of peduncle showed association with number of flower

per shoot (0.745*) at P≤0.05, length of petal also correlated with breadth of petal (0.834**) at P ≤0.01.

The morphological data are correlated with each other and to observe maximum variation in the morphological traits principal component analysis (PCA) was performed. Screed test has provided a maximum of five component matrix to explain the total variation available in the morphological traits (Fig. 2). The scree plot which was showing maximum variation within the component reduced to two components matrix to explain the total variations available in the morphological traits. Both the components together have shown only 50% of the total variations available in the morphological traits. It may suggest that not only two components are sufficient to explain the variation available in the morphological traits but all the five components are necessary to explain the complete variation of the morphological traits (Table 4).

The morphological traits were analyzed for their variation due to their phenotype, genotype and environment and interaction between genotypic and environmental variation. The maximum phenotypic variability was observed in the plant height (0.834), genotypic variability observed in leaf length (0.672) while the variation due to interaction of genotypic and environment observed in leaf length (0.712). The variations in the traits, which have showed 50% or more are taken into consideration. The other parameter has shown over estimated or very less variation in their phenotype. Most of the parameters over estimated or under estimated (Table 5).

The morphological parameters were also analyzed for their heritability, environmental ability and repeatability. The morphological traits circumference (0.816), leaf length (0.655), petiole length (0.549) showed heritable character. The trait plant height (0.819), node length (0.554), length of pedicel (0.529), and length of carpel (0.915) are under the influence of environmental at an altitude of 1780 masl. The repeatability of morphological trait

circumference (0.875), node length (0.538) and petiole length (0.568) were recorded. The genotypic coefficient variation and phenotypic coefficient variation of the morphological traits were not recorded similar, therefore, suggested that all the morphological traits are under the influence of environment as well as genotype of the trait at an altitude of 1780 masl of Wokha district (Table 5).

Cophenetic correlation coefficient (CP) is the linear correlation between the dissimilarities and their distances with each other of each pair of observations and merging of dissimilarities and distances together at a single point in the cluster.

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 1780 masl of Wokha district and observes 84.44 % cophenetic correlation coefficient among studied quantitative traits. All the quantitative traits merged together into three groups. Altitude and plant height are group together and suggested favorable condition for plant height. The altitude is also favorable for length of stamen and length of pedicel as grouped in to the same cluster (Fig. 3).

Altitude 1854 masl

The morphological parameter of *Rhododendron* at an altitude of 1854 masl was statistically described for mean, standard errors, standard deviation and variance (Table 6). The highest mean was recorded for number of flower per shoot (11.00±0.892) followed by leaf length (10.778±441) and number of anthers (10.087± 0.06) respectively. The other parameters were also favored by the altitude 1854 masl but less as compared to the number of flower per shoot, leaf length and number of anthers.

The analysis of variance (ANOVA) was performed for morphological traits and was observed that length of pedicel, length of petal, length of stamen and length of carpel shows significance variance (F=5.874, 4.712, 5.379, 4.695) at $P \leq 0.05$ respectively (Table 7). The

other parameters also showed significant variances but the probability level was very high (P≥0.05 and 0.01).

All the morphological parameters was correlated for their association with each other using bivariate Pearson correlation (2 tailed) and it was observed that number of trees highly correlated with height of the tree (0.938**) at P ≤0.01. Number of branching showed 100% correlation with number of nodes (1.00**) at P ≤0.01. The circumference associated with leaf length (0.840**) at P ≤0.01. Length of petal associated with breadth of petal (0.775*) at P ≤0.05 (Table 8).

The morphological data was correlated with each other and to observe the maximum variation in the morphological traits Principal component analysis (PCA) was performed. Scree plot has been analyzed and a maximum of five components was observed to explain the total variations available in the morphological trait (Fig. 4). On the basis of the scree plot the component was reduced in to two components matrix to explain the total variation available in the morphological traits. Both the components explain only 39 % of the total variation available in the morphological trait. It suggest that not only two component sufficient to explain the variation available in the morphological trait but all the five components are necessary to explain complete variation of the morphological traits (Table 9).

The morphological traits were analyzed for their variations due to their phenotype, genotype, environment and the interaction between genotype and environment. The variations due to phenotype, genotype and the interaction due to genotype and environment was not recorded at an altitude of 1854 masl of Wokha district where as variation due to environment was recorded in the leaf breadth (0.956). The variations of the traits which were 50% or more taken into consideration and reported. The parameters such as phenotypic variations, genotypic variation and variation due to interaction between genotypic and environment shown over estimated or under estimated (Table 10).

The morphological parameters were also analyzed for their heritability, environmentability and repeatability. The morphological traits such as plant height (0.640), circumference (0.872), length of pedicel (0.875), length of petals (0.780), length of stamen (0.818) and length of carpel (0.787) showed heritability of the traits. The environmentability of the trait was recorded for length of peduncle (0.600), number of flowers per shoot (0.671) and breadth of petals (0.800). The repeatability of the traits was recorded for circumference (0.890), length of pedicel (0.875), length of petals (0.780), length of stamen (0.818) and length of carpel (0.818) respectively. The phenotypic coefficient variation and genotypic coefficient variation was not recorded for similar values for any of the morphological traits suggest that these morphological traits are under the influence of environment and genotype (Table 10).

Cophenetic correlation coefficient (CP) is the linear correlation between the dissimilarities and their distances with each other of each pair of observations and merging of dissimilarities and distances together at a single point in the cluster.

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 1854 masl of Wokha district and observed 81.75 % cophenetic correlation coefficient among studied quantitative traits. All the quantitative traits merged together into three groups. Altitude and plant height group together and suggested favorable condition for plant height. The altitude is also favorable for number of branches and length of petal as grouped in to the same cluster (Fig. 5).

Altitude 1952 masl

The morphological parameter of Rhododendrons at an altitude of 1952 masl was statistically described for mean, standard error, standard deviation and variance (Table 11). The highest mean was recorded for number of flower per shoots (15.022±0.729) followed by leaf length (11.644±0.209) and number of anthers (10.022±0.022) respectively. The other

parameters also favored by the altitude 1952 masl but less as compared to number of flowers per shoot, leaf length and number of anthers.

The analyses of variance (ANOVA) was performed for the morphological traits and observed that all the morphological parameters are significantly varied but the probability level was very high for all the traits instead of P≤0.05 respectively (Table 12).

All the morphological parameters was correlated for their association with each other using bivariate Pearson correlation (2 tailed) and it was observed that number of trees are correlated with circumference (0.622**) at P ≤ 0.01. Simultaneously, the number of trees are negatively correlated with the altitude (-0.05**) at P ≤0.01. A negative correlation with the altitude suggests that as increase in altitude, decrease in number of trees. Plant height also suggested dependent on the circumference (0.690**) as well as altitude (0.634**) at P ≤0.01. But the plant height of the tree is increasing as it increases in altitude, number of branch correlated with number of nodes (0.925**) at P ≤0.01. The number of branching may increase by increase in number of nodes. Circumference of the tree is negatively correlated with the altitude (-0.700**) at P ≤0.01. Circumference also correlated with number of flower per shoot (0.58*) at P ≤0.05. Leaf length correlated with leaf breadth (0.760**) at P ≤0.01 and leaf length is also associated with petiole length (0.516*) at P ≤0.05. Length of peduncle is associated with number of flower per shoot (0.448*) and breadth of petal (0.601**) at P ≤0.05 and P ≤0.01 respectively. Number of flower per shoot is correlated with breadth of the petal (0.552**) at P ≤0.01. Length of petal is correlated with breadth of petal (0.681**) and length of carpel (0.465*) at P ≤0.01 and 0.05 respectively (Table 13).

The morphological data was correlated with each other for their growth and development and to differentiate and to observe maximum variation in the morphological traits principal component analysis (PCA) was performed. Principal component analysis could give an idea how many traits or components are associated for the total variations in the

morphological traits. A scree plot was analyzed and it showed five components are involved for the 77 % variations in the morphological traits (Fig. 6). On the basis of scree plot which was showing maximum variation between the components reduced to two component matrix to explain the total variation available in the morphological traits. But both the component has showed only 33 % of the total variation available in the morphological traits. It may suggest that not only two components are sufficient to explain the variation available in the morphological traits but all the five components are necessary to explain the complete variation in the morphological traits (Table 14).

The morphological traits were also analyzed for their variation due to their phenotype, genotypic, environment and interaction between genotype and environment. The variation due to environmental interaction was recorded for number of branches, number of internodes and leaf length. The other variance or components such as variation due to phenotype and variation due to interaction between genotype and environmental value are not included most of the parameter over estimated or under estimated for the morphological parameters (Table 15).

The morphological parameters were also analyzed for their heritability, environmentability and repeatability. Most of the morphological traits showed heritable character at an altitude of 1952 of Wokha district. The heritable traits are plant height (0.958), number of branches (0.969), circumference (0.700), number of internodes (0.969), node length (0.840), leaf breadth (0.916), petiole length (0.989), breadth of petal (0.900), length of stamen (0.707) and length of carpel (0.551). Some of the morphological traits are under the influence of environment and their environmental ability for the traits leaf length (0.898), length of peduncle (0.750), number of flower per shoot (0.648), length of pedicel (0.667) and length of petals (0.542). The repeatability of the traits was also recorded for circumference (0.725), node length (0.872), leaf breadth (0.916), petiole length (0.989), breadth of petals (0.916), length of stamen (0.930) and length of carpel (0.586) (Table 15).

The genotypic coefficient variation and phenotypic coefficient variation of the morphological traits was not recorded for similar values of all the morphological traits. It suggests that these traits are under the influence of environment and genotype of the morphological trait at an altitude of 1952 masl of Wokha district (Table 15).

Cophenetic correlation coefficient is the linear correlation between the dissimilarities and their distances with each other of each pair of observations and merging of dissimilarities and distances together at a single point in the cluster.

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 1952 masl of Wokha district and observed 86.35 % cophenetic correlation coefficient among studied quantitative traits. Almost all the quantitative traits are merged together into a single group which also indicates that altitude is approximately favorable for all the quantitative traits studied, but most favorable traits are number of branches and length of petal (Fig. 7).

The morphological traits were analyzed for their variations due to their phenotype (V_P), genotype (V_G), environment interaction (V_E) and the interaction between genotype and environment ($V_{G\times E}$). The maximum phenotypic variability was observed in plant height (0.834) followed by leaf length. Leaf length variability was recorded due to genotypic (0.612) and interaction of genotype with the environment (0.712) at an altitude of 1780 masl. The variations in leaf breadth were recorded high (0.956) which may be due to the environmental condition at an altitude of 1802 masl. Approximately, 50% variations were also recorded in the traits number of branching (0.500) and number of internodes (0.500) while 60% variation was observed in the leaf length (0.605) at an altitude of 1952 masl.

Morphogenetical variations and diversities of* Rhododendrons *of Kohima

Altitude 1653 masl

The morphological parameter of the *Rhododendron* at an altitude of 1653 masl was statistically described for mean, standard error, standard deviation and variance (Table 16). The highest mean was recorded for number of flowers per shoot (10.545 ± 0.331) followed by number of anthers (10.0± 000) and leaf length (9.8± 0.311). Similarly variance was recorded for number of branches and number of internodes are similar (5.835) followed by height of the tree (5.714). The high mean value for number of flower per shoots suggests that the altitude 1653 masl is favorable for the growth of the flower and also the other parameter favored by the altitude 1653 masl but less as compared to the number of flower per shoot.

The analysis of variance (ANOVA) was performed for the morphological traits and was observed that all the morphological traits are significantly varied but the probability level was very high except the trait plant height with probability level 0.01 (Table 17).

All the morphological parameters was correlated for their association with each other using bivariate Pearson correlation (2 tailed) and it was observed that plant height showed correlation with number of branch (0.373*), number of internodes (0.373*) and length of carpel (0.363*) at P≤0.01 (Table 18). The number of branches showed 100% association with number of internodes at P≤0.01. The circumference of the tree showed correlation with length of anther (0.426*) at P≤0.05. The morphological trait leaf length (0.778*) correlated with leaf breadth at P≤0.05 and length of pedicel (0.482**) at P≤0.01. Length of peduncle also associated with length of pedicel (0.516**) at P≤0.01. Number of flowers per shoot negatively correlated with length of stamen and length of anther at P 0.05 and P 0.01 respectively. Similarly length of pedicels correlated with length of stamen and breadth of anther at 0.05. Length of petal has shown a good relation with breadth of petal (0.768**), length of stamen (0.624**) length of carpel (0.702**) and length of anther (0.372*) at P≤0.01 and P≤0.05 respectively. Similarly breadth of petal correlated length of stamen (0.580**) and length of carpel (0.831**) at P≤0.01. Breath of petal has also shown negative association with breadth of anther (-0.579**) at P≤0.01.

Length of stamen correlated with length of anther (0.480**) and length of carpel (0.494**) at P≤0.01. Length of anther directly related to the breadth of anther (0.456**) at P≤0.01. The breadth of anther negatively correlated with length of carpel (-0.414*) at P≤0.05.

The morphological data or the trait was significantly correlated with each other and therefore to observe maximum variation in the morphological trait variation principal component analysis (PCA) was performed to observe the principal component of the variations. A scree test was analyzed in the form of scree plot (Fig. 8). Initially the scree plot has provided seven component matrixes to explain the total variation available in the morphological traits. The eight components variation reduced in two components to explain the variations in the morphological traits. Both the components have shown approximately similar percent of variation that is 18.6 and 17.0 available in the morphological traits. It may suggest that not only two components sufficient to explain the variation available in the morphological traits but the entire seven components are necessary to explain the complete variation in the morphological traits (Table 19).

The morphological traits were analyzed for their variation due to their phenotype, genotype and environment and interaction between genotypic and environment. The maximum phenotypic variability was observed with leaf length (0.930) the other parameters has shown over estimated or very less (less than 50%) variation in their phenotype. None of the parameter has shown variation in the traits due to its genotypic constituent. No record even data on any morphological variation due to the interaction of genotype and environment. Most of the parameter over estimated or under estimated (Table 20).

Morphological parameters are also analyzed for their heritability, environment ability and repeatability. Plant height has shown high heritability (0.823) suggest that the trait has the capacity to transfer its character at an altitude of 1653 masl. It may also suggest that the environment conditions are favorable for the trait at an altitude of 1653masl. The environment

ability was recorded for most of the morphological trait such as number of branches, number of internodes, node length, petiole length, number of flower per shoot and length of pedicel. The high environmental ability was recorded for number of flower per shoot followed by length of pedicel. These are the morphological traits which are under the control of environment or the traits are more likely to grow at an altitude of 1653 masl. None of the trait has shown its repeatability at an altitude of 1653 masl (Table 20).

The genotypic coefficient of variation and phenotypic coefficient variation was recorded approximately similar for trait plant height. It suggests less effect of growth environment as well as genotype. The high heritable character may be altitudinal (1653 masl). The traits which are not similar in genotypic coefficient variation or environmental coefficient variation are under the influence of climatic factor available at an altitude of 1653 masl which effects the variations in the traits (Table 20).

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 1653 masl of Kohima district and observe 90.27 % cophenetic correlation coefficient among studied quantitative traits. All the quantitative traits suggested goodness of fit with UPGMA cluster with 90.27 % of cophenetic correlation coefficient (CP). Almost all the quantitative traits are merged together into two groups which also indicate that altitude is approximately favorable for all the quantitative traits studied. But altitude is most favoring for the petiole length which grouped together (Fig. 9).

Altitude 2050 masl

The morphological parameters for their mean, standard error, standard deviation and variance were analyzed (Table 21). Maximum mean (17.0 ±1.683) was recorded for number of trees followed by number of anthers (10.0 ±000) and number of branching (9.9±0.586) respectively. The mean value of leaf length (9.363±.284) is approximately close to the mean

value of number of branching. Mean values were recorded at an altitude of 2050 masl of Kohima district. The high mean value indicates the favorable climatic condition and growth of the trees at an altitude of 2050masl. The other parameters were also favored by the altitude 2050 masl but a little less as compare to the number of trees and number of anthers.

The analysis of variance (ANOVA) was performed for the morphological traits and observed that length of pedicel and length of anther showed significance variance (F=2.592 and 2.910) at P ≤ to 0.05) (Table 22). The other parameter also showed significance variance but the probability level was very high.

All the morphological parameter was correlated for their association with each other using bivariate Pearson correlation (2 Tailed). The number of trees was recorded with good association with plant height (0.398*), Length of pedicel (0.634**), length of anther (0.365**), breadth of anther (0.657**), length of carpel (0.619**) and altitude (0.729**) at P≤0.05 and P ≤.01 respectively. The association of number of trees with altitude suggests that altitude have favorable condition for growth and development and found more number of trees. Similarly the climatic factor at an altitude of 2050 favors the growth of flower trait also. Plant height is also correlated with most of the morphological trait such number of branching (0.508**), circumference (0.790**), number of internodes (0.508**), number of node length (0.474**), leaf length (0.483**), petiole length (0.372*), length of pedicel (0.450**) and length of carpel (0.344*) at P≤0.01 and P≤0.05 respectively. Number of branches shown good relation with number of internodes (1.00**) and circumference (0.405) at P≤0.01 and P≤0.05 respectively. The circumference showed correlation with number of inter nodes (0.405*), node length (0.501**), leaf length (0.509**), leaf breadth (0.391*) and petiole length (0.534**) at P≤ 0.05 and P≤0.01 respectively. Node length correlated with leaf length (0.391*) and leaf breadth (0.357*) at P≤0.05. Leaf length correlated with leaf breadth (0.823**), petiole length (0.676**) and length of the petal at P≤0.01 and P≤0.05 respectively. Leaf breadth correlated with petiole

length (0.564**), length of petal (0.385*) and length of stamen (0.347*) at P≤0.05 and P≤0.01. Length of peduncle correlated with number of flower per shoot (0.436*), length of pedicel (0.609**), breadth of petal (584**) and altitude (0.382*) at P≤0.05 and P≤0.01. Number of flower per shoot shown correlation with petal breadth (0.426*) and it is negatively correlated with length of anther (-0.360*) at P≤0.05. Length of pedicel correlated with breadth of the petal (0.795**) and altitude (0.486**) at P ≤0.01. Length of petal has shown correlation with length of stamen (0.400*) at P≤0.05. Length of stamen correlated with length of anther (0.500**) and length of carpel (0.382*) at P≤0.01 and P≤0.05. Length of anther highly correlated with breadth of anther (0.931**), length of carpel (0.807**) and altitude (0.530**) at P≤0.01. Breadth of anther highly correlated with carpel length (0.903**) and altitude (0.575**) at P≤0.01.Length of carpel has shown correlation with altitude (0.454**) at P≤0.01 (Table 23).

The morphological traits length of peduncle, length of pedicel, length of anther, breadth of anther and length of carpel are significantly favored by the altitude 2050 masl of Kohima district.

The morphological data was correlated with each other therefore to observe maximum variation in the morphological data principal combined analysis (PCA) was performed. The principal component of the morphological variation was analysis through a scree plot (Fig. 10). Initially scree plot has provided a maximum of five component matrix to explain the variations available in the morphological traits. The five components of morphological component were reduced to two components to find out the components which compose of maximum variation for the morphogenetic variability. Although we explain variation in morphological traits all the components are required but these two components compose of only 46% variation of the total variability (Table 24).

The morphological traits were analyzed for their variations due to their phenotype, genotype, environmental interaction and the interaction between genotype and environment.

The maximum phenotypic variability was recorded for leaf length (0.874) at an altitude of 2050 masl of Kohima district. The variability due to genotype was not recorded at this altitude. Similarly the variation due to interaction of genotype and environment was also not recorded. The variation due to environment was recorded for petal length. The other morphological parameter also shown variation but this variation was over estimated or very less in their phenotype variability (Table 25).

The morphological traits number of trees (0.819), length of pedicel (0.636) and length of carpel (0.707) show good heritable character at this altitude. The variation in the morphological traits such as number of branches (0.575), node length (0.825), length of peduncle (0.800), number of flowers per shoot (0.927) and petal breadth (0.600) are due to the environmental variations. The repeatability of length of pedicel (0.636) and length of carpel (0.767) were recorded. None of morphological traits were recorded for similar values of genotypic coefficient variation and environmental coefficient variation suggest that all the traits are under the influence of environment and genotype at an altitude of 2050masl (Table 25).

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 2050 masl of Kohima district and observes 9.83 % cophenetic correlation coefficient (CP) among studied quantitative traits. All the quantitative traits suggested badness of fit with UPGMA cluster with 9.83 % of cophenetic correlation coefficient. Almost all the quantitative traits are merged together into two groups and altitude is closer to plant height favorable condition (Fig. 11).

Altitude 2284 masl

The morphological parameters of *Rhododendrons* at an altitude of 2284 masl were statistically described for mean standard error, standard deviation and variance (Table 26). The highest mean was recorded for circumference of the tree (12.271± 11.675) followed by number of anthers (10.015 ± 0.012) and leaf length (9.511 ± 0.133) respectively. The other parameters

were also favored by the altitude 2284 but less as compared to circumference, number of anthers and leaf length. The standard division and the variance among the morphological trait were also recorded.

The analysis of variance (ANOVA) was performed for the morphological traits showed significance variation but the probability level was very high (Table 27).

All the morphological parameters was correlated for the association with each other using bivariate Pearson correlation (2 Tailed) and it was observed that number of trees showed a good and positive correlation with plant height (0.420**), number of branches (0.182**), number of inter node (0.182**), leaf length (0.318**), number of flowers per shoot (0.258**) respectively. The number of trees also showed negative correlation with length of pedicel (-0.274**), length of petal (-0.384**), breadth of petal (-0.355**), length of stamen (-0.416**), length of anther (-0.216**), breadth of anther (-0.336**) and length of carpel (-0.368**) at P≤0.01 respectively (Table 28). Plant height positively correlated with number of branching (.358**), number of inter node (0.358**), node length (0.359**), leaf length (0.230**), length of peduncle (0.131*) and number of flower per shoot (0.329**) at P≤0.01 and P≤0.05 respectively. Plant height negatively associated with length of pedicel (-0.225**), length of petal (-0.345**), breadth of petal (-0.332**), length of stamen (-0.291**), length of anther (-0.250**), breadth of anther (-0.255**), length of carpel (-0.325**) at P≤001 and P≤005. Number of branches highly correlated with number of inter node (1.00**), leaf length .169**) and number of flower per shoot (0.914**) at P≤0.05. Similarly negative correlation has been observed for length of pedicel (-0.247**), length of petal (-0.239**), breadth of petal (-0.226**), length of stamen (-0.167**), breadth of anther (-0.242**) and length of carpel (-0.225**) at p≤0.01 respectively. Circumference is associated with length of peduncle (0.345**) and length of pedicel at (0.134*) P≤0.01 respectively. Number of inter nodes positively correlated with leaf length (0.169**) and number of flowers per shoot (0.194**) at P≤0.01.

Similarly negatively correlation was observed in length of pedicel (-0.247**), length of petal (-0.239**), breadth of petal (-0.226**), length of stamen (-0.167**), breadth of anther (-0.242**), length of carpel (-0.255**) at P≤0.01. Node length is correlated with length of peduncle (0.123*) at P≤0.05. Leaf length correlated with leaf b (0.179**) and number of flower per shoot (0.576**) at P≤0.01. Leaf length also negatively correlated with length of pedicel (-0.499**), length of petal (-0.587**), breadth of petal (-.500**), length of stamen (-.597**), length of anther (-0.271**), breadth of anther (-0.506**) and length of carpel (-0.548**) at P≤0.01 respectively. Leaf length is also correlated with altitude (0.173**) at P≤0.01. Length of peduncle showed association with length of pedicel (0.229**) at P≤0.01. Length of peduncle is also associated with altitude (0.135*) at P≤0.05. The morphological trait number of flower per shoot is negatively correlated with length of pedicel (-0.645**), length of petal (-0.783**), breadth of petal (-0.768**) length of stamen (-738**), length of anther (-0.445**), breadth of anther (-0.693**) and length of carpel (-0.719**) at P≤0.01 respectively. The number of flower per shoot is also correlated with altitude (0.412*) at P 0.05. Length of pedicel shows association with length of petal (0.720**), breadth of petal (0.661**), length of stamen (0.646**), length of anther (0.378**), breadth of anther (0.604**) and length of carpel (0.622**) at P 0.01. Length of petal is associated with breadth of the petal (0.881**), length of stamen (0.865**), length of anther (0.502**), breadth of anther (0.768**) and length of carpel (0.862**) at P≤0.01.Length of petal negatively associated with the altitude (-0.155*) at P≤0.05. Breadth of petal associated with length of stamen (0.802**), length of anther (0.531**), breadth of anther (0.769**) and length of carpel (0.792**) at P≤0.01. Length of stamen correlated with length of anther (0.499**), breadth of anther (0.770**) and length of carpel (0.870**) at P≤0.01. Length of stamen is negatively correlated with the altitude (-0.187*) at P≤0.05. Length of anther is correlated with breadth of anther (0.563**) and length of carpel (0.491**) at P≤0.01. Length of anther negatively associated with altitude (-0.136*) at P≤0.05. Breadth of anther correlated with

length of carpel (0.767**) at P≤0.01 (Table 28). The altitude 2284 masl of Kohima district has suggested a mixed response against the association of morphological traits with each other. Some of the morphological traits are associated in a good way at this altitude for their growth and development but on the other side same morphological traits or others also negatively associated with this altitude which affects the overall growth of the *Rhododendron* species. The traits which are positively associated with the altitude for their growth and development are leaf length, length of peduncle, number of per shoot, but on the other hand the traits which are negatively associated with the altitude are length of the petal, length of the stamen and length of the anther respectively. The morphological trait length of the stamen and length of the anther are the two important traits which are involve in the fertilization and gives new progeny but negative effect of the altitude may interfere in the fertilization and may affect the protection of new seed or progenies in the *Rhododendron*.

The morphological data was correlated with each other positively or negatively therefore to observe maximum variation in the morphological trait principal component analysis (PCA) was performed to observe the principal component of the variation. A screed plot was analysis which provided a maximum of five component matrix to explain the total variation available in the morphological traits (Fig. 12). On the basis of the screed plot showing maximum variation between the components reduced to two component matrix to explain the total variation available in the morphological traits. Both the components explain only 46% of the total variation available in the morphological traits. It may suggest that not only two components are sufficient to explain the variation available in the morphological data. Instead all the five components are necessary to explain complete variation in the morphological traits and the maximum % of variation (35.96) contributed by number of trees recorded. It may be suggested that the total number of trees counted for the purpose played a key role in the total variation for the morphological traits recorded (Table 29).

The morphological traits were analyzed for their variations due to their phenotype genotype environment and the interaction between genotype and environment. The maximum phenotypic variability was observed with length of petals (0.621) followed by length of carpel (0.572) the variability in the morphological trait due to genotype was not recorded. The environmental variation was observed in petal length (0.906) and length of stamen (0.718). A mixed response of variation due to genotype and environment was recorded for plant height (0.516). The other parameters have shown over estimated or very less than 50% variation in their phenotype. Most of the parameter over estimated or under estimated (Table 30).

The morphological parameter was also analyzed for their heritability, environmentability and repeatability. The morphological traits number of flower per shoot, length of petals, breadth of petals and length of anthers has shown heritability with heritable value (0.529), (0.513), (0.504) and (0.750) respectively at an altitude of 2284 masl. The environmental condition at an altitude of 2284 masl is more conducive for their growth development and heritability. Most of the morphological traits are under the influence of environmental conditions or enviromentalability at an altitude of 2284 masl of Kohima district. The morphological traits which are under the environmental influence are number of trees, plant height, number of branches, number of internodes, leaf length , length of pedicel, length of stamen, length of carpel. The repeatability of the morphological traits are recorded for plant height (0.731), length of petals (0.979), breadth of petals (0.683), length of stamen (0.807), length of carpel (0.685) and length of anther (0.750) (Table 30).

The genotypic coefficient of variation and phenotypic coefficient variation was recorded approximately similar for the morphological traits breadth of petals, suggest no effect of environment and genotype on this trait. On the other hand rest of the morphological traits is under the effect of environment as they are genotypic coefficient variation or phenotypic coefficient variation is not similar (Table 30).

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 2284 masl of Kohima district and observes 85.60 % cophenetic correlation coefficient (CP) among studied quantitative traits. All the quantitative traits suggested goodness of fit with UPGMA cluster with 85.60 % of cophenetic correlation coefficient. Almost all the quantitative traits are merged together into three groups and altitude is closer to petiole length (Fig. 13).

The maximum phenotypic variation was observed in the trait leaf length (0.930). The trait petal length varied (0.657) due to the variation in the environment. The phenotypic and genotypic coefficient variation (24.467) was recorded similar for the trait plant height which suggests the equal effects of the environment and genotype on the trait. The trait variations were recorded at an altitude of 1653 masl. The total phenotypic variability in the trait leaf length was recorded as 0.874 at an altitude of 2050 masl. The trait petal length variation (0.906) was maximum and due to variation in environment. The trait plant height (0.516) varied due to the interactions of genotype and environment. The phenotypic and genotypic coefficient variation (17.829) was recorded similar for the trait petal breadth which suggests the equal effects of the environment and genotype on the trait at an altitude of 2284 masl.

Morphogenetical variations and diversities of* Rhododendrons *of Kiphire

Altitude 2688 masl

The morphological parameters of Rhododendrons at an altitude of 2688 masl were statistically described for mean, standard error, standard deviation and variance (Table 31). The highest mean was recorded for leaf length (19.3864±0.58143) followed by number of anthers (16.00±0.00), number of flowers per shoots (15.09±0.460) respectively. Variance was recorded for leaf length was high as compared to the number of anther and number of flowers per shoot the high mean value of leaf length also indicates that the environmental conditions at an altitude of 2688 masl is favorable to the phenotypic trait followed by number of anthers and number of

flower per shoot. The others parameters also favored by the altitude 2688 masl but less as compared to leaf length and number of flower per shoots.

The analyses of variance (ANOVA) was performed for the morphological trait and was observed that length of anther, breadth of anther and length of carpel show significance variance (f=2.839,3.119, 2.859) at p≤0.05 respectively (Table 32). The other parameters also show significance variances but the probability level was very high.

All the morphological parameters was correlated for their association with each other using bivariate Pearson correlation (2 Tailed) and it was observed that number of branches showed a good correlation with circumference (0.555**) and number of internodes (0.993**) and length of pedicel (0.425*) at p≤0.01 and p≤0.05 respectively. The circumference has shown it correlation with number of internodes (0.549**) at p≤0.01. The number of internodes associated with length of pedicel (0.463*) at p≤0.05. Leaf length was correlated with leaf breadth and petal length at p≤0.01 but on other hand it has shown negative correlation with length of pedicel and altitude at p≤0.05 and 0.01 respectively. Leaf breadth was also correlated with petal length and on similar pattern to leaf length shown negative correlation with length of pedicel and altitude at p≤0.05 and 0.01 respectively. Length of peduncle is also associated with number of flower per shoot (0.739**) at p≤ 0.01. Length of anther was recorded at good correlation with breadth of anther (0.587**) at p≤0.01 (Table 33).

The morphological data or traits was highly correlated with each other therefore to observe maximum variation in the morphological treads variations principal component analysis (PCA) was performed to observe the principal component. A scree test was analyzed in the form of a scree plot (Fig.14). Initially a screed plot has provided a maximum of eight component matrix to explain the total variant available in the morphological trades but for other components it is difficult to explain the variation as it has shown more or less similar type of

variation also the first eight component has shown high values for the variation but later it goes down.

On the basis of a scree plot which was showing maximum variation between the components reduced to two components matrix to explain the total variation available in the morphological traits. Both the components has shown similar variation and explained only 37 % of the total variation available at the morphological traits. It suggest that not only two components is sufficient to explain the variation available in the morphological traits but all the eight components are necessary to explain complete variation in the morphological traits the maximum % of variation (20.945) contributed by number of trees recorded. It may be suggested that the total number of trees counted for the purpose played a key role in the total variation for the morphological traits recorded (Table 34).

The morphological traits were analyzed for their variations due to their phenotype genotype environment interaction and the interaction between genotype and environment. The maximum phenotypic variability was observed with leaf breadth (0.717) followed by number of branches and number of internodes. The other parameter has shown over estimated or very less (less than 50 %) variations in their phenotype. None of the parameter has shown variation in the traits due to its genotypic constituent. Leaf breadth has shown maximum variability approximately 86.2 % due to the environmental interaction. We have not recorded any morphological variation due to the interaction of genotypic and environment. Most of the parameter over estimated or under estimated (Table 35).

The morphological parameters are also analyses for their heritability, environmentalability and repeatability. Leaf length has shown high heritability followed by leaf breadth and circumference. These are the traits which the capacity to transfer its character at an altitude of 2688masl. It may also be suggested that the environmental condition are favorable for the trait at an altitude of 2688 masl. The high environmentalability was recorded for

peduncle length followed by length of petals. These are the traits which are under the control of environment or the traits are more likely to grow at an altitude of 2688 masl. Length of carpel can be selected for its repeatability character followed by length of petals (Table 35).

The genotypic coefficient of variation and phenotypic coefficient of variation was recorded approximately similar for number of branches and number of internodes suggest no effect of environment and genotype on these traits (Table 35).

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 3096 masl of Kiphire district and observes 89.68 % cophenetic correlation coefficient (CP) among studied quantitative traits. All the quantitative traits suggested goodness of fit with UPGMA cluster with 89.68 % of cophenetic correlation coefficient. Almost all the quantitative traits are merged together into four groups and altitude is closer to number of petals which suggest easy growth of petals at this altitude (Fig. 15).

Altitude 3112 masl

The morphological parameters were used for analysis of their mean, standard error, standard deviation and variance (Table 36). The maximum mean for recorded for number of trees at 3112 masl followed by leaf length, number of anthers and number of flower per shoots. The maximum mean for number of trees at 3112 masl indicates that climatic conditions and altitude are favorable for the growth of trees and found more number of trees as compare to the altitude 2688masl. The other mean value for leaf length number of anthers and number of flower per shoot are similar as observe at an altitude 2688 masl and 3112 masl. On the similar patterns the high variations observe for number of trees and leaf length.

The analysis of variance (ANOVA) was done for the morphological traits at node length and length of pedicel shows variation at $p \leq 0.05$ (Table 37). Others parameters also showed good variation but the probability level for the variation was very high.

The morphological parameters correlate for their association with each other. Number of trees showed negative correlation with number of flowers per shoot (-0.339**) and altitude (-0.542**) at p≤0.01. Plant height of trees showed association with number of branches (0.373**) and number of internodes (0.373**) at p≤0.05. Number of branch has shown 100 % correlation with number of internodes at p≤0.01. It also suggests that number of branches may depend on number of internodes. Circumference has shown its association with breadth with the anther (0.429**) at p≤0.01. Leaf length has shown its association with leaf breadth (0.417**) and petiole length (0.280*) at p≤0.01 and at p≤0.05 respectively. Leaf breadth is associated with petiole length (0.614**) and has shown negative correlation with breadth of the petal (-0.283*) at p≤0.01 and p≤0.05 respectively. Petiole length has shown correlation with altitude at p≤0.01. Petiole length may increase when the altitude is increase. Peduncle length also associated with length of petal length of stamen length of anther and length of carpel at p≤0.05 and p≤0.01 respectively. Length of peduncle is an important trait which seems to be related to the reproductive structure of flower at an altitude of 3112 masl. Number of flowers per shoot is negatively correlated with length of the petal and length of stamen at p≤0.05 and p≤0.01. The length of pedicel is associated with breadth of petal at p≤0.05. Length of petal correlated with breadth of petal and length of carpel at p≤0.01. Length of petal has shown direct correlation with the reproduction of flower. Breadth of the petal showed association with length of the carpel at p≤0.05. Length of stamen showed correlation with length of the anther and length of the carpel at p≤0.01 and p≤0.05. It suggests that length of stamen contribute some factor towers length of anther and length of carpel. Length of anther correlated with length of carpel at p≤0.01. Most of the flower structure has shown the correlation with reproduction structure such as stamen and carpel suggest that flower structure contributes towards the growth of stamen and carpel (Table 38).

Morphological traits are correlated with each other as shows some variation within and between the parameters therefore to explain the total variation and the components involve in the variation principal component analysis (PCA) was performed. A scree test was performed to know the component involve in the total variation among the parameters (Fig. 16). Initially it has shown seven components which are involve in the total variation of the parameter out of which total number of trees counted has shown 16 % variation followed by plant height and number of branches. The minimum two component matrix has analysis to observe the most important component involve to explain the variation available in the parameters and we found that number of trees and the important key factor for total variation available in the morphological traits (Table 39).

The morphological traits were analysis for their variation due to phenotype, genotype, environment and interaction of genotype with environment. The maximum phenotypic variation is observed in leaf breadth at an altitude of 3112 masl. The variation due to genotype was observed in the number of flower per shoot which was observed more than 50 % variation among number of flowers per shoot. The variation among the parameters was observed among the circumference which is recorded 60.9 %. A very high variation was observed in the node length and a high variation with node length because of the interaction with the environment. Other parameter variation also recorded which may be over or under estimated and below 50 % variations (Table 40).

The parameters also analyzed for their heritability, environmental and repeatability. The number of trees reported has shown approximately 75 % heritable character. It may suggest that number of trees may increase when the altitude increases. Similarly node length has shown its heritable character at an altitude of 3112 masl. The environmentalability of different parameters recorded and observed that number of internodes, leaf breadth, petiole length, number of flowers per shoot, length of pedicel and breadth of petals are under the control of environment.

None of the parameter has observed for its repeatability character. The other parameters may or over estimated or below 50 % heritable, environment and repeatable character (Table 40).

The genotypic and phenotypic coefficient or variations were recorded similar for length of peduncle at an altitude of 3112 masl (Table 40).

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 3112 masl of Kiphiri district and observes 92.88 % cophenetic correlation coefficient (CP) among studied quantitative traits. All the quantitative traits suggested goodness of fit with UPGMA cluster with 92.88 % of cophinitic correlation coefficient. Almost all the quantitative traits are merged together into four groups and altitude is closer to length of peduncle which suggests easy growth of peduncle length at this altitude (Fig. 17).

Altitude 3430 masl

The different morphological parameter or character collected at an altitude of 3430 masl analyzed for mean standard error, standard deviation and variance (Table 41). The circumference was recorded with highest mean value followed by number of trees. The other morphological parameter has also shown mean range from 0.1 to 14 which are very less as compared to the circumference and no of tress recorded.

Analyses of variance (ANOVA) for recorded for morphological data and it was observed that none of the parameter falls in the range of probability level of 5 % and 1 % (Table 42).

The parameters were correlated with each other for their association and involvement for the growth of the plants. The number of trees recorded at an altitude 3430 masl showed correlation with almost all other morphological parameter such as plant height, leaf length, leaf breadth, petiole length, length of peduncle, number of flowers per shoot, number of petals, length of petal, breadth of petal, number of anther, length of the stamen, breadth of anther and

length of carpel but it has shown negative correlation with the altitude at P≤0.01 (Table 43). The negative correlation may suggest that altitude may not be favorable for the number of trees available at that altitude. Plant height has shown negative correlation with no of branching, number of nodes and altitude at p≤0.01. It means the altitude as well as number of node and number of branching is not favorable for plant height at altitude while some other parameters such as leaf length leaf breadth, petiole length, peduncle length, number of flower per shoot, number of petals, length of petals, breadth of petals, number of anthers, length of stamen, breadth of anther and breadth of carpel showed good correlation at p≤0.01 while node length and length of anther correlated at p≤0.05. Number of branching has shown good association with number of nodes and the altitude but rest of the parameters has shown negative correlation such as leaf length, leaf breadth, petiole length, number of flower per shoot, number of petal, breadth of petal, number of anthers, length of stamen, breadth of anther and length of carpel at p≤0.01 and length of peduncle, length of petal at p≤0.05. Number of nodes showed negative correlation with all other parameter at p≤0.01 except altitude. Node length is positively associated with leaf length and breadth of anther at p ≤0.05 and breadth of anther at p≤05 while it has shown negative correlation with length of pedicel at p≤0.05. Leaf length has shown positive correlation with all other parameter at p ≤0.01 except altitude while it is negatively correlated at p ≤0.01. Similar trend has also observed in the leaf breadth where altitude is negatively correlated while other parameters are positively correlated at p≤0.01and p≤0.05 respectively. Petiole length has the similar trend as leaf length and leaf breadth. Length of peduncle also showed positive correlation with all other parameter while negative for altitude at p≤0.01. Number of flower per shoot also showed the similar trend as length of peduncle. Length of pedicel has shown association with number of petals, breadth of petal and number of anthers at p≤0.01. Number of petal are associated with length of the petal, breadth of the petal, number of anther, length of stamen, breadth of anther and length of carpel at negatively correlated with

altitude at p≤0.01. Length of petal has shown exactly similar pattern to the number of petals. Breadth of anther correlated with number of anther, length of stamen, breadth of anther, length of carpel and negatively correlated with altitude at p≤0.01. Number of anther negatively correlated with anther but showed positive correlation with length of carpel, breadth of anther and length of stamen. Length of stamen positively correlated with breadth of anther, length of carpel and negatively correlated with altitude at p≤0.01. Length of anther correlated with breadth of anther at p≤0.01 while it is correlated with length of carpel and negatively correlated with altitude at p≤0.05. Breadth of anther is positively associated with length of carpel but negatively associated with altitude at p±0.01. Length of carpel is negatively correlated with altitude (Table 43).

The morphological parameter are correlated with each other and associated for development and growth of the plants but the observed maximum amount of a variation among the morphological parameters. The analyses of scree plot and initially it has shown five different components involve in the total variation and the parameters (Fig. 18). Number of trees component analyze 44 % of the total variation available in the total component. The five components analysis was reduced to two component analyses and was observed component one that is number of trees still responsible for total variations available in the morphological parameters (Table 44).

Morphological variation was also reported in the form of variation due the phenotype and genotype, variation due to environment and variation due to environment and genotype interaction. Variation due to phenotype recorded very high in leaf length followed by plant height. The high variation in phenotype may be over estimated because of no data collection at an altitude of 3430masl. Genotypic variation was recorded high in petiole length than petal length. Other parameter also show variation due to genotype but value recorded less than 50 %. Over or under estimated genotypic are recorded which may be the result of data analysis error.

Environmental variation was observed in number of petals. Other parameter also show environmental variation which is less than 50 % or over estimated. None of the parameter has shown correlation variation duo to interaction of phenotypic and environment (Table 45).

Heritability, environmentability and repeatability recorded and it was observed that most of the morphological parameters have shown good heritable character while node length and carpel length are under the influence of environment (Table 45).

The genotypic and phenotypic, coefficient variation was analyzed for the morphological parameter and breadth of anther show equal genotypic and phenotypic coefficient variation which indicate less effect of environment and the trait (Table 45).

UPGMA cluster analysis using the Pearson correlation similarity index was studied for morphogenetic relationship based on selected quantitative traits at an altitude of 3430 masl of Kiphire district and observes 89.14 % cophenetic correlation coefficient (CP) among studied quantitative traits. All the quantitative traits suggested goodness of fit with UPGMA cluster with 89.14 % of cophenetic correlation coefficient. Almost all the quantitative traits are merged together into four groups and altitude is closer to node length which suggests easy growth of node length at this altitude (Fig. 19).

The morphological traits were analyzed for their variations due to their phenotype (V_P), genotype (V_G), environment interaction (V_E) and the interaction between genotype and environment ($V_{G\times E}$). The maximum phenotypic variability was observed in the trait leaf breadth (0.717) followed by number of branches (0.623) and number of internodes (0.608). The trait leaf breadth was recorded the value (0.862) for the variation in the trait and the variability among the trait may be due to the variation in the environment. The variations in both the traits were recorded at an altitude of 2688masl. The maximum phenotypic variation in the trait leaf breadth recorded the value as 0.666 (66.6 %). The variation in the trait number of flowers per peduncle was due to genetic variation and recorded as 0.573. The trait girth variation may be

due to environmental variation and recorded the value 0.609. The trait node length variation was recorded maximum (0.914) which also indicates the maximum interaction of genotype with the environment. The phenotypic and genotypic coefficient variation (7.371) was recorded similar for the trait peduncle length which suggests the equal effect of the environment and genotype on the trait. All the variations recorded for the trait at an altitude of 3112 masl. The traits petiole length (0.979) and petal length (0.928) showed high variation which may be the due to the variation in the genotypes. The variation was observed at an altitude of 3430 masl.

Repeatability (R), Heritability (H^2) and Environmentability (E)

Repeatability permits the estimation of sample size which could be properly used to measure the heritability of the sample size. Heritability may help to design the breeding programs by reducing the Standard Error of work involved in designing the program (Falconer, 1981; Shaw, 1987). Therefore, the preliminary measurement of repeatability of a trait could be satisfactorily used to identify a particular trait for further genetical analysis. Also, repeatability can be used to indicate whether efforts to measure heritability are likely to be worthwhile. The statistical explanation of repeatability and heritability suggests that low repeatability cannot accompany high heritability, unless small sample sizes have resulted in erroneous estimates. The low repeatability puts a ceiling on heritability and results in slow evolution (little change in a phenotype from generation to generation), even if a trait is subject to strong selection. The change in phenotype between generations can be predicted by multiplying the heritability of a trait by the selection differential on that trait. Higher repeatability indicates that repeated measures of the same individual or trait have substantially less variation than measures of different individuals or traits. Higher repeatability may accompany higher heritability, in which case environmental variation is low and most of the genetic variation is additive in nature. The possible reason of repeatability being considerably or significantly higher than heritability could be that environmental variation is high, or that non-additive variance (such as dominance

effects) makes a major contribution to genetic variance. A combination of high repeatability and low heritability could indicate that a trait has been under strong selection in the past and is still closely associated with fitness. The strong past selection would reduce additive genetic variance and increase the role of dominance variance (Mather and Jinks 1971). Repeatability could be low for two reasons because it is computed as a ratio: 1) the numerator can be relatively small, which will occur if all individuals or traits are very similar. The similarity might be attributable to either genetic or environmental effects, but further experimentation would be necessary to understand the relative influence of each effect. 2) A second cause of low repeatability is a relatively large denominator, which is a consequence of environmental influences. All the altitudes of all the three districts favor one or more trait for its repeatability, heritability and environmentability. The high value of repeatability suggests the high heritability of the character, but it has not been observed in most of the traits except the traits such as girth at all altitudes of Wokha district, node length, stamen length and carpel length at 1952 masl of Wokha district. The altitude (1952 masl) may favor the growth of the girth, node length, stamen length and carpel length. It might be concluded that the traits have potential towards high evolutionary trends and could be utilized further in plant breeding programs.

The value of R was over +1 or under –1 or zero 0 estimated for quantitative trait, plant height at all the altitudes for all the three districts except the values 0.55 and 0.73 at altitudes of 1780 masl and 2284 masl of Wokha and Kohima but heritability of the trait was found to be low (0.18 and 0.28) suggesting the higher effect of the environment on this trait. The environmentability of the trait is considerably higher (0.82 and 0.78). Another quantitative trait, number of branches has shown more than 50% values (0.57, 0.57 and 0.58) for the effect of environment (environmentability) on this trait at all the altitudes (1653, 2050 and 2284 masl) of Kohima district. Similarly, less than 50% values (0.42, 0.42 and 0.41) for heritability was recorded for the trait. The repeatability for the trait was overestimated +1 because value

estimated more than unity, otherwise in normal condition it is equal to or less than one. The repeatability was over +1 or under –1 estimated for rest of the two districts (Wokha and Kiphire) at all the altitudes. The heritability of the trait was observed to be quite high (0.96) at 1952 masl altitude but it may be because of the overestimation of the R value (1.45) for Wokha district. In Wokha district, the repeatability (0.87, 0.89 and 0.72) and heritability (0.81, 0.87 and 0.70) of quantitative trait, girth was observed to be very high at all the three altitudes (1780, 1854 and 1952 masl) respectively. The high heritability suggested the maximum changes during evolution in trait, girth from generation to generation. The high heritability also indicates the lesser effect of environment on the trait and low environmentability value. The 3 altitudes of Kiphire (2688, 3112 and 3430 masl) and Kohima (1653, 2050 and 2284 masl) were not found suitable for the trait, girth with negative, zero or overestimated values of R, H^2 and E respectively. The higher and more than 50% heritability (0.96 and 0.56) was recorded for the trait, number of internodes at 1952 and 3430 masl of Wokha and Kiphire but it may be because of the overestimation of the R. It may also be suggested that this trait has been fixed for its high heritability during space and time of evolution. The E was also over or underestimated except the values 0.69, 0.57 and 0.58 at 1952, 3112, 1653 and 2284 masl of Wokha, Kiphire and Kohima respectively. The R and E (0.53 and 0.55) of quantitative trait, node length was recorded more than 50% and high (0.87 and 0.84) at an altitude of 1780 and 1952 masl of Wokha district respectively. It may be suggested that the altitude (1952 masl) is suitable for the growth of the node length. The R of the trait is high (0.85) but the low heritability (0.32) generally increases the E (0.67) which indicates that the trait is in control of environmental condition at an altitude of 3430 masl of Kiphire district. The R (0.54) and E (0.57) estimated more than 50% and low R (0.20) and H^2 (0.17) but high E (0.82) at an altitude of the 1653 and 2050masl of Kohima district respectively. It was observed that the growth of the trait is slow and environment dependent. The trait, leaf length is under the control of environment (E = 0.89)

and also controls the growth (R = 0.16) and heritability (H^2 = 0.10) of the trait at an altitude of the 1952 masl of Wokha district.

On the other hand, the trait leaf length is heritable (H^2 = 0.818) in Kiphire at an altitude of 2688masl but R and E values are not supportive. The heritability of the trait may be the result of overestimation of the R. The trait, leaf breadth showed equal R (0.91) and H^2 (0.91) but low E (0.08) and high E (0.96) and low R (0.10) and H^2 (0.03) at an altitude of 1952 and 3112 masl of Wokha and Kiphire districts respectively. The same trait shows two different results, one is environment favorable and other is unfavorable. Both the traits, leaf length and leaf breadth are influenced by the environment at both the altitudes of both the districts. For the trait, petiole length, both heritability (0.45) and environment (0.45) are equally contributing or having equal effect towards the repeatability (R = 0.56) and growth of the trait in the environmental conditions at an altitude of 1780 masl. On the other hand, high heritability (H^2 = 0.98) contributes towards the high repeatability (R = 0.98) and vice versa of the trait at an altitude of 1952 masl in Wokha district respectively. More than 60% environmental effect (E = 0.75, 0.61) was observed on this trait at an altitude of 2688 and 3112 masl of Kiphire and also more than 50% environmental effect (E = 0.582) was observed on this trait at an altitude of 1653 masl of Kohima district. Since this trait is under the control of environmental conditions of the altitudes, low heritability and repeatability was observed. The trait, peduncle length was also observed under the influences of environmental condition of the altitudes. Approximately, 60–70% environmental influences (E = 0.60, 0.75) were recorded for this trait at an altitude of 1854 and 1952 masl of Wokha and almost 80% environmental influences (E = 0.80) recorded for the trait at an altitude of 2050 masl of Kohima district. The good heritability (H^2 = 0.727) of the trait was observed in Kiphire district at 3430 masl. The length of pedicel is under the control of environmental condition or environment dependent at all the altitudes of all districts. Whereas higher heritability of the trait (0.87) was observed at 1854masl, it is found moderate (0.63) at

2050 masl in Wokha and Kohima districts. The trait, number of flowers per pedicel was supported by the environmental condition (E = 0.92) at an altitude of 2050 masl of Kohima district only. The high repeatability (R = 0.78 and 0.98) of the trait, petal length was observed at 1854masl and 2284 masl in Wokha as well as Kohima districts. The repeatability (R = 0.91, 0.82 and 0.68) of petal breadth was observed at altitudes 1952, 3430 and 2284 masl of all the three districts. The H^2 and R of the stamen length were recorded at the altitudes 1854 and 1952 masl of Wokha district and 3430 masl of Kiphire district. The R of the trait was high (0.80) at 2284 masl of Kohima district. The R and H^2 of the carpel length were supported at the altitudes 1854 and 1952 masl of Wokha, 2688masl of Kiphire and 2050 masl of Kohima districts.

Altitudinal diversity and density of **Rhododendrons**

The density of *Rhododendron* species were recorded from all the altitudes of three district of Nagaland. The density may be defined as the number of trees per unit area or number of tree per meter square or the number of trees per hectare. In our experiment I have used quadrate method 50x50 meter square to count the number of trees and converted the values into hectare. At all the altitudes only 4 species of *Rhododendron* were recorded. *Rhododendron arboreum* was commonly available in all the altitudes of all the districts. *Rhododendron formosum* and *Rhododendron macabeanum* was common in all the altitudes of Kiphire District. *Rhododendron formosum* was also counted from the highest altitude (2284 masl) of Kohima District. *Rhododendron triflorum* is the only species which is recorded at the highest altitude (3430 masl) of Kiphire district. The density of *Rhododendron macabeanum* which is restricted to the Kiphire district was 62 trees per hectare for all the altitudes in Kiphire district. The density of *Rhododendron triflorum* was observed 6.75 (~7) trees per hectare at 3430 masl of Kiphire district. 26.25 (~26) trees per hectare were recorded for *Rhododendron formosum* which is restricted to the highest altitude of Kiphire and Kohima district. Since *Rhododedron arboreum* is common to all altitudes of all the district was recorded highest density of trees per

hectare. The altitude wise density of all the four *Rhododendron* species were recorded and found all the altitudes of Kiphire districts and higher altitude of Kohima district indicated 65 trees per hectare (Table 46).

Altitudinal diversity of Rhododendrons was estimated through Simpson and Shannon indexes based on morphogenetical traits and suggested 100% diversity (Shannon index) of *Rhododendron* species at all the three altitudes of Kiphire district as all the 4 species was collected from the same altitudes (Table 47 and Fig. 20).

Rhododendron (species wise) diversity through the Simpson and Shannon indexes suggested that *Rhododendron arboreum* well distributed at all the altitude of 3 districts and therefore, more diverse (Table 48).

Two way cluster analysis (Euclidean pair) between altitude and *Rhododendron* species suggest altitudes of Wokha and Kohima are more or less similar and in one group, but altitudes of Kiphire in another group. It may be because of Kiphire altitudes are more favorable for *Rhododendron* species, where all the four species of *Rhododendron* collected which makes more diverse than other altitudes. On the other hand, only 1 or 2 species are favored by the altitudes of Wokha and Kohima. Similarly, *R. arboreum* and *R. macabeanum* diversed from each other and makes two separates group while *R.formosum* and *R.trifolium* are in the same group and shows more or less similar traits (Fig. 21).

Principal component analysis (biplot) between altitudes and *Rhododendron* species suggest that most of the species are favored and distributed at altitudes of Kiphire and Kohima (Fig. 22).

Other species of *Rhododendron* located on the site which was not a part of this study or which does not fall under the area of 50×50 square meters quadrate size i.e. *R. elliotii* (red in colour and observed very few in number e.g. 9-10 trees as compared to the other species) and *R.*

dalhousiae (it is not confirmed that it is the same species or other which is white in colour with bell shaped corolla and very less in number e.g. 2-3 trees as compared to other species).

Rhododendron species which covered in our study in 50×50 m^2 area are presented in fig. 23-26.

In recent years, some studies of genetic variation along elevation gradients have been performed because topographical heterogeneity of alpine plants' habitat causes substantial changes in environmental conditions (Ohsawa and Ide, 2008; Byars *et al*., 2009; Thiel-Egenter *et al*., 2009). A strong isolation of populations at different altitudes may be observed because of mountain barriers and drastic differences in phenology between lower and higher elevations, which restricts the gene flow and leads to genetic differentiation (Runions and Geber, 2000; Arnaud-Haond *et al*., 2006). As a result, patterns of genetic variation along altitudinal gradients are complex and varied (Ohkawa *et al*., 2006; Jump *et al*., 2006; Kandedmir *et al*., 2004; Byars *et al*., 2009). The variability of specific species on mountains is significant when assessing the distribution, evolution and adaptive ability, and providing indicators of conservation strategies of alpine plants (Yan *et al*., 2009; Jump *et al*., 2006; Truong *et al*., 2007). The rich geographic variation on the mountain provides ideal niches for studying relationships between genetic variation of plant species and variations in altitude.

A voluminous work has been done on the quantitative morphogenetic traits and to identify a stable character to be utilized in plant breeding programs for the enhancement of the particular trait as well whole plant (Abebe *et al*., 2009; Ayalew *et al*.,2011;Hadado *et al*., 2010; Jalata *et al*., 2011; Mekonen *et al*., 2015). At present, the work of the morphogenetic diversity of the Rhododendrons of Nagaland, was found similar to work recorded earlier by other authors in different crops, legumes, spices, plants and trees (Alelign *et al*., 2007; Espinosa and Cabrera, 2011; Pogorzelec *et al*., 2014; Earl and VonHoldt, 2012; Wroblewska, 2013; Sochor *et al*., 2013).

Morphogenetic traits are complex traits and highly influenced by many genetic factors as well as environmental factors. A direct selection of any trait for plant breeding program may be misleading. The successful selection of any trait depends on the information gathered through genetic variability and association of morpho-agronomic traits. Therefore, at the selected altitudes, environmental conditions are favored by *Rhododendron* species. The *Rhododendron* species could be selected from the altitude which is best suited to them for their whole growth and development as well as their traits which may be utilized for further analysis.

The decrease in *Rhododendron* population diversity may be the anthropogenic activity and the disturbances at the basic stage of the propagation of the seedling and in order to effective implementation of protective measures to preserve the diversity of *Rhododendron* require at the imitate basis. At present only a small number of *Rhododendron* populations which remains isolated and differentiation among them in small quantity. The preventive measure should start at large scale for the existing diversity of *Rhododendron*.

The activities should undertake as early as possible because there is a constant decrease in number and no new individuals in the population. The conservation also must try in-situ and ex-situ. Reintroduction and strengthening the population should be grown in laboratory from the seeds collected in the natural habitats. Vegetative propagation and cultivation through soft and woody cutting collected from the plants and growing in the natural habitats.

Chapter - 4

Summary and Conclusion

Morphogenetical variations and diversities of* Rhododendrons *of Wokha

Altitude 1780 masl

The highest mean was recorded for number of flower per shoot (15.66±1.364), followed by number of anthers (10.00±0.000) and leaf length (9.255±0.245) respectively and indicates favorable condition to trait followed by number of anthers and leaf length. Analysis of variance (ANOVA) for all the morphological traits is significantly varied at more than 5 % and 1 % probability level. Number of trees showed a good correlation with altitude (0.908*), Leaf breadth with petal length (0.720*), and length of peduncle with number of flower per shoot (0.745*) at P≤0.05 respectively, length of petal correlated with breadth of petal (0.834**), and number of branches 100% correlated with number of nodes (1.000**) at P≤0.01 respectively. PCA components have shown only 50 % of the total variations available in the morphological traits. The maximum phenotypic variability was observed in the plant height (0.834), genotypic variability observed in leaf length (0.672) while the variation due to interaction of genotypic and environment observed in leaf length (0.712). The traits circumference (0.816), leaf length (0.655), petiole length (0.549) showed heritable character. The trait plant height (0.819), node length (0.554), length of pedicel (0.529), and length of carpel (0.915) are under the influence of environment. The repeatability for the trait circumference (0.875), node length (0.538) and petiole length (0.568) were recorded. The genotypic coefficient variation and phenotypic coefficient variation suggested that all the morphological traits are under the influence of

environment. UPGMA cluster analysis index observes 84.44 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Altitude 1854 masl

The highest mean was recorded for number of flower per shoot (11.00±0.892) followed by leaf length (10.778±441) and number of anthers (10.087± 0.06) respectively. The analysis of variance (ANOVA) for length of pedicel, length of petal, length of stamen and length of carpel showed significant variation (F=5.874, 4.712, 5.379, 4.695) at P ≤ 0.05 respectively. Number of trees correlated with height of the tree (0.938**), number of branching showed 100% correlation with number of nodes (1.00**) , and circumference associated with leaf length (0.840**) at P ≤0.01 respectively. Length of petal associated with breadth of petal (0.775*) at P ≤0.05. PCA components explain only 39 % of the total variation available in the morphological trait. Variation due to environment was recorded in the leaf breadth (0.956). Plant height (0.640), circumference (0.872), length of pedicel (0.875), length of petals (0.780), length of stamen (0.818) and length of carpel (0.787) showed heritability of the traits. Environmentability for length of peduncle (0.600), number of flowers per shoot (0.671) and breadth of petals (0.800). Repeatability was recorded for circumference (0.890), length of pedicel (0.875), length of petals (0.780), length of stamen (0.818) and length of carpel (0.818) respectively. PCV and GCV for the traits were not similar and suggested under the influence of environment and genotype. UPGMA cluster analysis index observes 81.75 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Altitude 1952 masl

The highest mean was recorded for number of flower per shoots (15.022±0.729) followed by leaf length (11.644±0.209) and number of anthers (10.022±0.022) respectively. Analysis of variance (ANOVA) for all the morphological traits is significantly varied at more than 5 % and 1 % probability level. All the traits are highly correlated with each other except

number of trees and circumference with altitude at P ≤0.01. PCA component has showed only 33 % of the total variation available in the morphological traits. The variation due to environmental interaction was recorded for number of branches, number of internodes and leaf length. Most of the traits were heritable in nature [plant height (0.958), number of branches (0.969), circumference (0.700), number of internodes (0.969), node length (0.840), leaf breadth (0.916), petiole length (0.989), breadth of petal (0.900), length of stamen (0.707) and length of carpel (0.551)]. Traits are under the influence of environment are leaf length (0.898), length of peduncle (0.750), number of flower per shoot (0.648), length of pedicel (0.667) and length of petals (0.542). Repeatability of the traits were recorded for circumference (0.725), node length (0.872), leaf breadth (0.916), petiole length (0.989), breadth of petals (0.916), length of stamen (0.930) and length of carpel (0.586). PCV and GCV for the traits were not similar and suggested under the influence of environment and genotype. UPGMA cluster analysis index observes 86.35 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Morphogenetical variations and diversities of* Rhododendrons *of Kohima

Altitude 1653 masl

The highest mean was recorded for number of flowers per shoot (10.545 ± 0.331) followed by number of anthers (10.0± 000) and leaf length (9.8± 0.311) suggested the altitude is favorable for the growth of the flowers. Analysis of variance (ANOVA) for all the morphological traits is significantly varied at more than 5 % and 1 % probability level. All the traits are highly correlated with each other at P ≤0.01and P≤0.05. PCA components have shown approximately similar percent of variation that is 18.6 and 17.0 available in the morphological traits. Phenotypic variability was observed with leaf length (0.930). No variation due to genotype and interaction of both and repeatability recorded. Plant height has shown high heritability (0.823) suggest that the environment conditions are favorable for the trait. Other

traits are under the influence of environment. PCV and GCV for the trait plant height were similar and suggested no influence of environment indicates highly heritable trait. UPGMA cluster analysis index observes 90.27 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Altitude 2050 masl

Maximum mean (17.0 ±1.683) was recorded for number of trees followed by number of anthers (10.0 ±000) and number of branching (9.9±0.586) respectively indicates the favorable climatic condition and growth of the tree. The analysis of variance (ANOVA) observed that length of pedicel and length of anther showed significance variance [(F=2.592 and 2.910) at P ≤ to 0.05)]. All the traits are highly correlated with each other at P ≤0.01and P≤0.05. PCA components compose of only 46% variation of the total variability. Phenotypic variability was recorded for leaf length (0.874). No variation due to genotype and interaction of both recorded. Variation due to environment was recorded for petal length. The repeatability of length of pedicel (0.636) and length of carpel (0.767) were recorded. PCV and GCV for the traits were not similar and suggested under the influence of environment and genotype. UPGMA cluster analysis index observes 9.83 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Altitude 2284 masl

The highest mean was recorded for circumference (12.271± 11.675) followed by number of anthers (10.015 ± 0.012) and leaf length (9.511 ± 0.133) respectively. Analysis of variance (ANOVA) for all the morphological traits is significantly varied at more than 5% and 1% probability level. All the traits are correlated with each other at P ≤0.01and P≤0.05. PCA components explain only 46 % of the total variation available in the morphological traits. Phenotypic variability was observed with length of petals (0.621) followed by length of carpel (0.572). Variability due to genotype was not recorded. Environmentability observed in petal

length (0.906) and length of stamen (0.718). A mixed response of variation due to genotype and environment was recorded for plant height (0.516). Number of flower per shoot, length of petals, breadth of petals and length of anthers has shown heritability with heritable value (0.529), (0.513), (0.504) and (0.750) respectively. Repeatability of the morphological traits are recorded for plant height (0.731), length of petals (0.979), breadth of petals (0.683), length of stamen (0.807), length of carpel (0.685) and length of anther (0.750). PCV and GCV for the trait breadth of petal were similar and suggested no influence of environment indicates highly heritable trait. UPGMA cluster analysis index observes 85.60 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Morphogenetical variations and diversities of* Rhododendrons *of Kiphire Altitude2688masl

The highest mean was recorded for leaf length (19.3864±0.58143) followed by number of anthers (16.00±0.00), number of flowers per shoots (15.09±0.460) respectively indicates that the environmental conditions are favorable to the phenotypic traits. Analyses of variance (ANOVA) observed length of anther, breadth of anther and length of carpel show significance variance (f=2.839, 3.119, 2.859) at $p \leq 0.05$ respectively. Number of branches showed a good correlation with circumference (0.555**), number of inter nodes (0.993**), length of pedicel (0.425*) at $p \leq 0.01$ and $p \leq 0.05$, circumference with number of inter nodes (0.549**) at $p \leq 0.01$, number of internodes with length of pedicel (0.463*) at $p \leq 0.05$, leaf length with leaf breadth and petal length at $p \leq 0.01$ but on other hand it has shown negative correlation with length of pedicel and altitude at $p \leq 0.05$ and 0.01 respectively, length of peduncle with number of flower per shoot (0.739**) and length of anther with breadth of anther (0.587**) at $p \leq 0.01$ respectively. PCA components explained only 37 % of the total variation available at the morphological traits. Phenotypic variability was observed with leaf breadth (0.717). No variability due to genotype and interaction of both recorded. Variation due to environment was

recorded for leaf breadth. Leaf length has shown high heritability followed by length of carpel, leaf breadth and circumference. The genotypic coefficient of variation and phenotypic coefficient of variation was recorded approximately similar for number of branches and number of internodes suggest no effect of environment and genotype on these traits. UPGMA cluster analysis index observes 89.68 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Altitude 3112 masl

The maximum mean for number of trees followed by leaf length, number of anthers and number of flower per shoots indicates that climatic conditions and altitude are favorable for the growth of trees. Analysis of variance (ANOVA) for traits at node length and length of pedicel shows variation at $p \leq 0.05$. Most of the traits are correlated with each other at $P \leq 0.01$and $P \leq 0.05$. PCA components explain only 29% of the total variation available in the morphological traits. Phenotypic variation is observed in leaf breadth. Number of trees shown approximately 75% heritable character. The genotypic and phenotypic coefficient of variations was recorded similar for length of peduncle. UPGMA cluster analysis index observes 92.88 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

Altitude 3430 masl

The circumference was recorded with highest mean value followed by number of trees. Analysis of variance (ANOVA) for all the morphological traits is significantly varied at more than 5 % and 1 % probability level. Most of the traits are correlated with each other at $P \leq 0.01$and $P \leq 0.05$. PCA component analyses 44% of the total variation available in the total component. Genotypic variation was recorded high in petiole length than petal length. Environmental variation was observed in number of petals. Most of the morphological parameters have shown good heritable character. Carpel lengths are under the influence of environment. PCV and GCV for the trait breadth of anther were similar and suggested no

influence of environment indicates highly heritable trait. UPGMA cluster analysis index observes 89.14 % cophenetic correlation coefficient (C.P.) among studied quantitative traits.

***Altitudinal diversity and density of* Rhododendrons**

At all the altitudes which studied at present distributed 4 species of Rhododendrons such as *Rhododendron arboreum*, *Rhododendron formosum*, *Rhododendron macabeanum*, and *Rhododendron triflorum*. *Rhododendron arboreum* was commonly available in all the altitudes of all the districts. *Rhododendron formosum* and *Rhododendron macabeanum* was common in all the altitudes of Kiphire District. *Rhododendron formosum* was also counted from the highest altitude (2284 masl) of Kohima District. *Rhododendron triflorum* is the only species which is recorded at the highest altitude (3430 masl) of Kiphire district. The density of *Rhododendron macabeanum* which is restricted to the Kiphire district was 62 trees per hectare for all the altitudes in Kiphire district. The density of *Rhododendron triflorum* was observed 6.75 (~7) trees per hectare at 3430 masl of Kiphire district. 26.25 (~26) trees per hectare were recorded for *Rhododendron formosum* which is restricted to the highest altitude of Kiphire and Kohima district. Since *Rhododedron arboreum* is common to all altitudes of all the district was recorded highest density of trees per hectare.

Altitudinal diversity of Rhododendrons based on morphogenetical traits suggested 100% diversity (Shannon index) of *Rhododendron* species at all the 3 altitudes of Kiphire district (as 4 *Rhododendron* species was collected). *Rhododendron* (species wise) diversity suggested that *Rhododendron arboreum* (Shannon index) well distributed at all the altitude of 3 districts and therefore, more diverse.

Two ways cluster analysis (Euclidean pair) between altitude and *Rhododendron* species suggest altitudes of Wokha and Kohima are more or less closer than Kiphire. Similarly, *R. arboreum* and *R. macabeanum* are diversed from each other than *R. formosum* and *R. trifolium*. Altitudes of Kiphire and Kohima are more favorable for the Rhododendron species than Wokha

indicated by Principal component analysis (biplot) between altitudes and *Rhododendron* species.

The purpose of the study was to observe the morphogenetic variability among the Rhododendrons of the different altitudes of the 3 districts of the Nagaland. From the present study, the best associated and heritable traits could be selected for the plant breeding program of the Rhododendrons. The *Rhododendron* species could be selected from the altitude which is best suited to them for their whole growth and development as well as their traits which may be utilized for further analysis. Similarly, a voluminous work has been done on the quantitative morphogenetic traits and to identify a stable character to be utilized in plant breeding programs for the enhancement of the particular trait as well whole plant. But unfortunately the quantitative traits were so complex which suggest a mixed response at all altitudes of 3 districts and difficult to select a particular trait and to recommend for a breeding program in *Rhododendron* as each trait affected by different climatic factors such as pH, light, soil type and soil pH etc. on all altitudes and districts. It needs to be a rigorous and molecular work to define exact trait for breeding program.

Moreover, the three districts populated in the surrounding head quarters of Wokha, Kohima and Kiphire at an approximately altitude of 1314, 1444 and 896 masl respectively (Census, 2011). But, in the present study the altitudes (1780, 1854, 1952; 1653, 2050, 2284; 2688, 3112, 3430 masl respectively) are much higher than populated altitudes of three district and less intervened by the inhabited population and comes under mountains and forest area. Also, there was report that below 1500 masl and above 4500 masl of altitudes *Rhododendron* populations decrease drastically (Bhattacharya, 2011; Singh *et al*., 2003). A decrease in *Rhododendron* populations below 1500 and above 4500 masl of altitude, most probably by intervention of human beings for their livelihood and anthropogenic activity as well as unfavorable climatic conditions for the *Rhododendron* populations.

On the other hand, the decrease in *Rhododendron* population diversity may be the anthropogenic activity (cutting the trees for jhum and terrace cultivation, predation in the jungle for wild fauna and flora, habitation at higher altitudes without proper planning and so on) and the disturbances at the basic stage of the propagation of the seedlings. Today's demand is to preserve and protect the *Rhododendron* diversity at priority basis by implementing effective protective measures. At present only a small number of *Rhododendron* populations which remains isolated. The preventive measure should start at large scale for the existing diversity of Rhododendrons.

Table 1. Mean± S.E., S.D. and Variance calculations of morphogenetic traits of Rhododendrons at an altitude of 1780 masl of Wokha.

Morphological parameters	Mean±S.E.	S.D.	Sample Variance
PH	8.532±0.648	1.945	3.783
NBr	7.666±1.258	3.774	14.250
Circ	0.552±0.111	0.33335	0.111
NoIN	6.666±1.258	3.77492	14.250
NL	0.795±0.168	0.504	0.254
LL	9.255±0.245	0.73673	0.543
LB	2.800±0.062	0.1870	0.035
PtlL	1.611±0.167	0.501	0.251
Alt	1.780±4.170	12.511	156.528
LPdl	0.477±0.040	0.120	0.014
N FPS	15.666±1.364	4.092	16.750
L Pcl	0.855±0.055	0.1666	0.028
NoP	5.000±0.000	0.000	0.000
LoP	4.655±0.123	0.371	0.138
BoP	1.933±0.086	0.259	0.068
NoA	10.000±0.000	0.000	0.000
LoS	2.761±0.103	0.310	0.096
LoA	0.200±0.000	0.000	0.000
BoA	0.100±0.000	0.000	0.000
LoC	4.111±0.135	0.407	0.166

Table 2. Analysis of Variance (ANOVA) calculations of morphogenetic traits of Rhododendrons at an altitude of 1780 masl of Wokha.

		Sum of Squares	Df	Mean Square	F	Sig.
PH	Between Groups	30.087	7	4.298	23.878	.156
	Within Groups	.180	1	.180		
	Total	30.267	8			
Nbr	Between Groups	113.500	7	16.214	32.429	.134
	Within Groups	.500	1	.500		
	Total	114.000	8			
Circ	Between Groups	.851	7	.122	3.232	.405
	Within Groups	.038	1	.038		
	Total	.889	8			
NoIn	Between Groups	113.500	7	16.214	32.429	.134
	Within Groups	.500	1	.500		
	Total	114.000	8			
NL	Between Groups	1.987	7	.284	6.111	.302
	Within Groups	.046	1	.046		
	Total	2.034	8			
LL	Between Groups	3.737	7	.534	.882	.678
	Within Groups	.605	1	.605		
	Total	4.342	8			
LB	Between Groups	.275	7	.039	7.857	.268
	Within Groups	.005	1	.005		
	Total	.280	8			
PtlL	Between Groups	2.004	7	.286	57.254	.101
	Within Groups	.005	1	.005		
	Total	2.009	8			
LPdl	Between Groups	.096	7	.014	.683	.735
	Within Groups	.020	1	.020		
	Total	.116	8			
NFPS	Between Groups	102.000	7	14.571	.455	.818

	Within Groups	32.000	1	32.000		
	Total	134.000	8			

	NT	PH	NBr	Circ	NN	NL	LL	LB	PL	Alt	L Peduncle	NFPS	L Pedcil	N Petal	L Petal	B Petal	L Stamen	L Carpel	N Anther	L Anthr	B Anthr

LPcl	Between Groups	.202	7	.029	1.444	.567
	Within Groups	.020	1	.020		
	Total	.222	8			
NoP	Between Groups	.000	7	.000	.	.
	Within Groups	.000	1	.000		
	Total	.000	8			
LoP	Between Groups	1.022	7	.146	1.825	.517
	Within Groups	.080	1	.080		
	Total	1.102	8			
bOp	Between Groups	.520	7	.074	3.714	.380
	Within Groups	.020	1	.020		
	Total	.540	8			
NoA	Between Groups	.000	7	.000	.	.
	Within Groups	.000	1	.000		
	Total	.000	8			
LoS	Between Groups	.449	7	.064	.200	.939
	Within Groups	.320	1	.320		
	Total	.769	8			
LoA	Between Groups	.000	7	.000	.	.
	Within Groups	.000	1	.000		
	Total	.000	8			
BoA	Between Groups	.000	7	.000	.	.
	Within Groups	.000	1	.000		
	Total	.000	8			
LoC	Between Groups	1.249	7	.178	2.230	.475
	Within Groups	.080	1	.080		
	Total	1.329	8			

NT	1	-.366	.012	-.169	.012		-.477	-.122	-.082	.908*	-.304	-.167	.274	a	-.393	-.509	.530	-.146	a	a	a
PH		1	-.436	.668*	-.436		.068	-.421	-.283	-.568	.462*	.280	-.125	a	.156	.172	.044	-.073	a	a	a
NBr			1	-.389	1.000**		.327	.372	.604	.228	-.597	-.186	.450	a	.300	-.013	-.114	.116	a	a	a
Circ				1	-.389		.002	.462	-.335	-.411	.007	-.461	.049	a	-.296	-.383	-.379	.087	a	a	a
NoIn					1		.327	.372	.604	.228	-.597	-.186	.450	a	.300	-.013	-.114	.116	a	a	a
NL																					
LL							1	.336	.455	-.205	-.436	-.267	.023	a	.595	.244	-.321	.156	a	a	a
LB								1	.147	.032	-.500*	.016	.441	a	.720*	.591	-.237	.639	a	a	a
PtlL									1	.045	-.369	-.059	.276	a	.285	.006	.080	.330	a	a	a
Alt										1	-.442*	-.207	.143	a	-.237	-.401	.432	-.268	a	a	a
LPdl											1	.745*	-.555	a	-.221	.227	.343	-.428	a	a	a
NFPS												1	-.208	a	.302	.588	.599	-.192	a	a	a
LPcll													1	a	.207	-.164	.168	.615	a	a	a
NoPl														a	a	a	a	A	a	a	a
LoPl															1	.834*	-.109	.466	a	a	a
BoP																1	-.122	.315	a	a	a
LoS																	1	-.298	a	a	a
LoC																		1	a	a	a
NoA																			a	a	a
LoA																				1	a
BoA																					1

Table 3. Pearson correlation (2 tailed) for association of morphogenetic traits of Rhododendrons at an altitude of 1780 masl of Wokha.

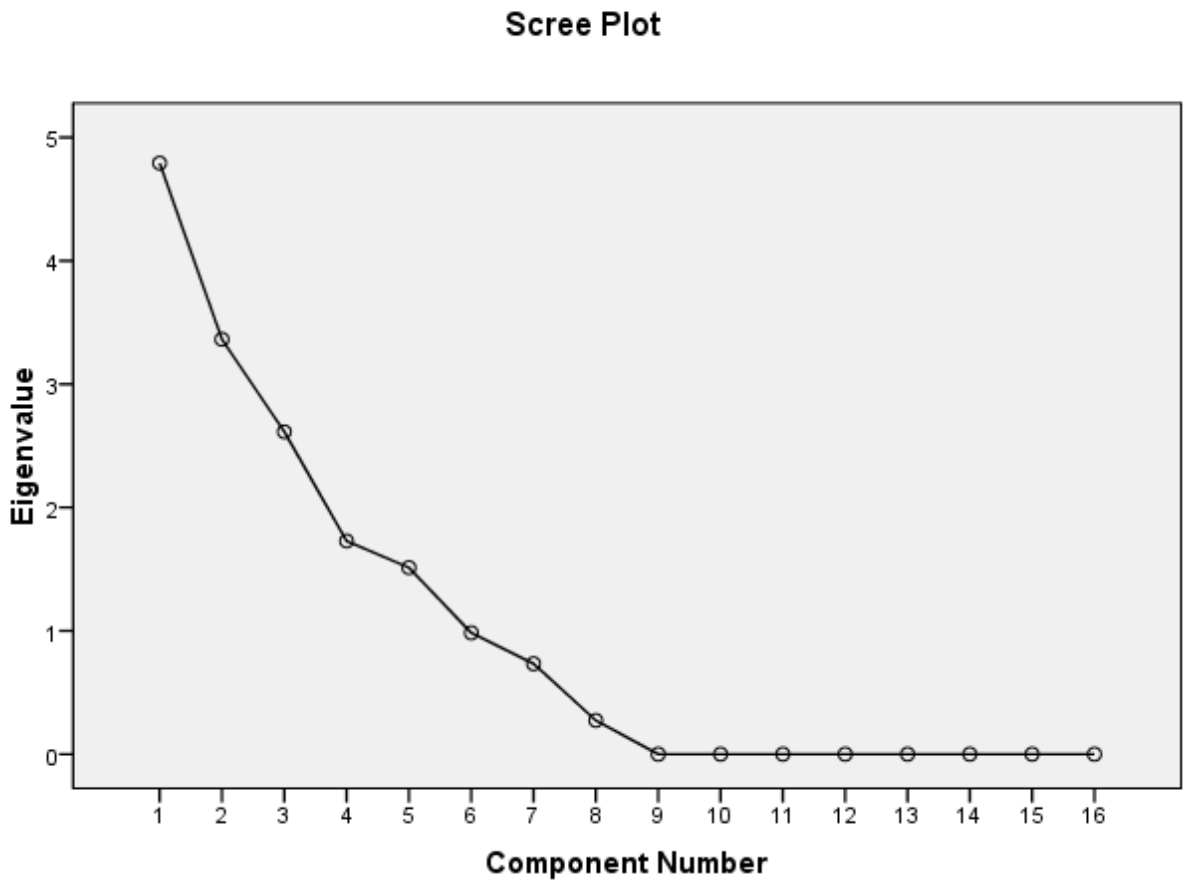


Fig. 2. Scree plot estimation to explain total variations in Rhododendrons at an altitude of 1780 masl of Wokha.

Table 4. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 1780 masl of Wokha.

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.792	29.951	29.951	4.275	26.717	26.717
2	3.363	21.018	50.969	3.880	24.253	50.969
3	2.614	16.338	67.307			
4	1.728	10.800	78.107			
5	1.512	9.451	87.558			
6	.984	6.150	93.708			
7	.733	4.583	98.290			
8	.274	1.710	100.000			
9	3.350E-16	2.094E-15	100.000			
10	2.769E-16	1.731E-15	100.000			
11	2.107E-16	1.317E-15	100.000			
12	1.254E-16	7.840E-16	100.000			
13	1.161E-17	7.259E-17	100.000			
14	-2.208E-16	-1.380E-15	100.000			
15	-2.561E-16	-1.601E-15	100.000			
16	-6.355E-16	-3.972E-15	100.000			

Extraction Method: Principal Component Analysis.

Table 5. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficient) of morphogenetic traits of *Rhododendron* at an altitude of 1780 masl of Wokha.

	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
PH	0.834	0.151	2.051	0.309	0.181	0.819	0.551	0.045	0.107
NBr	4.508	-0.753	15.783	-11.884	-0.167	1.167	-2.803	0.113	0.276
Circ	0.136	0.111	0.076	0.008	0.816	0.184	0.875	0.603	0.668
NoIN	4.444	-0.752	15.589	-11.722	-0.169	1.169	-2.806	0.130	0.316
NL	0.130	0.058	0.218	0.012	0.446	0.554	0.538	0.302	0.453
LL	1.025	0.672	1.061	0.712	0.655	0.345	1.350	0.088	0.109
LB	0.107	-0.002	0.328	-0.000	-0.018	1.018	-0.018	0.015	0.116
PtlL	0.051	0.028	0.071	0.001	0.549	0.451	0.568	0.103	0.140
LPdl	0.008	-0.003	0.035	-0.000	-0.375	1.375	-0.375	0.114	0.187
N FPS	7.365	-1.150	25.545	-29.376	-0.156	1.156	-4.144	0.068	0.173
L Pcl	0.013	0.006	0.021	0.000	0.461	0.539	0.461	0.090	0.133
NoP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LoP	0.072	-0.012	0.254	-0.003	-0.166	1.166	-0.208	0.023	0.057
BoP	6.666	-3.426	10.280	-35.219	-0.513	1.513	-5.797	0.957	1.335
LoS	3.344	-2.625	17.908	-47.008	-0.784	1.784	-14.842	0.586	0.662
LoC	0.070	0.006	0.194	0.001	0.085	0.915	0.100	0.018	0.064

NoA	0.004	-0.006	0.031	-0.000	-1.500	2.500	-1.500	0.007	0.006
LoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

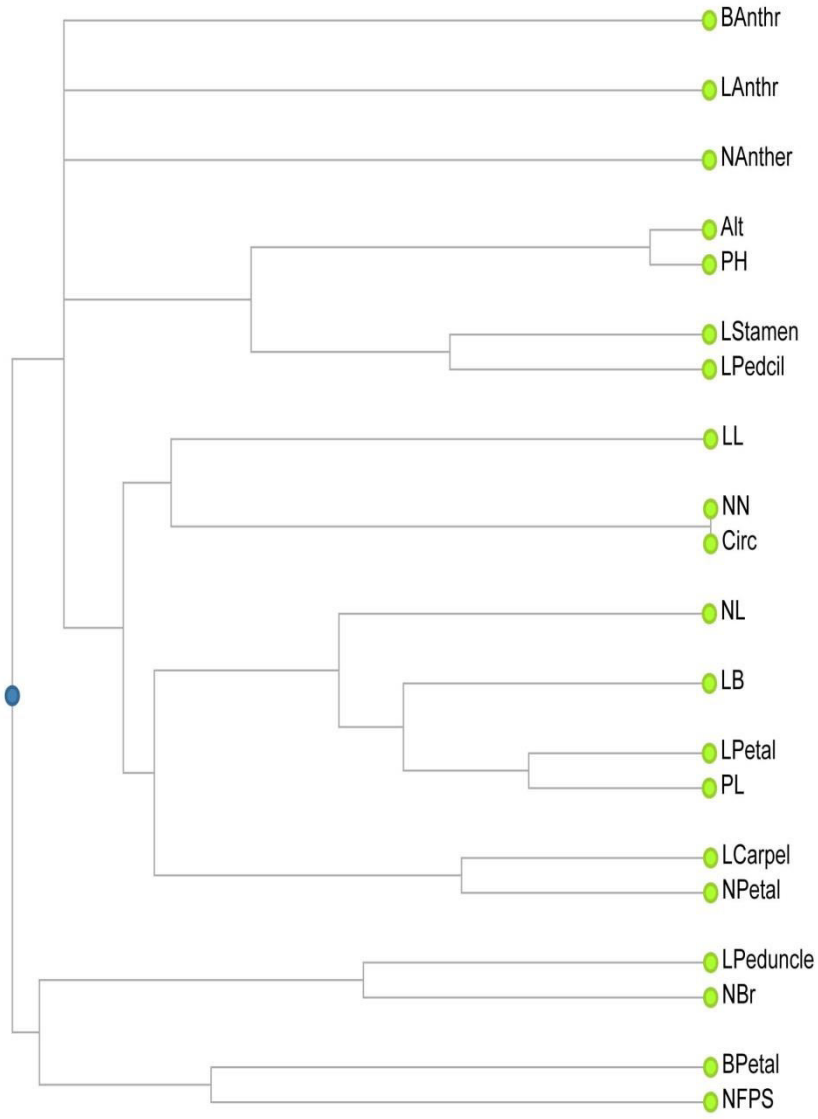


Fig. 3. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 1780 masl of Wokha. (Cophenetic Correlation coefficient (CP) =0.8444).

Table 6. Mean ± S.E, S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 1854 masl of Wokha.

Morphological parameters	Mean±S.E.	S.D.	Sample Variance
PH	6.932±0.742	3.561	12.685
NBr	9.217±0.864	4.144	17.178
Circ	0.673±0.0074	0.355	0.127
NoIN	8.217±0.864	4.144	17.178
NL	0.861±0.107	0.516	0.267
LL	10.778±0.441	2.115	4.476
LB	3.539±0.192	0.923	0.853
PtlL	1.691±0.055	0.266	0.071
Alt	1.854±7.814	37.478	1.405
LPdl	0.469±0.025	0.122	0.015
N FPS	11.000±0.829	3.977	15.818
L Pcl	0.891±0.030	0.144	0.021
NoP	5.000±0.000	0.000	0.000
LoP	4.321±0.065	0.313	0.098
BoP	1.926±0.070	0.337	0.114
NoA	10.087±0.060	0.288	0.083
LoS	2.760±0.066	0.321	0.103
LoA	0.200±0.000	0.000	0.000
BoA	0.100±0.000	0.000	0.000
LoC	4.243±0.082	0.395	0.156

Table 7. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 1854 masl of Wokha.

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	245.890	16	15.368	2.779	.106
	Within Groups	33.180	6	5.530		
	Total	279.069	22			
Nbr	Between Groups	117.413	16	7.338	.169	.998
	Within Groups	260.500	6	43.417		
	Total	377.913	22			
Circ	Between Groups	2.659	16	.166	7.942	.009
	Within Groups	.126	6	.021		
	Total	2.785	22			
NoIn	Between Groups	117.413	16	7.338	.169	.998
	Within Groups	260.500	6	43.417		
	Total	377.913	22			
NL	Between Groups	3.971	16	.248	.784	.677
	Within Groups	1.899	6	.316		
	Total	5.870	22			
LL	Between Groups	62.265	16	3.892	.645	.775
	Within Groups	36.214	6	6.036		
	Total	98.479	22			
LB	Between Groups	13.038	16	.815	.852	.632
	Within Groups	5.737	6	.956		
	Total	18.775	22			
PtlL	Between Groups	.792	16	.049	.387	.939
	Within Groups	.767	6	.128		
	Total	1.558	22			
LPdl	Between Groups	.275	16	.017	1.901	.220
	Within Groups	.054	6	.009		
	Total	.329	22			

NFPS	Between Groups	278.083	16	17.380	1.492	.325
	Within Groups	69.917	6	11.653		
	Total	348.000	22			
LPcl	Between Groups	.431	16	.027	5.874	.019
	Within Groups	.028	6	.005		
	Total	.458	22			
NoP	Between Groups	.000	16	.000	.	.
	Within Groups	.000	6	.000		
	Total	.000	22			
LoP	Between Groups	2.000	16	.125	4.712	.032
	Within Groups	.159	6	.027		
	Total	2.159	22			
bOp	Between Groups	1.930	16	.121	1.261	.411
	Within Groups	.574	6	.096		
	Total	2.504	22			
NoA	Between Groups	.409	16	.026	.108	1.000
	Within Groups	1.417	6	.236		
	Total	1.826	22			
LoS	Between Groups	2.122	16	.133	5.379	.023
	Within Groups	.148	6	.025		
	Total	2.270	22			
LoA	Between Groups	.000	16	.000	.000	1.000
	Within Groups	.000	6	.000		
	Total	.000	22			
BoA	Between Groups	.000	16	.000	.000	1.000
	Within Groups	.000	6	.000		
	Total	.000	22			
LoC	Between Groups	3.182	16	.199	4.695	.033
	Within Groups	.254	6	.042		
	Total	3.437	22			

Table 8. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 1854 masl of Wokha.

	NT	PH	NBr	Circ	N N	NL	LL	LB	PL	L Peduncle	NFPS	L Pedcil	N Petal	L Petal	B Petal	L Stamen	L Carpel	N Anther	L Anthr	B Anthr	Alt
NT	1	.938**	.145	.356*	.145		.233	.160	-.616	.139	-.448	-.177	a	.524	.637	-.377	-.461	A	a	A	.800
PH		1	.405	.433	.405		.289	.218	-.507	-.002	-.446	-.146	a	.343	.429	-.318	-.318	A	a	A	.753
NBr			1	.382	1.000**		.323	.483	.031	-.377	-.411	.214	a	-.243	-.299	.105	.077	A	a	A	-.008
Circ				1	.382		.840**	.463	.136	.471	-.478	.617	a	-.030	.330	-.446	.052	A	a	A	.228
NoIn					1		.323	.483	.031	-.377	-.411	.214	a	-.243	-.299	.105	.077	A	a	A	-.008
NL																					
LL							1	.735	-.074	.672	-.034	.699*	a	.150	.516	-.543	-.243	A	a	A	.343
LB								1	.187	.305	-.011	.332	a	-.076	.285	-.567	-.199	A	a	A	.426
PtlL									1	-.051	.242	-.237	a	-.848**	-.529	-.286	.172	A	a	A	-.397
LPdl										1	.210	.511	a	.354	.713*	-.516	-.501	A	a	A	.242
NFPS											1	-.073	a	.126	.060	-.030	-.302	A	a	A	.008
LPcll												1	a	.192	.187	.142	.127	A	a	A	-.186
NoPl													a	a	a	a	a	A	a	A	A
LoPl														1	.775*	.090	-.578	A	a	A	.420
BoP															1	-.535	-.676	A	a	A	.634
LoS																1	.358	A	a	A	-.572
LoC																	1	A	a	A	-.441
NoA																		A	a	A	A
LoA																			a	A	A
BoA																				A	A
Alt																					1

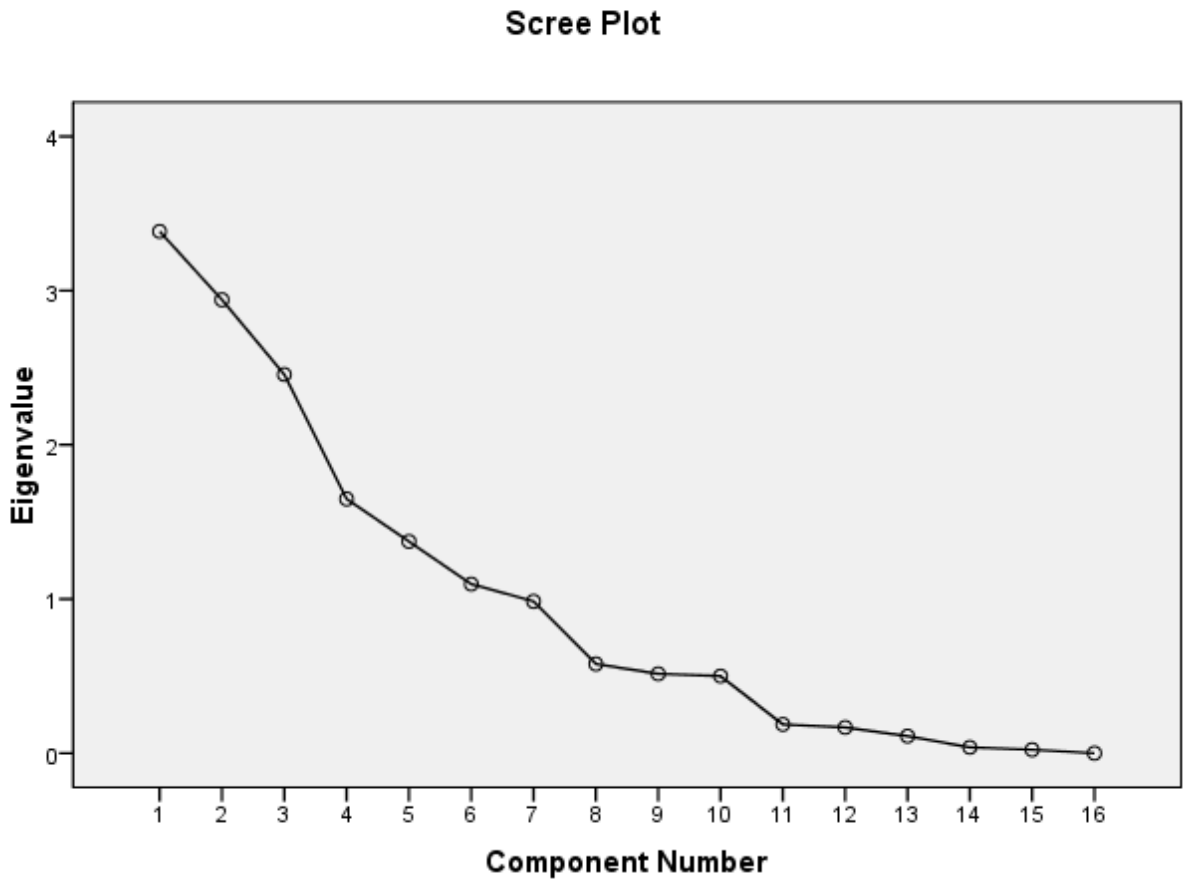


Fig. 4. Scree plot estimation to explain total variations in *Rhododendron* at an altitude of 1854 masl of Wokha.

Table 9. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 1854 masl of Wokha.

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.384	21.150	21.150	3.373	21.082	21.082
2	2.941	18.379	39.528	2.951	18.447	39.528
3	2.456	15.348	54.877			
4	1.649	10.304	65.180			
5	1.373	8.584	73.764			
6	1.096	6.853	80.617			
7	.985	6.153	86.770			
8	.578	3.614	90.384			
9	.514	3.214	93.598			
10	.500	3.126	96.725			
11	.186	1.166	97.890			
12	.167	1.043	98.934			
13	.111	.691	99.625			
14	.038	.235	99.860			
15	.022	.140	100.000			
16	2.329E-16	1.456E-15	100.000			

.Table 10. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 1854 masl of Wokha.

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
PH	5.122	3.279	5.530	18.132	0.640	0.360	4.180	0.261	0.326
NBr	2.446	-12.026	43.417	-522.132	-4.916	5.916	-218.380	0.376	0.169
Circ	0.055	0.048	0.021	0.001	0.872	0.128	0.890	0.325	0.348
NoIN	2.446	-12.026	43.417	-522.132	-4.916	5.916	-218.380	0.376	0.169
NL	0.037	-0.068	0.316	-0.021	-1.837	2.837	-2.405	0.302	0.223
LL	1.298	-0.714	6.036	-4.309	-0.550	1.550	-3.869	0.078	0.105
LB	0.271	-0.047	0.956	-0.044	-0.173	1.173	-0.335	0.061	0.147
PtlL	0.016	-0.026	0.128	-0.003	-1.625	2.625	-1.812	0.095	0.074
LPdl	0.005	0.002	0.009	0.000	0.400	0.600	0.400	0.095	0.150
N FPS	5.793	1.909	11.653	22.245	0.329	0.671	4.169	0.125	0.218
L Pcl	0.008	0.007	0.005	0.000	0.875	0.125	0.875	0.093	0.100
NoP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LoP	0.041	0.032	0.027	0.000	0.780	0.220	0.780	0.041	0.046
BoP	0.040	0.008	0.096	0.000	0.200	0.800	0.200	0.046	0.103
LoS	0.044	0.036	0.025	0.000	0.818	0.182	0.818	0.068	0.076
LoC	0.066	0.052	0.042	0.002	0.787	0.213	0.818	0.053	0.060
NoA	0.008	-0.070	0.236	-0.016	-8.750	9.750	-10.750	0.026	0.008

LoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

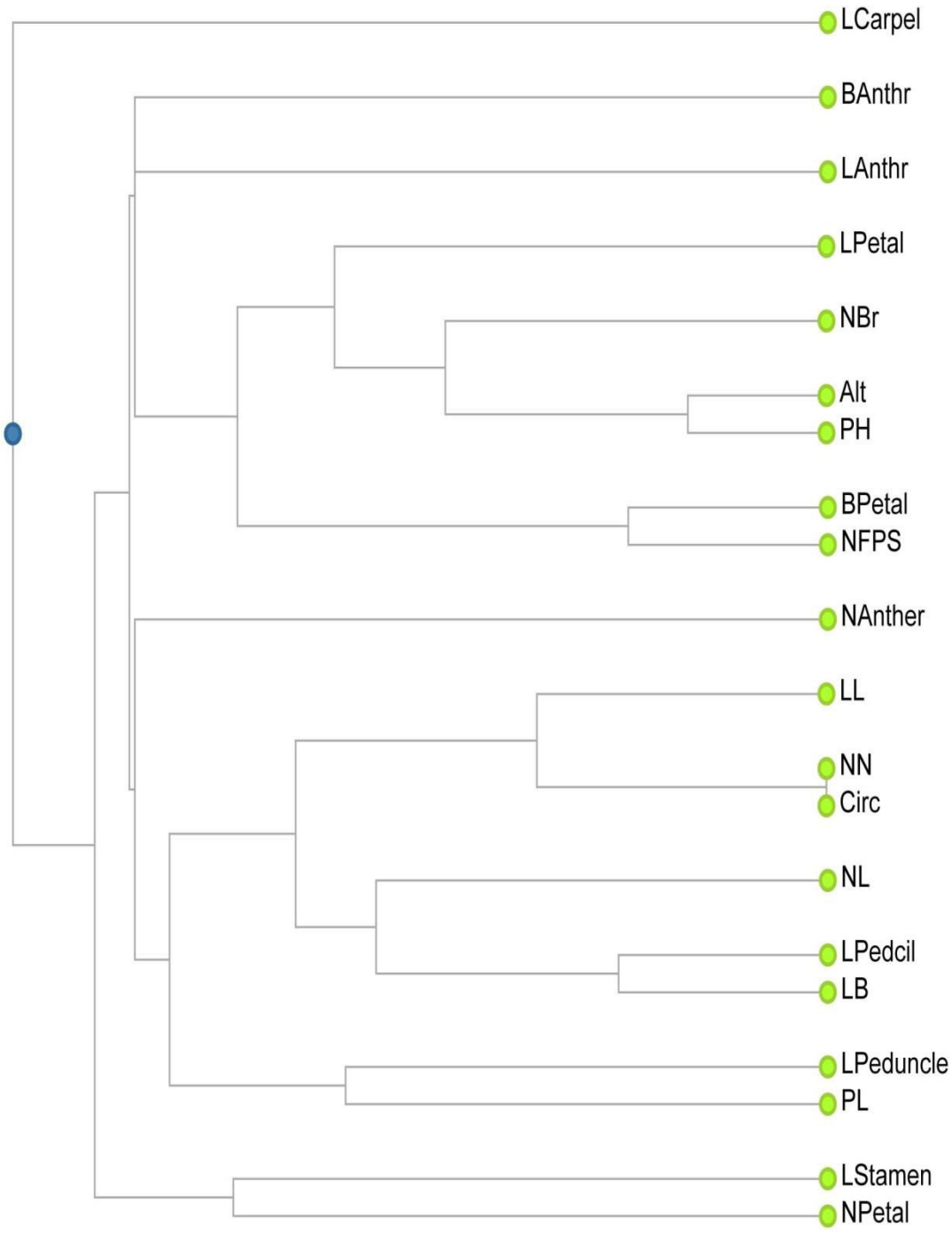


Fig.5. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 1854 masl of Wokha. (Cophenetic Correlation coefficient (CP) =0.81755).

Table 11. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of

Morphological parameters	Mean±S.E.	S.D.	Sample Variance
PH	5.614±0.223	1.502	2.257
NBr	8.511±0.572	3.841	14.756
Circ	0.690±0.071	0.477	0.228
NoIN	7.600±0.568	3.816	14.564
NL	8.787±0.081	0.545	0.298
LL	11.644±0.209	1.406	1.978
LB	3.682±0.084	0.569	0.325
PtlL	1.571±0.049	0.332	0.110
Alt	1.943±1.987	13.332	177.768
LPdl	0.500±0.026	0.175	0.031
N FPS	15.022±0.729	4.896	23.977
L Pcl	0.826±0.025	0.173	0.030
NoP	5.000±0.000	0.000	0.000
LoP	4.364±0.072	0.486	0.236
BoP	2.235±0.429	2.879	8.292
NoA	10.022±0.022	0.149	0.022
LoS	3.275±0.564	3.785	14.328
LoA	0.200±0.001	0.010	0.000
BoA	0.100±0.000	0.000	0.000
LoC	4.240±0.067	0.450	0.203

Rhododendron at an altitude of 1952 masl of Wokha.

		Sum of Squares	df	Mean Square	F	Sig.

Table 12. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 1952 masl of Wokha.

PH	Between Groups	50.089	20	2.504	1.221	.317
	Within Groups	49.226	24	2.051		
	Total	99.314	44			
Nbr	Between Groups	270.444	20	13.522	.857	.634
	Within Groups	378.800	24	15.783		
	Total	649.244	44			
Circ	Between Groups	8.212	20	.411	5.426	.000
	Within Groups	1.816	24	.076		
	Total	10.028	44			
NoIn	Between Groups	266.667	20	13.333	.855	.636
	Within Groups	374.133	24	15.589		
	Total	640.800	44			
NL	Between Groups	7.868	20	.393	1.801	.085
	Within Groups	5.241	24	.218		
	Total	13.109	44			
LL	Between Groups	61.559	20	3.078	2.900	.007
	Within Groups	25.472	24	1.061		
	Total	87.031	44			
LB	Between Groups	6.419	20	.321	.979	.514
	Within Groups	7.866	24	.328		
	Total	14.286	44			
PtlL	Between Groups	3.139	20	.157	2.198	.034
	Within Groups	1.714	24	.071		
	Total	4.852	44			
LPdl	Between Groups	.525	20	.026	.755	.736
	Within Groups	.835	24	.035		
	Total	1.360	44			
NFPS	Between Groups	441.894	20	22.095	.865	.626
	Within Groups	613.083	24	25.545		
	Total	1054.978	44			
LPcl	Between Groups	.816	20	.041	1.915	.065
	Within Groups	.512	24	.021		
	Total	1.328	44			

NoP	Between Groups	.000	20	.000	.	.														
	Within Groups	.000	24	.000																
	Total	.000	44																	
LoP	Between Groups	4.316	20	.216	.851	.640														
	Within Groups	6.087	24	.254																
	Total	10.403	44																	
bOp	Between Groups	118.144	20	5.907	.575	.894														
	Within Groups	246.719	24	10.280																
	Total	364.863	44																	
NoA	Between Groups	.228	20	.011	.364	.987														
	Within Groups	.750	24	.031																
	Total	.978	44																	
LoS	Between Groups	200.649	20	10.032	.560	.904														
	Within Groups	429.795	24	17.908																
	Total	630.443	44																	
LoA	Between Groups	.001	20	.000	.400	.979														
	Within Groups	.004	24	.000																
	Total	.005	44																	
BoA	Between Groups	.000	20	.000	.000	1.000														
	Within Groups	.000	24	.000																
	Total	.000	44																	
LoC	Between Groups	4.283	20	.214	1.102	.406														
	Within Groups	4.663	24	.194																
	Total	8.946	44																	

	NT	PH	NBr	Circ	NN	NL	LL	LB	PL	AL	LPedunc	NBS	LPedcil	NPetal	LPetal	BPetal	LStamen	LCarpel	NAnther	LAnthr	BAnthr
NT	1	.479*	.422	.622**	.391*		-.053	.239	.280	-.905	.223	.281	-.321	a	-.061	.199	.099	-.142	a	-.185	A
PH		1	.330	.690**	.281		.103	.122	.355	-.634	.313	.586**	.228	a	.404	.511*	.312	-.055	a	.146	A
NBr			1	.205	.923**		-.062	.044	.305	-.444	.255	.108	-.114	a	.131	.168	-.344	.310	a	.082	A

Table 13. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 1952 masl of Wokha.

Circ				1	.209		.161	.170	.266	.700**	.257	.458*	-.101	a	.207	.335	.205	.274	a	-.434	A
NoIn					1		-.036	.032	.371	-.397	.218	.109	-.094	a	.140	.034	-.270	.357	a	-.186	A
NL																					
LL							1	.760**	.516*	.064	.020	.229	.002	a	.000	.061	-.382	.067	a	-.076	A
LB								1	.355	-.129	.077	.346	.155	a	-.192	-.062	-.333	-.221	a	-.072	A
PtlL									1	-.185	-.023	.100	-.152	a	.198	-.009	-.249	.146	a	-.089	A
Alt										1	-.311	-.360	.481*	a	-.058	-.324	-.192	.013	a	.257	A
LPdl											1	.448*	-.017	a	.449*	.601**	-.137	.366	a	-.265	A
NFPS												1	-.034	a	.417	.552**	.256	.245	a	-.236	A
LPcll													1	a	-.143	-.241	-.076	.060	a	-.091	A
NoPl														a	a	a	a	A	a	a	A
LoPl															1	.681**	.342	.465*	a	.083	A
BoP																1	.216	.185	a	.222	A
LoS																	1	-.059	a	-.071	A
LoC																		1	a	-.266	A
NoA																			a	a	A
LoA																				1	A
BoA																					1

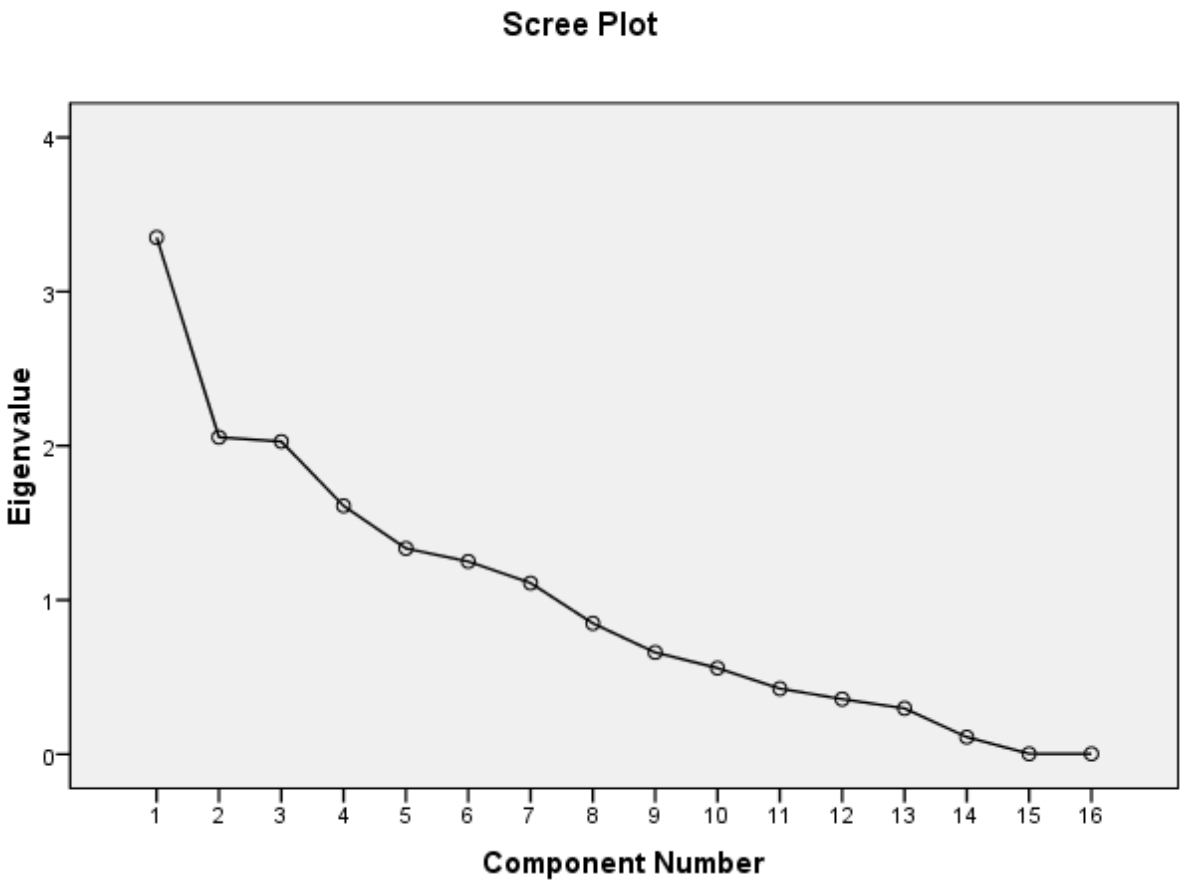


Fig. 6. Scree plot estimation to explain total variation in *Rhododendro*n at an altitude of 1952 masl of Wokha.

Table 14. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 1952 masl of Wokha.

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.351	20.944	20.944	2.707	16.916	16.916
2	2.056	12.848	33.792	2.700	16.876	33.792
3	2.028	12.677	46.469			
4	1.610	10.066	56.534			
5	1.334	8.340	64.874			
6	1.250	7.811	72.685			
7	1.110	6.938	79.623			
8	.848	5.303	84.925			
9	.660	4.124	89.049			
10	.558	3.489	92.538			
11	.425	2.656	95.194			
12	.357	2.232	97.426			
13	.297	1.856	99.282			
14	.110	.690	99.972			
15	.003	.017	99.989			
16	.002	.011	100.000			

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
	2.056	12.848		33.792	2.700		16.876		33.792

Table 15. Phenotypic and Genotypic variance components (Heritability, Environmrntability, Repeatability, Genotypic and Phenotypic Coefficient) of morphogenetic traits of *Rhododendron* at an altitude of 1952 masl of Wokha.

PH	1.432	1.372	0.180	0.246	0.958	0.042	1.129	0.208	0.213
NBr	5.404	5.238	0.500	2.619	0.969	0.031	1.453	0.268	0.273
Circ	0.040	0.028	0.038	0.001	0.700	0.300	0.725	0.242	0.289
NoIN	5.404	5.238	0.500	2.619	0.969	0.031	1.453	0.301	0.305
NL	0.094	0.079	0.046	0.003	0.840	0.160	0.872	0.031	0.034
LL	-0.224	-0.023	0.605	-0.013	0.102	0.898	0.160	0.013	0.040
LB	0.012	0.011	0.005	0.000	0.916	0.084	0.916	0.028	0.029
PtlL	0.094	0.093	0.005	0.000	0.989	0.011	0.989	0.194	0.195
LPdl	-0.008	-0.002	0.020	-0.000	0.250	0.750	0.250	0.089	0.178
N FPS	-16.475	-5.809	32.000	-185.888	0.352	0.648	11.635	0.160	0.270
L Pcl	0.009	0.003	0.020	0.000	0.333	0.667	0.333	0.066	0.114
NoP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LoP	0.048	0.022	0.080	0.001	0.458	0.542	0.383	0.033	0.050
BoP	0.060	0.054	0.020	0.001	0.900	0.100	0.916	0.103	0.109
LoS	-0.362	-0.256	0.320	-0.081	0.707	0.293	0.930	0.154	0.183
LoC	0.058	0.032	0.080	0.002	0.551	0.449	0.586	0.042	0.056
NoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

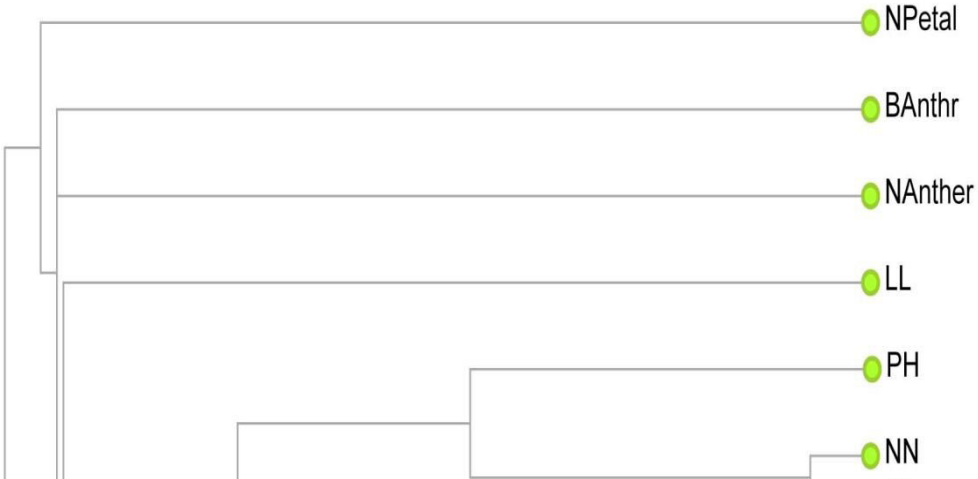


Fig. 7. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 1952 masl of Wokha. (Cophenetic Correlation coefficient (CP) = 0.863511).

Table 16. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 1653 masl of Kohima.

Morphological parameters	N	Mean		Std. Deviation	Variance
	Statistic	Statistic	Std. Error	Statistic	Statistic
NT	33	17.0000	1.68325	9.66954	93.500

PH	33	6.5190	.41613	2.39048	5.714
NBr	33	8.9091	.42051	2.41562	5.835
Circ	33	.6253	.04290	.24646	.061
NoIn	33	7.9091	.42051	2.41562	5.835
NL	33	.8738	.10782	.61936	.384
LL	33	9.8000	.31152	1.78955	3.203
LB	33	3.3545	.10863	.62404	.389
PtlLL	33	1.7030	.07455	.42828	.183
LPdl	33	.4545	.02045	.11750	.014
NFPS	33	10.5455	.33169	1.90543	3.631
LPcl	33	.7212	.02529	.14525	.021
NoP	33	5.0000	.00000	.00000	.000
LoP	33	3.9030	.07223	.41494	.172
BoP	33	1.5848	.02428	.13947	.019
NoA	33	10.0000	.00000	.00000	.000
LoS	33	2.2455	.05128	.29458	.087
LoA	33	.2348	.00799	.04590	.002
BoA	33	.1045	.00254	.01460	.000
LoC	33	3.8000	.05401	.31024	.096
ALt	33	1.6534E3	1.36849	7.86137	61.801
Valid N (listwise)	33				

Table 17. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 1653 masl of Kohima.

Morphological parameters		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	160.824	18	8.935	5.676	.001
	Within Groups	22.036	14	1.574		
	Total	182.861	32			
Nbr	Between Groups	128.894	18	7.161	1.733	.150
	Within Groups	57.833	14	4.131		

	Total	186.727	32			
Circ	Between Groups	1.056	18	.059	.925	.569
	Within Groups	.888	14	.063		
	Total	1.944	32			
NoIn	Between Groups	128.894	18	7.161	1.733	.150
	Within Groups	57.833	14	4.131		
	Total	186.727	32			
NL	Between Groups	8.494	18	.472	1.747	.147
	Within Groups	3.782	14	.270		
	Total	12.276	32			
LL	Between Groups	50.218	18	2.790	.747	.723
	Within Groups	52.262	14	3.733		
	Total	102.480	32			
LB	Between Groups	6.238	18	.347	.780	.695
	Within Groups	6.223	14	.445		
	Total	12.462	32			
PtlL	Between Groups	4.056	18	.225	1.740	.149
	Within Groups	1.813	14	.130		
	Total	5.870	32			
LPdl	Between Groups	.187	18	.010	.570	.870
	Within Groups	.255	14	.018		
	Total	.442	32			
NFPS	Between Groups	64.515	18	3.584	.971	.531
	Within Groups	51.667	14	3.690		
	Total	116.182	32			
LPcl	Between Groups	.440	18	.024	1.457	.240
	Within Groups	.235	14	.017		
	Total	.675	32			
NoP	Between Groups	.000	18	.000	.	.
	Within Groups	.000	14	.000		
	Total	.000	32			
LoP	Between Groups	2.725	18	.151	.761	.711
	Within Groups	2.785	14	.199		

	Total	5.510	32			
bOp	Between Groups	.287	18	.016	.667	.793
	Within Groups	.335	14	.024		
	Total	.622	32			
NoA	Between Groups	.000	18	.000	.	.
	Within Groups	.000	14	.000		
	Total	.000	32			
LoS	Between Groups	1.318	18	.073	.702	.763
	Within Groups	1.459	14	.104		
	Total	2.777	32			
LoA	Between Groups	.031	18	.002	.652	.805
	Within Groups	.037	14	.003		
	Total	.067	32			
BoA	Between Groups	.003	18	.000	.813	.665
	Within Groups	.003	14	.000		
	Total	.007	32			
LoC	Between Groups	1.683	18	.094	.937	.559
	Within Groups	1.397	14	.100		
	Total	3.080	32			
	Within Groups	14.511	14	1.036		
	Total	32.000	32			

	NT	PH	NBr	Circ	N Inter Node	NL	LL	LB	PL	L Pedun cle	NFPS	L Ped cil	N Pet al	L Pet al	B Peta l	N Ant her	L Stam en	L Ant her	P Ant hr	L Car pel	Alt
NT	1	.043	.045	.190	.045	.050	.103	.212	.248	.226	.210	.283	a	.227	.120	a	.124	-.074	-.011	.235	.030
PH		1	.373*	.165	.373*	.069	.005	.106	.096	.052	.200	.213	a	.290	.165	a	.122	.152	-.045	.363*	.265
NBr			1	.337	1.000**	.283	.193	.337	.012	-.037	.120	.202	a	.197	.005	a	.074	.199	.056	.200	.007
Circ				1	.337	.036	-.140	-.050	.039	-.090	-.134	-.156	a	.080	-.068	a	-.011	.426*	.099	-.146	.081
NoIn					1	.283	.193	.337	.012	-.037	.120	.202	a	.179	.005	a	.074	.199	.056	.200	.007

NL						1	-.279	-.251	.059	-.001	-.163	-.113	a	-.021	-.055	a	.178	.075	.216	-.172	.038
LL							1	.778**	.313	.012	.131	.482**	a	.129	.078	a	.107	.110	.132	.228	.113
LB								1	.237	-.072	.082	.301	a	.085	.096	a	.134	.133	.109	.239	.284
PtlL									1	-.152	-.132	.004	a	-.139	-.109	a	-.078	.050	.098	-.103	.058
L Pdl										1	.338	.516**	a	.330	.090	a	.129	-.190	.124	.317	.127
NFPS											1	.341	a	.065	-.086	a	-.357*	-.546**	-.260	.116	.228
L Pcll												1	a	.315	.016	a	.411*	.073	.395*	.305	.100
NoPl													a	a	a	a	a	a	A	a	a
LoPl														1	.768**	a	.624**	.372*	-.312	.702**	.026
BoP															1	a	.580**	.109	-.579**	.831**	.023
LoS																a	a	a	A	a	a
LoC																	1	.480**	.150	.494**	.168
NoA																		1	.456**	-.011	.136
LoA																			1	-.414*	.028
BoA																				1	.008
Alt																					1

Table 18. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 1653 masl of Kohima.

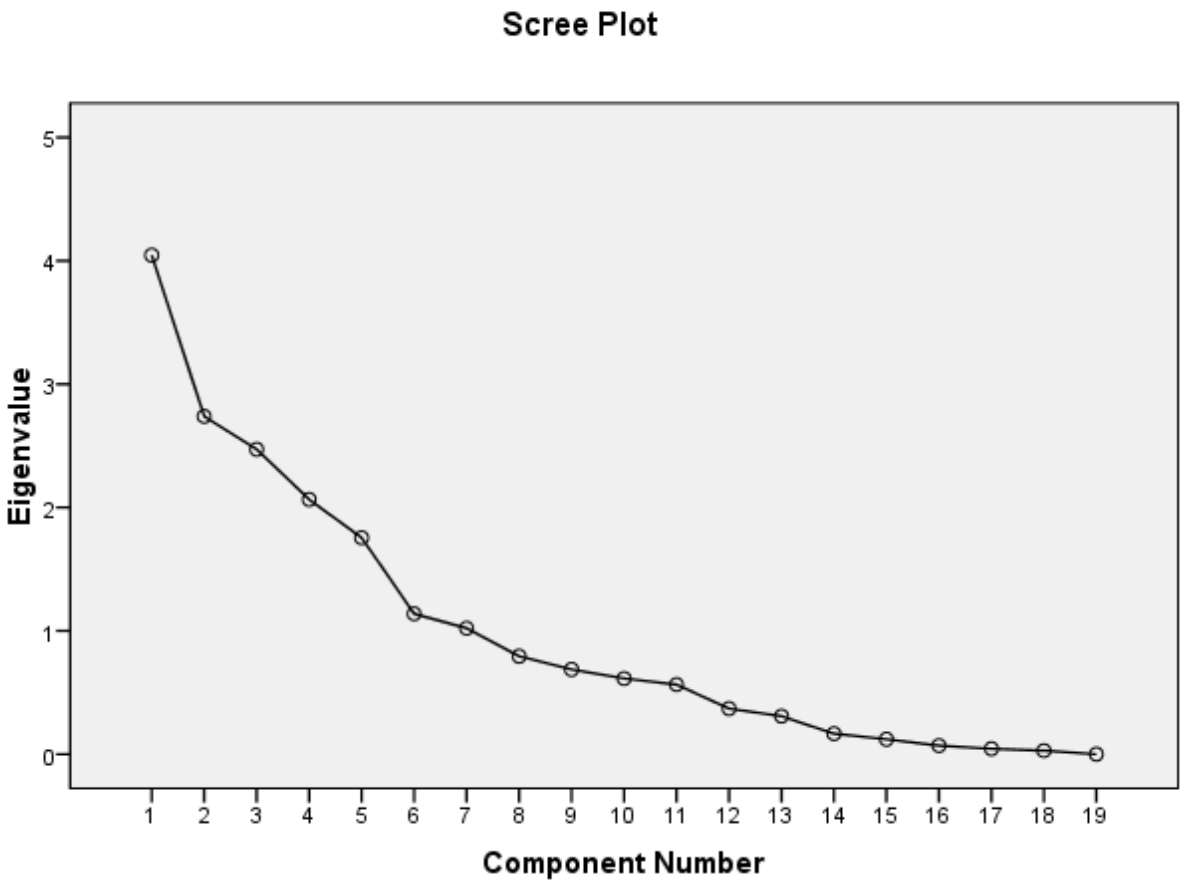


Fig. 8. Scree plot estimation to explain total variation in *Rhododendron* at an altitude of 1653 masl of Kohima.

Table 19. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 1653 masl of Kohima.

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.046	21.292	21.292	3.550	18.685	18.685
2	2.738	14.413	35.705	3.234	17.020	35.705
3	2.471	13.007	48.712			
4	2.065	10.867	59.580			
5	1.755	9.235	68.815			
6	1.138	5.991	74.806			
7	1.021	5.374	80.180			
8	.794	4.179	84.359			
9	.687	3.614	87.973			
10	.614	3.229	91.203			
11	.564	2.970	94.173			
12	.370	1.945	96.118			
13	.308	1.623	97.741			
14	.166	.875	98.615			
15	.121	.637	99.252			
16	.069	.365	99.618			
17	.044	.231	99.849			
18	.029	.151	100.000			
19	-1.520E-16	-8.001E-16	100.000			

Extraction Method: Principal Component Analysis.

PH	21.976	-21.008	128.952	-2709.023	-0.955	1.955	-124.227	26.961	27.575
NBr	2.977	2.453	1.574	3.861	0.823	0.177	2.120	24.025	24.467
Circ	2.387	1.01	4.131	4.172	0.423	0.577	2.170	11.280	17.341
NoIN	0.02	-0.001	0.063	-0.000	-0.050	1.050	-0.050	5.059	0.226
NL	2.387	1.01	4.131	4.172	0.423	0.577	2.170	12.706	19.534
LL	0.157	0.067	0.270	0.018	0.426	0.574	0.541	26.649	45.387
LB	0.930	-0.314	3.733	-1.172	-0.337	1.337	-1.597	5.717	9.840
PtlL	0.116	-0.032	0.445	-0.014	-0.267	1.267	-0.396	5.333	10.154
LPdl	0.074	0.031	0.130	0.004	0.418	0.582	0.301	10.338	15.973
N FPS	0.004	-0.002	0.018	-0.000	-0.500	1.500	-0.500	9.850	13.930
L Pcl	1.195	-0.035	3.690	-0.129	0.029	0.971	-0.137	1.774	10.366
NoP	0.007	0.002	0.017	0.000	0.285	0.715	0.285	6.202	11.604
LoP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoP	0.050	-0.016	0.199	-0.003	-0.320	1.320	-0.380	3.240	5.729
LoS	0.006	-0.002	0.024	-0.000	-0.333	1.333	-0.333	2.823	4.890
LoC	0.024	-0.010	0.104	-0.001	-0.416	1.416	-0.458	4.454	6.900
NoA	0.031	-0.002	0.100	-0.000	-0.064	1.064	-0.064	1.176	4.633
LoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoA	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
PH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 20. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 1653masl of Kohima.

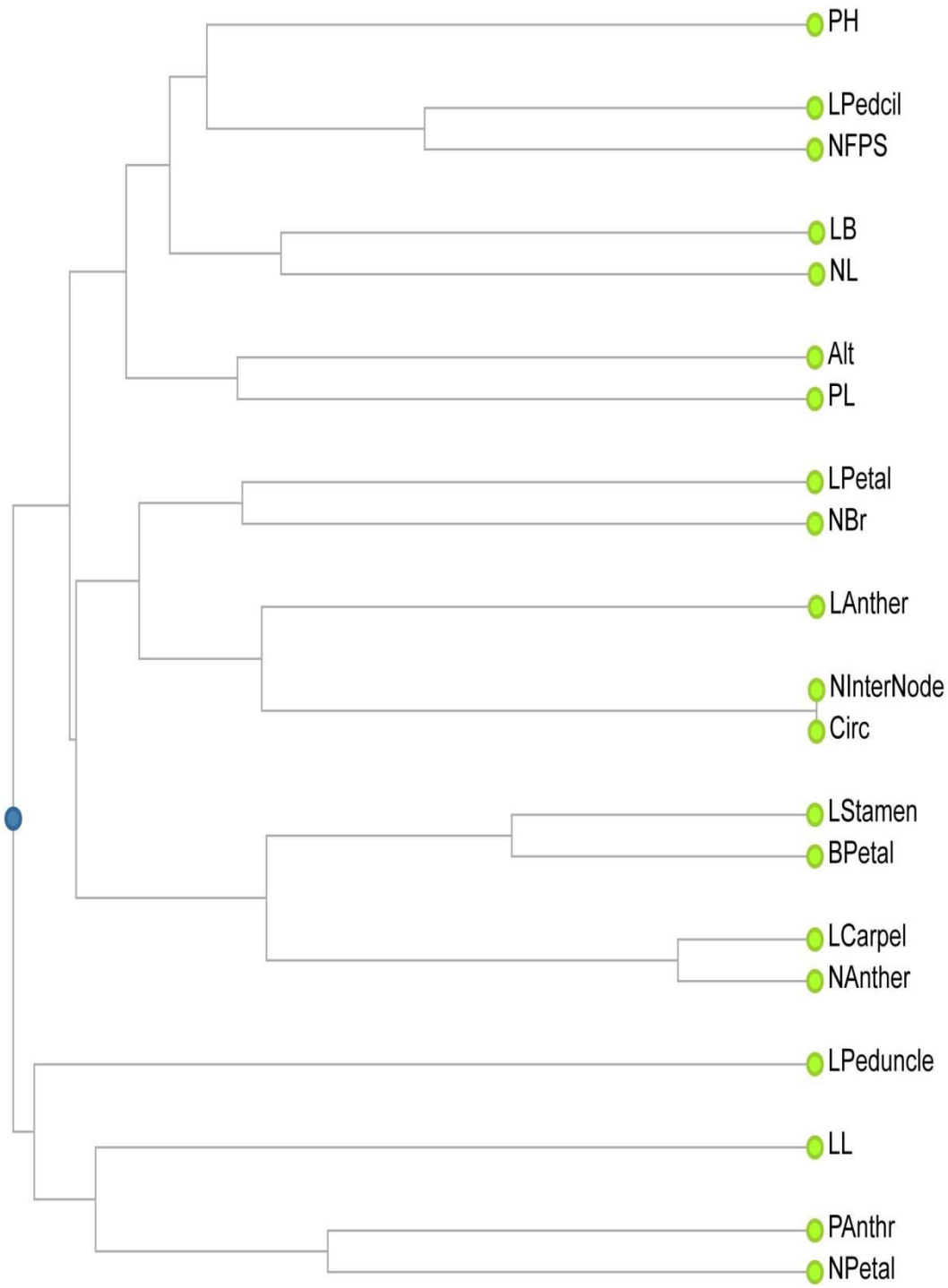


Fig. 9. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 1653 masl of Kohima (Cophenetic Correlation coefficient (CP) = 0.9027).

Table 21. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 2050 masl of Kohima.

Morphological parameters	N	Mean		Std. Deviation	Variance
	Statistic	Statistic	Std. Error	Statistic	Statistic
NT	33	17.0000	1.68325	9.66954	93.500
PH	33	4.9017	.33980	1.95199	3.810
NBr	33	9.9091	.58608	3.36678	11.335
Circ	33	.4101	.05304	.30471	.093
NoIn	33	8.9091	.58608	3.36678	11.335
NL	33	.5967	.08538	.49047	.241
LL	33	9.3636	.28427	1.63302	2.667
LB	33	3.1788	.10223	.58724	.345
PtlL	33	1.7152	.05985	.34380	.118
LPdl	33	.3455	.02091	.12013	.014
NFPS	33	8.7273	.36482	2.09572	4.392
LPcl	33	.5455	.02465	.14162	.020
NoP	33	5.0000	.00000	.00000	.000
LoP	33	3.4697	.13473	.77399	.599
BoP	33	1.4970	.03212	.18453	.034
NoA	33	10.0000	.00000	.00000	.000
LoS	33	2.0848	.04979	.28600	.082
LoA	33	.1685	.00797	.04577	.002
BoA	33	.0864	.00394	.02261	.001
LoC	33	3.5576	.06686	.38408	.148
Alt	33	2.0503E3	.71067	4.08248	16.667
Valid N (listwise)	33				

Table 22. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 2050 masl of Kohima.

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	31.458	9	3.495	.889	.550
	Within Groups	90.471	23	3.934		
	Total	121.929	32			
Nbr	Between Groups	146.977	9	16.331	1.741	.136
	Within Groups	215.750	23	9.380		
	Total	362.727	32			
Circ	Between Groups	.328	9	.036	.318	.961
	Within Groups	2.643	23	.115		
	Total	2.971	32			
NoIn	Between Groups	146.977	9	16.331	1.741	.136
	Within Groups	215.750	23	9.380		
	Total	362.727	32			
NL	Between Groups	2.488	9	.276	1.220	.330
	Within Groups	5.210	23	.227		
	Total	7.698	32			
LL	Between Groups	23.590	9	2.621	.976	.484
	Within Groups	61.747	23	2.685		
	Total	85.336	32			
LB	Between Groups	2.574	9	.286	.777	.639
	Within Groups	8.461	23	.368		
	Total	11.035	32			
PtlL	Between Groups	.412	9	.046	.312	.963
	Within Groups	3.371	23	.147		
	Total	3.782	32			
LPdl	Between Groups	.164	9	.018	1.407	.242
	Within Groups	.298	23	.013		
	Total	.462	32			
NFPS	Between Groups	41.745	9	4.638	1.080	.414

Table 23.

					Within Groups					98.800		23		4.296						
					Total					140.545		32								
				LPcl	Between Groups					.323		9		.036		2.592		.032		
					Within Groups					.319		23		.014						
					Total					.642		32								
	N T	PH	NBr	Circ	N Inter Node	NL	LL	LB	PL	L Pedu ncle	NF PS	L Ped cil	N Pet al	L Pet al	B Peta l	N Ant her	L Sta men	L Ant her	P Ant hr	L Carpel	Alt
NT	1	.398*	.256	.211	.256	.055	.126	-.078	.060	.266	-.210	.634**	a	-.115	.319	a	.059	.635**	.657**	.619**	.729**
			NoP		Between Groups					.000			9			.000			.		.
PH		1	.508**	.790**	.508**	.474**	.483**	.339	.372*	.127	-.010	.450**	a	.260	.176	a	.125	.225	.277	.344*	.222
					Within Groups					.000			23			.000					
					Total					.000			32								
NBr			1	.405*	1.000**	.036	.087	.064	-.020	.049	-.060	.330	a	.229	.216	a	.081	.192	.168	.272	.061
			LoP		Between Groups					4.065			9			.451			.687		.713
Circ				1	.405*	.501**	.509**	.391*	.534**	-.083	-.070	.228	a	.279	-.031	a	.204	.127	.139	.222	-.028
					Within Groups					15.107			23			.657					
					Total					19.170			32								
NoIn					1.000**	.036	.087	.064	-.020	.049	-.060	.330	a	.229	.216	a	.081	.192	.168	.272	.061
			bOp		Between Groups					.425			9			.047			1.635		.164
NL						1	.391*	.357*	.307	-.129	.090	.059	a	.178	-.115	a	.334	-.122	-.145	-.104	-.121
					Within Groups					.664			23			.029					
LL							1	.823**	.676**	-.208	-.002	.043	a	.358*	-.007	a	.298	.013	-.014	.126	.030
					Total					1.090			32								
LB			NoA		Between Groups			1	.564**	-.061	.000	.019	a	.385*	.008	a	.000	-.026	-.105	-.036	-.169
					Within Groups				1	-.123	.000	.127	a	.292	-.058	a	.000	.135	.048	.149	-.050
					Total					.000			32								
PtlL										1	.438*	.609**	a	-.109	.584**	a	-.252	.189	.235	-.018	.382*
LPdl																					
			LoS		Between Groups					.478			9			.053			.571		.806
					Within Groups					2.139			23			.093					
					Total					2.617			32								
NFPS											1	.254	a	.072	.246*	a	-.388	-.360*	-.213	-.162	-.161
LPcll												1	a	.130	.795**	a	-.218	.257	.297	.255	.486**
			LoA		Between Groups					.036			9			.004			2.910		.019
NoPl													a	a	a	a	a	A	a	a	a
					Within Groups					.031			23			.001					
LoPl														1	.039	a	.400*	.163	.181	.268	-.037
					Total					.067			32								
BoP															1	a	-.341	-.115	-.810	.020	.275
			BoA		Between Groups					.009			9			.001			3.418		.008
LoS													a	a	a	a	a	A	a	a	a
					Within Groups					.007			23			.000					
LoC																	1	.500**	.342*	.382*	.051
					Total					.016			32								
NoA																		1	.931**	.807**	.530**
			LoC		Between Groups					2.692			9			.299			3.392		.009
LoA																			1	.903**	.575**
					Within Groups					2.028			23			.088					
BoA																				1	.454**
					Total					4.721			32								
Alt																					1

Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 2050 masl of Kohima.

Fig. 10 Scree plot estimation to explain total variation in *Rhododendron* at an altitude of 2050 masl of Kohima.

Table 24. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 2050 masl of Kohima.

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.180	27.264	27.264	4.682	24.643	24.643
2	3.708	19.517	46.781	4.206	22.138	46.781
3	2.873	15.120	61.901			
4	1.844	9.706	71.607			
5	1.231	6.477	78.084			
6	.924	4.864	82.948			
7	.728	3.830	86.778			
8	.604	3.176	89.955			
9	.493	2.597	92.551			
10	.438	2.306	94.857			
11	.319	1.678	96.535			
12	.243	1.278	97.813			
13	.152	.802	98.616			
14	.114	.601	99.216			
15	.075	.397	99.613			
16	.040	.210	99.823			
17	.025	.132	99.955			
18	.009	.045	100.000			
19	1.531E-17	8.056E-17	100.000			

Table 25. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 2050 masl of Kohima.

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
PH	75.802	62.101	41.102	2552.475	0.819	0.181	34.492	46.355	51.214
NBr	1.165	-0.146	3.934	-0.574	-0.125	1.125	-0.618	7.796	22.023
Circ	5.443	2.317	9.380	21.733	0.425	0.575	4.418	15.361	23.544
NoIN	0.012	-0.026	0.115	-0.002	-2.166	3.166	-2.333	39.328	26.718
NL	-24.556	-27.683	9.380	-259.666	1.127	-0.127	11.701	59.057	55.622
LL	0.091	0.016	0.227	0.003	0.175	0.825	0.208	21.223	50.614
LB	0.874	-0.021	2.685	-0.056	-0.024	1.024	-0.088	1.547	9.984
PtlL	0.095	-0.027	0.368	-0.009	-0.284	1.284	-0.378	5.170	9.698
LPdl	0.016	-0.033	0.147	-0.004	-2.062	3.062	-2.312	10.592	7.375
N FPS	0.005	0.001	0.013	0.000	0.200	0.800	0.200	9.166	20.495
L Pcl	1.546	0.114	4.296	0.489	0.073	0.927	0.390	3.868	14.247
NoP	0.011	0.007	0.014	0.000	0.636	0.364	0.636	15.351	19.244
LoP	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
BoP	0.151	-0.068	0.657	-0.044	-0.450	1.450	-0.741	7.517	11.201
LoS	0.015	0.006	0.029	0.000	0.400	0.600	0.400	5.174	8.181
LoC	0.018	-0.013	0.093	-0.009	-0.722	1.722	-1.222	5.471	6.437
NoA	0.099	0.070	0.088	0.006	0.707	0.293	0.767	7.438	8.845
LoA	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
BoA	0.001	0.001	0.001	0.000	1.000	0.000	1.000	18.823	18.823
PH	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000

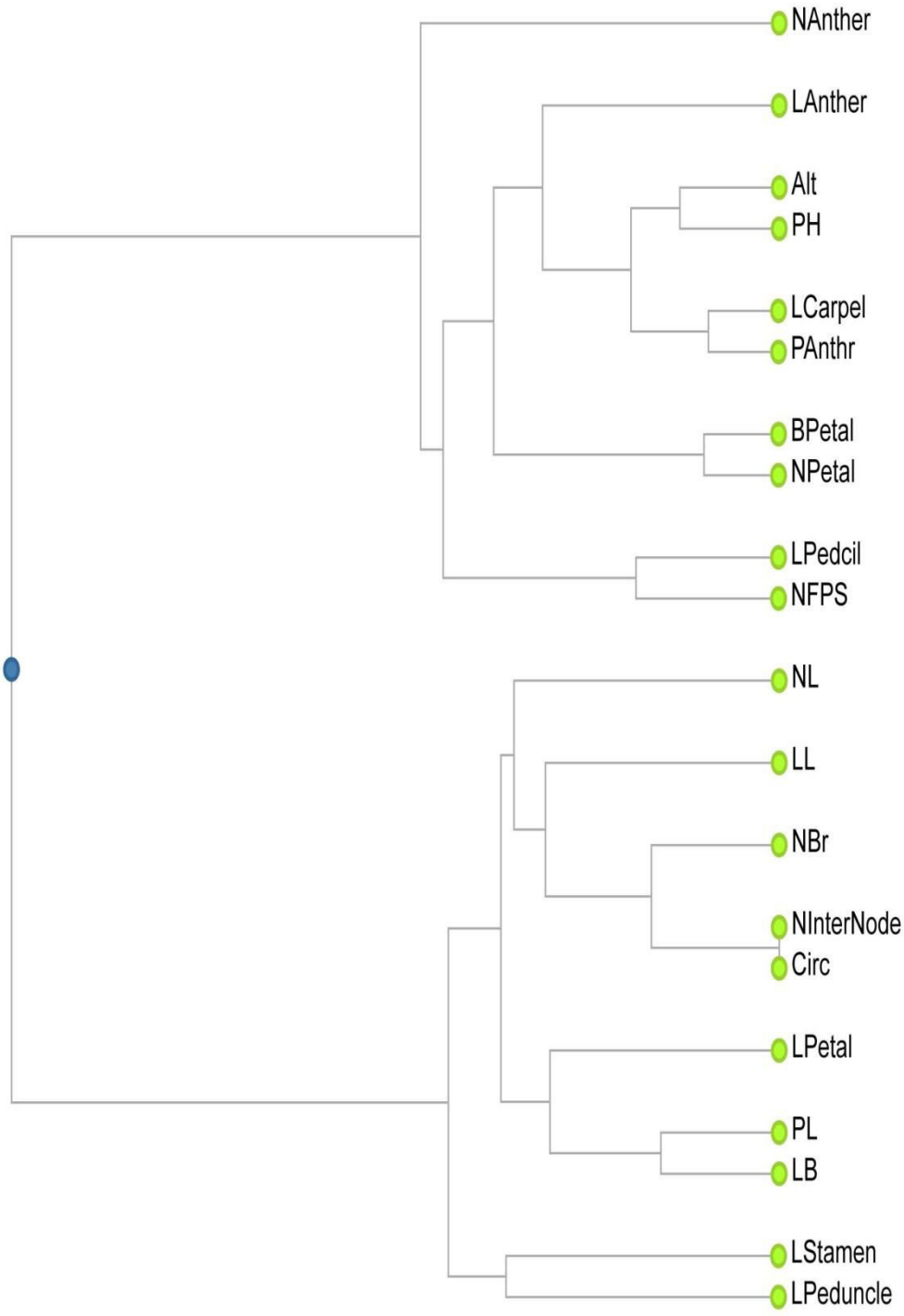


Fig. 11. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 2050 masl of Kohima. (Cophenetic Correlation coefficient (CP) = 0.0983).

Table 26. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 2284 masl of Kohima.

Morphological	N	Mean	Std. Deviation	Variance

Parameters	Statistic	Statistic	Std. Error	Statistic	Statistic
NT	261	1.3100E2	4.67262	75.48841	5.698E3
PH	261	4.2434	.09661	1.56080	2.436
NBr	261	9.3065	.16722	2.70148	7.298
Circ	261	12.2713	11.67595	188.63068	3.558E4
NoIn	261	8.3065	.16722	2.70148	7.298
NL	261	.6990	.03069	.49582	.246
LL	261	9.5111	.13351	2.15692	4.652
LB	261	3.2521	.12116	1.95732	3.831
PtlL	261	2.1797	.65379	10.56234	111.563
LPdl	261	.4149	.01210	.19545	.038
NFPS	261	8.4789	.23499	3.79632	14.412
LPcl	261	.7387	.02465	.39826	.159
NoP	261	5.0000	.00000	.00000	.000
LoP	261	4.3452	.06242	1.00836	1.017
BoP	261	1.9517	.03915	.63243	.400
NoA	261	10.0153	.01210	.19551	.038
LoS	261	2.9140	.05510	.89016	.792
LoA	261	.2674	.00987	.15948	.025
BoA	260	.1175	.00240	.03870	.001
LoC	261	4.3755	.06893	1.11363	1.240
Alt	261	2.2844E3	.39493	6.38022	40.707
Valid N (listwise)	260				

Table 27. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 2284 masl of Kohima.

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	90.544	30	3.018	1.279	.161

	Within Groups	542.838	230	2.360		
	Total	633.382	260			
Nbr	Between Groups	344.927	30	11.498	1.703	.016
	Within Groups	1552.552	230	6.750		
	Total	1897.479	260			
Circ	Between Groups	296699.288	30	9889.976	.254	1.000
	Within Groups	8954499.558	230	38932.607		
	Total	9251198.846	260			
NoIn	Between Groups	344.927	30	11.498	1.703	.016
	Within Groups	1552.552	230	6.750		
	Total	1897.479	260			
NL	Between Groups	5.836	30	.195	.770	.801
	Within Groups	58.082	230	.253		
	Total	63.918	260			
LL	Between Groups	177.955	30	5.932	1.322	.131
	Within Groups	1031.643	230	4.485		
	Total	1209.598	260			
LB	Between Groups	40.565	30	1.352	.325	1.000
	Within Groups	955.526	230	4.154		
	Total	996.091	260			
PtlL	Between Groups	1090.436	30	36.348	.299	1.000
	Within Groups	27915.946	230	121.374		
	Total	29006.382	260			
LPdl	Between Groups	.638	30	.021	.527	.981
	Within Groups	9.293	230	.040		
	Total	9.932	260			
NFPS	Between Groups	813.497	30	27.117	2.126	.001
	Within Groups	2933.637	230	12.755		
	Total	3747.134	260			
LPcl	Between Groups	7.429	30	.248	1.685	.018
	Within Groups	33.810	230	.147		
	Total	41.239	260			
NoP	Between Groups	.000	30	.000	.	.

	Within Groups	.000	230	.000		
	Total	.000	260			
LoP	Between Groups	55.911	30	1.864	2.056	.002
	Within Groups	208.455	230	.906		
	Total	264.367	260			
bOp	Between Groups	21.621	30	.721	2.012	.002
	Within Groups	82.370	230	.358		
	Total	103.992	260			
NoA	Between Groups	1.145	30	.038	.998	.475
	Within Groups	8.794	230	.038		
	Total	9.939	260			
LoS	Between Groups	40.784	30	1.359	1.892	.005
	Within Groups	165.237	230	.718		
	Total	206.021	260			
LoA	Between Groups	2.182	30	.073	3.774	.000
	Within Groups	4.432	230	.019		
	Total	6.613	260			
BoA	Between Groups	.058	30	.002	1.337	.122
	Within Groups	.330	229	.001		
	Total	.388	259			
LoC	Between Groups	51.412	30	1.714	1.454	.067
	Within Groups	271.031	230	1.178		
	Total	322.443	260			

Table 28. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 2284 masl of Kohima.

	NT	PH	NBr	Circ	N Inter Node	NL	LL	LB	PL	L Peduncle	NFPS	L Pedcil	N Petal	L Petal	B Petal	N Anther	L Stamen	L Anther	P Anthr	L Carpel	Alt
NT	1	.420**	.182**	-.093	.182**	.107	.318**	-.028	.015	-.030	.258**	.274**	a	.384**	.355**	-.005	.416**	-.216**	-.336**	-.368**	.109
PH		1	.358**	-.052	.358**	.359**	.230**	-.084	.004	.131*	.329**	.225**	a	.345**	.332**	.035	.291**	-.250**	-.255**	-.325**	.080
NBr			1	-.030	1.000**	.088	.169**	.036	.095	-.068	.194**	.247**	a	.239**	.226**	.006	.167**	-.098	-.242**	-.255**	-.066

Circ				1	-.030	-.038	.101	.015	.000	.345**	-.008	.134*	a	-.028	-.005	-.005	-.046	-.026	-.028	-.043	.055
NoIn					1	.088	.169**	.036	.095	-.068	.194**	.247**	a	.239**	.226**	.006	.167**	-.098	-.242**	-.255**	-.066
NL						1	-.066	-.093	.069	.123*	.044	.040	a	-.023	-.036	.034	.008	-.086	-.037	-.032	-.027
LL							1	.179**	.077	.103	.576**	.499**	a	.587**	.500**	-.061	.597**	-.271**	-.506**	-.548**	.173**
LB								1	.028	-.037	-.040	-.085	a	-.053	-.096	-.013	-.045	-.042	-.076	-.064	.086
PtlL									1	-.029	.047	-.073	a	-.087	-.073	-.009	-.071	-.039	-.045	-.090	.013
LPdl										1	.084	.229**	a	-.060	-.032	.095	-.089	-.024	-.025	.012	.135*
NFPS											1	.645**	a	.783**	.76****	-.088	.738**	-.445**	-.693**	-.719**	.142*
LPcll												1	a	.720**	.661**	.096	.646**	.378**	.604**	.622**	-.059
NoPl													a	a	a	a	a	A	a	A	a
LoPl														1	.881**	.104	.865**	.502**	.768**	.862**	.155*
BoP															1	.090	.802**	.531**	.769**	.792**	-.105
LoS																1	.088	.065	.066	.099	.060
LoC																	1	.499**	.770**	.807**	.187**
NoA																		1	.563**	.491**	.136*
LoA																			1	.767**	-.083
BoA																				1	-.098
Alt																					1

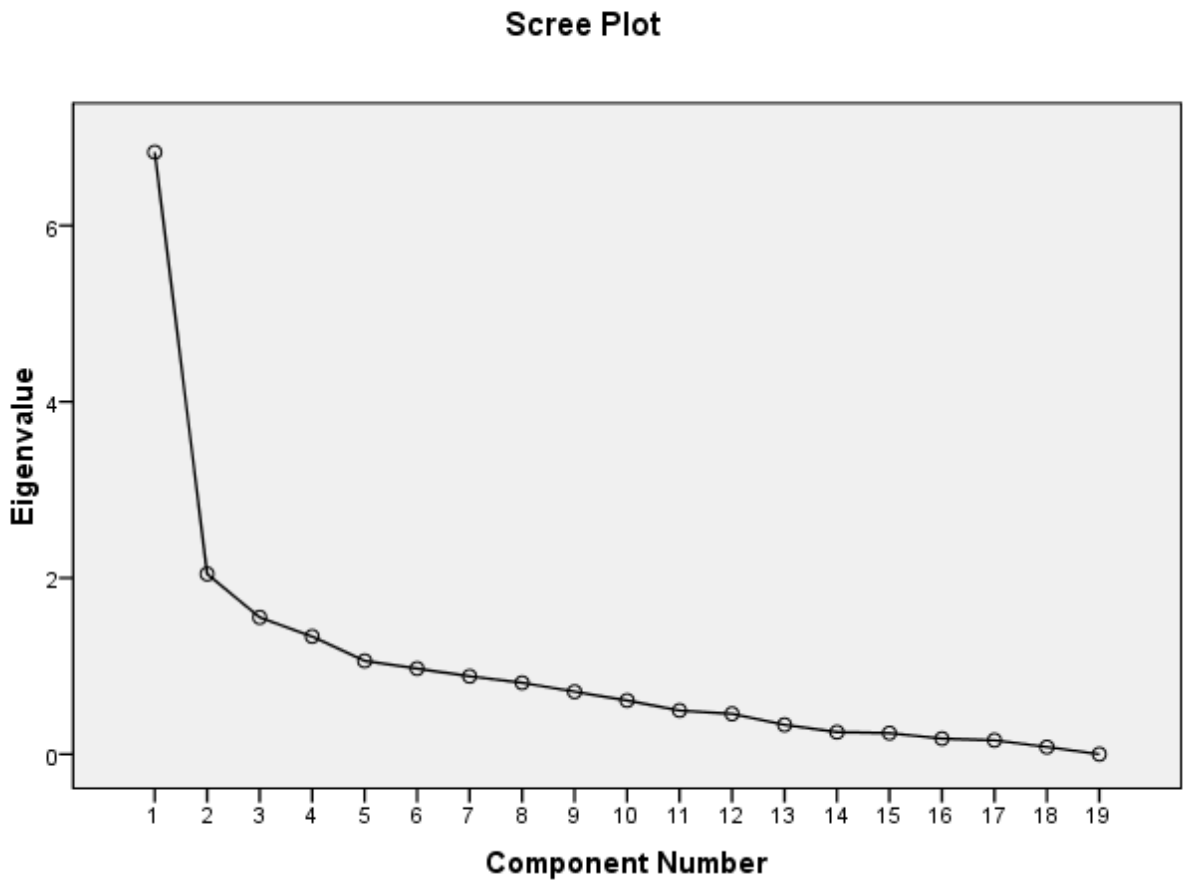


Fig. 12. Scree plot estimation to explain total variation in *Rhododendron* at an altitude of 2284 masl of Kohima.

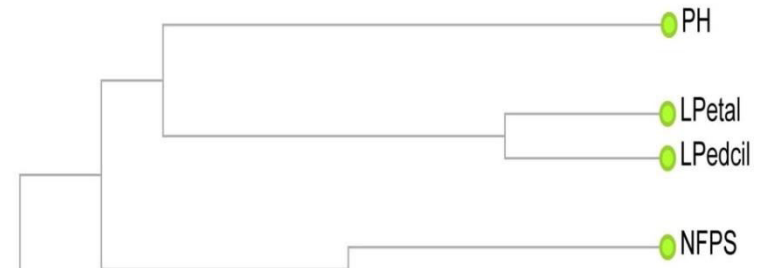
Table 29. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 2284 masl of Kohima.

	Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
	1	6.832	35.960	35.960	6.832	35.960	35.960	6.696	35.242	35.242
	2	2.045	10.761	46.722	2.045	10.761	46.722	2.181	11.479	46.722
	3	1.553	8.174	54.895						
NT	4	3075.574	1329.475	5238.297	6964184.904		0.432	0.568	2264.785	27.833	42.334
	5	1.059	5.573	67.499						
	6	.972	5.113	72.613						
	7	.884	4.654	77.267						
	8	.810	4.265	81.532						
	9	.709	3.732	85.264						
	10	.610	3.209	88.473						
	11	.495	2.606	91.079						
	12	.458	2.410	93.489						
	13	.333	1.755	95.244						
	14	.250	1.314	96.557						
	15	.239	1.258	97.816						
	16	.176	.928	98.743						
	17	.158	.831	99.574						
	18	.081	.426	100.000						
	19	-6.939E-18	-3.652E-17	100.000						

	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV

Table 30. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 2284 masl of Kohima.

PH	1.005	0.219	2.360	0.516	0.217	0.783	0.731	11.029	23.627
NBr	3.832	1.582	6.750	10.678	0.412	0.588	3.199	13.515	21.035
Circ	39296.658	-9680.877	38932.607	-376901779.656	-2.936	3.936	-114331.380	801.820	467.9044
NoIN	3.832	1.582	6.750	10.678	0.412	0.588	3.199	15.142	23.567
NL	0.065	-0.019	.253	-0.004	-0.292	1.292	-0.353	19.719	36.473
LL	1.977	0.482	4.485	2.161	0.243	0.757	1.336	7.299	14.783
LB	0.450	-0.934	4.154	-3.879	-2.075	3.075	10.695	29.718	20.627
PtlL	12.116	-28.342	121.374	-3439.981	-2.339	3.339	286.259	244.319	159.743
LPdl	0.007	-0.006	.040	-0.000	-0.857	1.857	-0.857	18.710	20.209
N FPS	9.038	4.787	12.755	61.058	0.529	0.471	7.285	25.807	35.460
L Pcl	0.082	0.033	.147	0.004	0.402	0.598	0.451	24.615	38.801
NoP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LoP	0.621	0.319	.906	0.289	0.513	0.487	0.979	12.998	18.136
BoP	0.240	0.121	.358	0.043	0.504	0.496	0.683	17.829	17.829
LoS	0.452	0.213	.718	0.152	0.471	0.529	0.807	15.837	23.071
LoC	0.572	0.180	1.178	0.212	0.314	0.686	0.685	9.697	17.287
NoA	0.012	0.000	.038	0.000	0.000	1.000	0.000	0.000	1.093
LoA	0.024	0.018	.019	0.000	0.750	0.25	0.750	50.248	58.022
BoA	0.000	0.000	.001	0.0000	0.000	1.000	0.000	0.000	0.000



Morphological	N	Mean	Std. Deviation	Variance

Fig. 13. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 2284 masl of Kohima. (Cophenetic Correlation coefficient (CP) = 0.8560).

Table 31. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 2688 masl of Kiphire.

parameters	Statistic	Statistic	Std. Error	Statistic	Statistic
NT	22	11.5000	1.38444	6.49359	42.167
PH	22	9.2659	.22966	1.07722	1.160
NBr	22	6.8636	.38531	1.80727	3.266
Circ	22	.7074	.06500	.30486	.093
NoIn	22	5.9091	.38314	1.79706	3.229
NL	22	1.8322	.35259	1.65379	2.735
LL	22	19.3864	.58143	2.72716	7.437
LB	22	9.6273	.23651	1.10935	1.231
PtlL	22	3.2136	.12763	.59865	.358
LPdl	22	.4182	.01695	.07950	.006
NFPS	22	15.0909	.46014	2.15824	4.658
LPcl	22	2.2227	.02863	.13428	.018
NoP	22	8.0000	.00000	.00000	.000
LoP	22	4.9409	.05982	.28058	.079
BoP	22	1.9318	.03744	.17563	.031
NoA	22	16.0000	.00000	.00000	.000
LoS	22	3.0114	.05170	.24247	.059
LoA	22	.2923	.00744	.03491	.001
BoA	22	.1709	.00677	.03176	.001
LoC	22	4.2909	.10360	.48591	.236
Alt	22	3.0960E3	.43644	2.04707	4.190
Valid N (listwise)	22				

Table 32. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 2688 masl of Kiphire.

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	9.250E8	36	2.570E7	.545	.981
	Within Groups	5.804E9	123	4.719E7		
	Total	6.729E9	159			
Nbr	Between Groups	183.191	36	5.089	.953	.551
	Within Groups	656.803	123	5.340		
	Total	839.994	159			
Circ	Between Groups	6.785	36	.188	.811	.763
	Within Groups	28.588	123	.232		
	Total	35.373	159			
NoIn	Between Groups	181.572	36	5.044	.942	.569
	Within Groups	658.803	123	5.356		
	Total	840.375	159			
NL	Between Groups	28.195	36	.783	1.088	.358
	Within Groups	88.580	123	.720		
	Total	116.775	159			
LL	Between Groups	2183.733	36	60.659	1.984	.003
	Within Groups	3759.738	123	30.567		
	Total	5943.471	159			
LB	Between Groups	964.322	36	26.787	1.949	.004
	Within Groups	1690.356	123	13.743		
	Total	2654.678	159			
PtlL	Between Groups	96.497	36	2.680	3.737	.000
	Within Groups	88.221	123	.717		
	Total	184.717	159			
LPdl	Between Groups	.843	36	.023	.983	.506
	Within Groups	2.932	123	.024		
	Total	3.775	159			
NFPS	Between Groups	735.285	36	20.425	2.165	.001
	Within Groups	1160.490	123	9.435		
	Total	1895.775	159			

LPcl	Between Groups	22.684	36	.630	1.682	.019
	Within Groups	46.073	123	.375		
	Total	68.757	159			
NoP	Between Groups	94.912	36	2.636	2.076	.002
	Within Groups	156.188	123	1.270		
	Total	251.100	159			
LoP	Between Groups	23.436	36	.651	1.483	.059
	Within Groups	53.993	123	.439		
	Total	77.429	159			
bOp	Between Groups	99.902	36	2.775	1.825	.008
	Within Groups	187.017	123	1.520		
	Total	286.919	159			
NoA	Between Groups	1197.030	36	33.251	.542	.982
	Within Groups	7547.745	123	61.364		
	Total	8744.775	159			
LoS	Between Groups	27.415	36	.762	3.008	.000
	Within Groups	31.139	123	.253		
	Total	58.554	159			
LoA	Between Groups	1.605	36	.045	.618	.951
	Within Groups	8.874	123	.072		
	Total	10.479	159			
BoA	Between Groups	.077	36	.002	1.820	.008
	Within Groups	.145	123	.001		
	Total	.223	159			
LoC	Between Groups	17.844	36	.496	1.723	.015
	Within Groups	35.376	123	.288		
	Total	53.220	159			

Table 33. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 2688 masl of Kiphire.

	NT	PH	NBr	Circ	N Inter Node	NL	LL	LB	PL	L Peduncle	NFPS	L Pedcil	N Petal	L Petal	B Petal	N Anther	L Stamen	L Anther	P Anthr	L Carpel	Alt

NT	1	.131	-.116	.221	-.131	.355	.171	.145	-.168	-.083	.160	-.418	a	.216	-.269	a	.318	.276	.266	.287	-.004
PH		1	.180	.379	.215	.342	-.058	-.054	-.043	-.186	-.054	.148	a	-.153	-.322	a	.105	.208	.223	.127	-.220
NBr			1	.555**	.993**	.028	-.156	-.186	-.055	-.280	-.302	.245*	a	.209	-.376	a	-.051	-.176	-.189	-.170	.296
Circ				1	.549**	.237	.066	.065	.288	-.217	-.212	-.016	a	.147	-.334	a	.103	-.038	-.303	-.167	.219
NoIn					1	.004	-.190	-.221	-.070	-.255	-.268	.463*	a	.197	-.413	a	-.025	-.156	-.165	-.192	.311
NL						1	-.016	-.068	-.090	-.376	-.262	-.245	a	.307	-.057	a	.353	-.240	.046	.139	-.136
LL							1	.914**	.603**	.043	-.014	-.459*	a	.410	.109	a	.238	.220	.177	-.041	-.554**
LB								1	.541**	.075	-.049	-.461*	a	.275	.154	a	.153	.173	.159	.048	-.566**
PtlL									1	.045	-.145	-.312	a	.263	.018	a	-.021	-.129	-.366	-.279	-.319
L Pdl										1	.739**	.138	a	-.334	.264	a	.038	.139	-.063	-.082	-.117
NFPS											1	.075	a	-.124	-.008	a	-.011	.414	.249	-.176	.022
L Pcll												1	a	-.215	.028	a	-.125	-.164	-.027	-.150	.277
NoPl													a	a	a	a	A	a	A	a	a
LoPl														1	.001	a	.136	-.258	.054	-.329	-.166
BoP															1	a	.064	-.067	-.133	.305	-.212
LoS																a	A	a	A	a	a
LoC																	1	.250	.020	.286	-.384
NoA																		1	.587**	.411	-.060
LoA																			1	.272	-.044
BoA																				1	-.349
Alt																					1

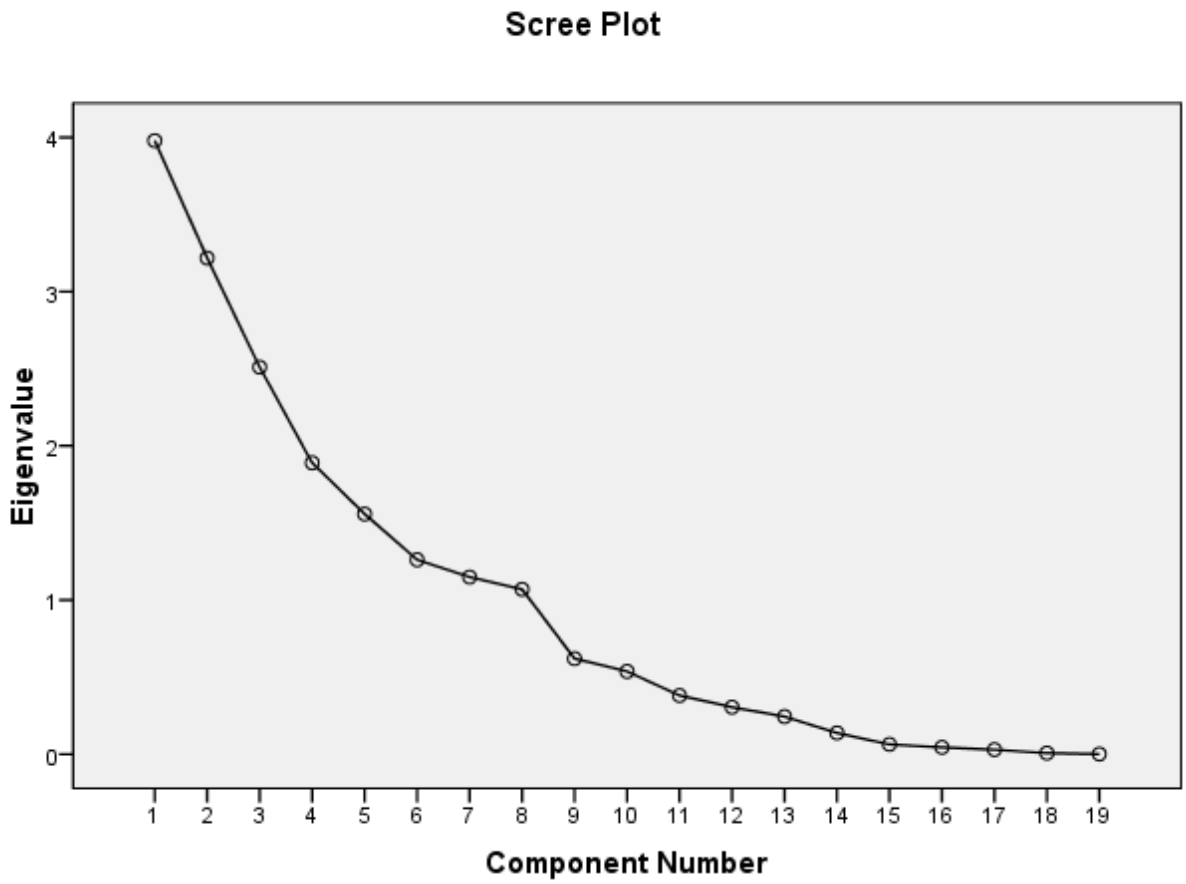


Fig. 14. Scree plot estimation to explain total variation in *Rhododendron* at an altitude of 2688 masl of Kiphire.

Table 34. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 2688 masl of Kiphire.

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.980	20.945	20.945	3.601	18.950	18.950
2	3.218	16.936	37.881	3.597	18.930	37.881

3	2.510	13.210	51.091						
4	1.889	9.944	61.035						
5	1.557	8.197	69.232						
6	1.261	6.635	75.867						

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
7	1.149	6.045	81.912						
8	1.069	5.628	87.540						
9	.620	3.261	90.801						
10	.537	2.824	93.625						
11	.380	2.002	95.626						
12	.305	1.604	97.230						
13	.244	1.285	98.515						
14	.138	.725	99.239						
15	.063	.333	99.572						
16	.044	.232	99.804						
17	.029	.153	99.958						
18	.007	.037	99.995						
19	.001	.005	100.000						

Table 35. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 2688 masl of Kiphire.

PH	11.745	-3.234	44.939	-145.332	-0.275	1.275	-12.649	15.637	29.800
NBr	0.357	-0.041	1.196	-0.049	-0.114	1.114	-0.252	2.185	6.448
Circ	0.623	-0.652	3.826	-2.494	-1.046	2.046	-5.049	11.765	11.500
NoIN	0.048	0.025	0.071	0.001	0.520	0.480	0.541	22.364	30.988
NL	0.608	-0.656	3.792	-2.487	-1.078	2.078	-5.169	13.706	13.195
LL	0.419	-0.690	3.327	-2.295	-1.646	2.646	-7.124	45.341	35.333
LB	5.966	4.882	3.253	15.881	0.818	0.182	3.480	11.397	12.599
PtlL	0.717	0.430	0.862	0.370	0.599	0.401	1.115	6.811	8.795
LPdl	0.144	0.035	0.328	0.011	0.243	0.757	0.319	5.822	11.810
N FPS	0.000	-0.002	0.008	-0.000	0.000	0.000	-0.000	10.698	0.000
L Pcl	1.131	-0.590	5.164	-3.046	-0.521	1.521	-3.214	5.090	7.047
NoP	0.006	0.000	0.018	0.000	0.000	0.000	0.000	0.000	3.486
LoP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoP	0.039	0.019	0.062	0.001	0.487	0.513	0.512	2.790	3.997
LoS	0.009	-0.001	0.032	-0.000	-0.111	1.111	-0.111	1.637	4.912
LoC	0.015	-0.006	0.064	-0.000	-0.400	1.400	-0.400	2.572	4.067
NoA	0.146	0.095	0.154	0.014	0.650	0.350	0.746	7.184	8.906
LoA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BoA	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
PH	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000

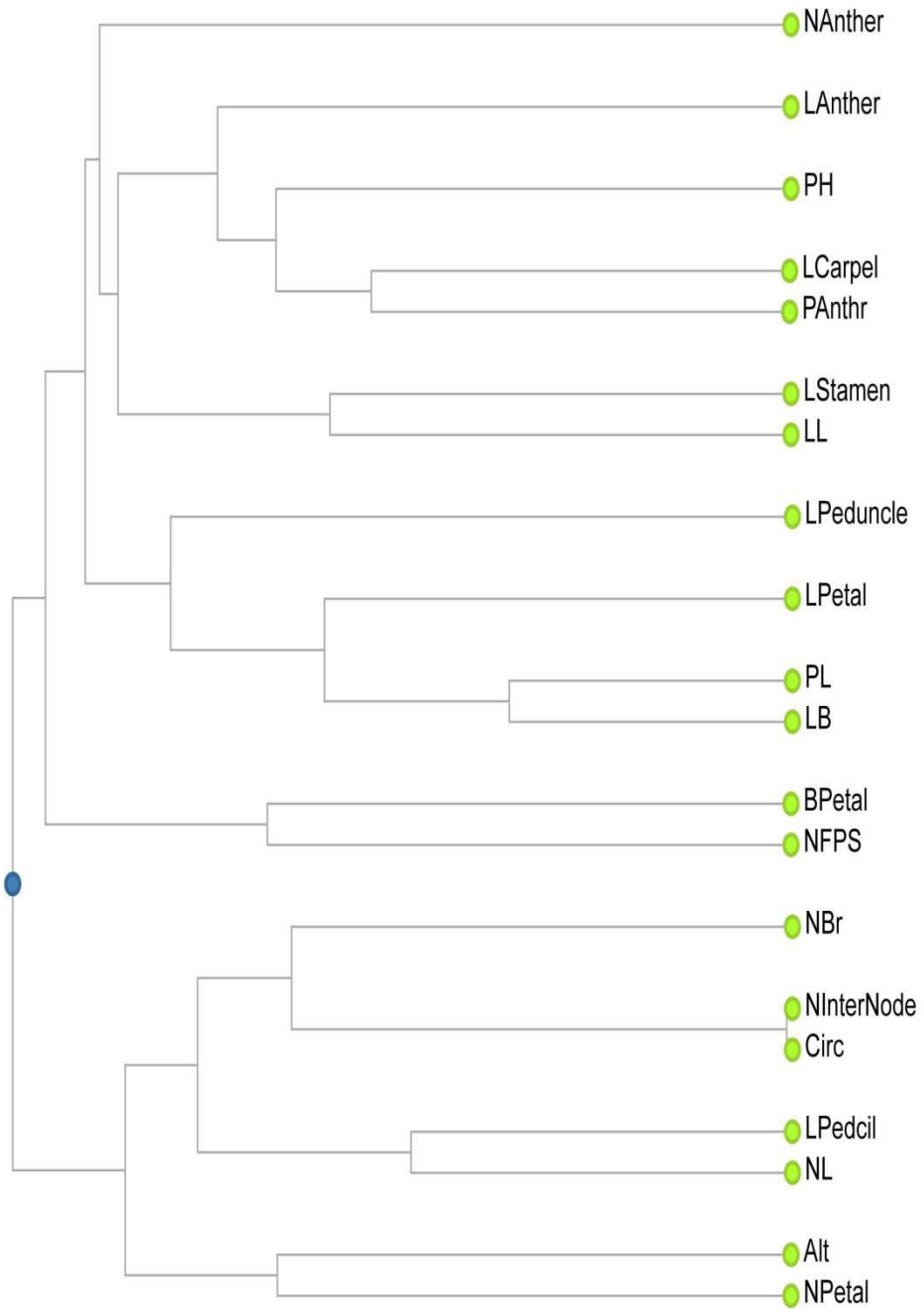


Fig. 15. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 2688 masl of Kiphire (Cophenetic Correlation coefficient (CP) = 0.896).

Table 36. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 3112 masl of Kiphire.

Morphological parameters	N	Mean		Std. Deviation	Variance
	Statistic	Statistic	Std. Error	Statistic	Statistic
NT	58	29.5000	2.21736	16.88688	285.167
PH	58	9.2759	.29639	2.25722	5.095
NBr	58	7.4828	.26058	1.98451	3.938
Circ	58	1.0573	.09480	.72199	.521
NoIn	58	6.4828	.26058	1.98451	3.938
NL	58	1.5732	.19159	1.45911	2.129
LL	58	19.3724	.43463	3.31005	10.956
LB	58	9.5993	.18344	1.39707	1.952
PtlL	58	3.1121	.07022	.53478	.286
LPdl	58	.4293	.00921	.07011	.005
NFPS	58	15.1207	.23729	1.80717	3.266
LPcl	58	2.1966	.01920	.14626	.021
NoP	58	8.0000	.00000	.00000	.000
LoP	58	4.9828	.05071	.38623	.149
BoP	58	1.9000	.02460	.18732	.035
NoA	58	16.0000	.00000	.00000	.000
LoS	58	3.0371	.03149	.23980	.058
LoA	58	.2979	.00389	.02960	.001
BoA	58	.2083	.02281	.17372	.030
LoC	58	4.2534	.06518	.49638	.246
Alt	58	3.1122E3	.95301	7.25793	52.678
Valid N (listwise)	58				

Table 37. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 3112 masl of Kiphire.

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	1109.549	50	22.191	4.995	.000
	Within Groups	355.377	80	4.442		

	Total	1464.926	130			
Nbr	Between Groups	393.011	50	7.860	1.555	.039
	Within Groups	404.500	80	5.056		
	Total	797.511	130			
Circ	Between Groups	30.911	50	.618	1.296	.149
	Within Groups	38.149	80	.477		
	Total	69.060	130			
NoIn	Between Groups	390.382	50	7.808	1.546	.041
	Within Groups	404.000	80	5.050		
	Total	794.382	130			
NL	Between Groups	103.098	50	2.062	1.308	.141
	Within Groups	126.127	80	1.577		
	Total	229.224	130			
LL	Between Groups	2383.026	50	47.661	2.934	.000
	Within Groups	1299.696	80	16.246		
	Total	3682.722	130			
LB	Between Groups	822.700	50	16.454	3.657	.000
	Within Groups	359.991	80	4.500		
	Total	1182.691	130			
PtlL	Between Groups	79.507	50	1.590	1.514	.048
	Within Groups	84.016	80	1.050		
	Total	163.522	130			
LPdl	Between Groups	.311	50	.006	.596	.975
	Within Groups	.835	80	.010		
	Total	1.146	130			
NFPS	Between Groups	1546.146	50	30.923	2.553	.000
	Within Groups	968.983	80	12.112		
	Total	2515.130	130			
LPcl	Between Groups	22.973	50	.459	3.571	.000
	Within Groups	10.292	80	.129		
	Total	33.265	130			
NoP	Between Groups	150.871	50	3.017	4.611	.000
	Within Groups	52.350	80	.654		

	Total	203.221	130			
LoP	Between Groups	16.769	50	.335	.820	.773
	Within Groups	32.730	80	.409		
	Total	49.499	130			
bOp	Between Groups	8.162	50	.163	1.041	.430
	Within Groups	12.551	80	.157		
	Total	20.713	130			
NoA	Between Groups	586.268	50	11.725	4.469	.000
	Within Groups	209.900	80	2.624		
	Total	796.168	130			
LoS	Between Groups	11.913	50	.238	.691	.919
	Within Groups	27.578	80	.345		
	Total	39.491	130			
LoA	Between Groups	.146	50	.003	.754	.858
	Within Groups	.310	80	.004		
	Total	.457	130			
BoA	Between Groups	.685	50	.014	.900	.653
	Within Groups	1.219	80	.015		
	Total	1.904	130			
LoC	Between Groups	29.172	50	.583	1.081	.372
	Within Groups	43.165	80	.540		
	Total	72.337	130			

Table 38. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 3112 masl of Kiphire.

	NT	PH	NBr	Circ	N Inter Node	NL	LL	LB	PL	L Peduncle	NFPS	L Pedcil	N Petal	L Petal	B Petal	N Anther	L Stamen	L Anther	P Anthr	L Carpel	Alt
NT	1	-.142	-.006	.006	-.006	.003	.116	.230	-.029	-.113	.339**	.233	a	-.094	-.082	a	.048	-.053	-.025	-.225	-.542**
PH		1	.373**	-.105	.373**	.074	.005	.203	.183	.011	-.022	.010	a	-.110	-.005	a	-.014	-.007	-.248	-.011	-.114
NBr			1	-.061	1.000**	.220	-.086	-.031	-.116	.010	.013	.133	a	.089	.080	a	.093	-.060	-.163	.004	-.146
Circ				1	-.061	.005	.069	.047	-.041	-.096	.020	.068	a	-.145	.004	a	.006	-.084	.429**	-.142	.088

NoIn					1	.220	-.086	-.031	-.116	.010	.013	.133	a	.089	.080	a	.093	-.060	-.163	.004	-.146
NL						1	.096	-.026	.044	.018	.160	.061	a	-.054	.143	a	.108	.094	.005	.156	-.038
LL							1	.497**	.280*	-.003	.110	.127	a	-.004	-.047	a	.000	.022	.097	.067	.167
LB								1	.614**	-.118	.061	.101	a	-.123	.283*	a	-.195	-.136	.097	.010	.137
PtlL									1	-.033	-.098	.099	a	.070	-.249	a	-.098	.110	.046	.233	.366**
L Pdl										1	.179	.215	a	.317*	.240	a	.320*	.266*	-.263	.347**	.175
NFPS											1	.187	a	.268*	.067	a	.681**	-.140	.206	-.001	.252
L Pcll												1	a	.167	.327*	a	.239	.027	.087	.119	-.049
NoPl													a	a	a	a	a	a	A	a	a
LoPl														1	.507**	a	.363**	.207	-.138	.422**	.087
BoP															1	a	.250	.133	-.150	.291*	-.021
LoS																a	a	a	A	a	a
LoC																	1	.411**	-.157	.281*	-.123
NoA																		1	-.192	.477**	-.008
LoA																			1	-.125	.157
BoA																				1	.159
Alt																					1

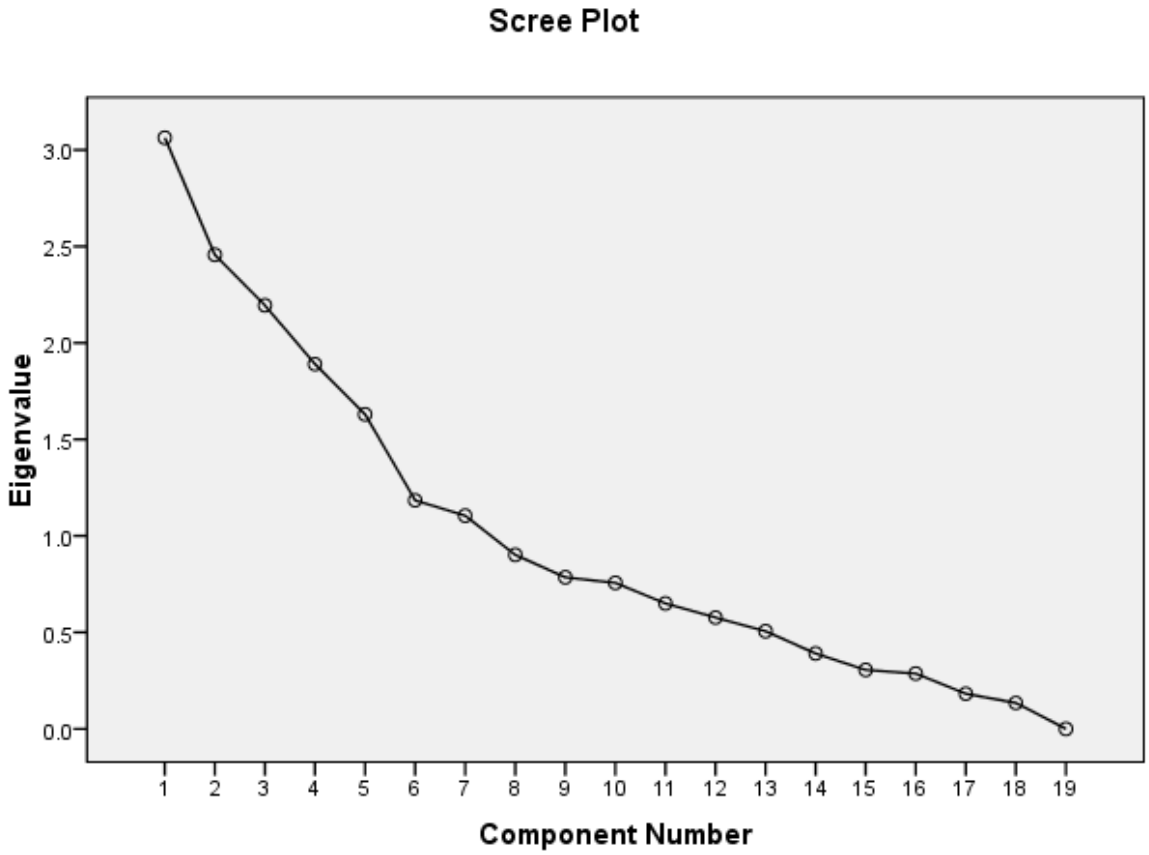


Fig. 16. Scree plot estimation to explain total variation in *Rhododendron* at an altitude of 3112 masl of Kiphire.

Table 39. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 3112 masl of Kiphire.

Components	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.063	16.122	16.122	2.946	15.503	15.503
2	2.457	12.929	29.051	2.574	13.548	29.051
3	2.195	11.551	40.602			
4	1.890	9.948	50.550			

5	1.630	8.579	59.129			
6	1.184	6.233	65.362			
7	1.105	5.816	71.178			
8	.902	4.746	75.924			
9	.785	4.133	80.057			
10	.757	3.982	84.039			
11	.650	3.422	87.461			
12	.577	3.037	90.498			
13	.506	2.664	93.161			
14	.391	2.055	95.217			
15	.305	1.607	96.824			
16	.287	1.510	98.334			
17	.182	.959	99.292			
18	.134	.708	100.000			
19	-6.593E-17	-3.470E-16	100.000			

Table 40. Phenotypic and Genotypic variance components (Heritability, Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 3112 masl of Kiphire.

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
PH	180.987	136.059	134.786	18338.848	0.751	0.249	107802.	39.540	45.603
NBr	1.605	-0.147	5.258	-0.772	-0.091	1.091	-0.572	4.133	13.659
Circ	1.625	0.496	3.389	1.680	0.305	0.695	1.339	9.412	17.037
NoIN	0.124	-0.079	0.609	-0.048	-0.637	1.637	-1.024	26.591	33.314
NL	1.625	0.496	3.389	1.680	0.305	0.695	1.339	10.865	19.666
LL	1.118	0.648	1.412	0.914	0.579	0.421	1.397	51.175	67.219
LB	2.974	-1.073	12.143	-13.029	-0.360	1.360	-4.741	5.347	8.902
PtlL	0.666	0.025	1.924	0.048	0.037	0.963	0.109	1.647	8.501
LPdl	0.126	0.049	0.232	0.011	0.388	0.612	0.476	7.113	11.406
N FPS	0.001	-0.001	0.006	-0.000	-1.000	2.000	-1.000	7.371	7.371
L Pcl	1.450	0.573	2.632	1.508	0.395	0.605	1.435	5.006	7.964
NoP	0.009	0.004	0.016	0.000	0.444	0.556	0.444	2.880	4.320
LoP	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
BoP	0.049	-0.001	0.150	-0.000	-0.020	1.020	-0.020	0.634	4.443
LoS	0.013	0.002	0.033	0.000	0.153	0.847	0.153	2.353	6.000
LoC	0.016	-0.004	0.062	-0.000	-0.250	1.250	-0.250	2.082	4.165
NoA	0.067	-0.024	0.273	-0.006	-0.358	1.358	-0.447	3.642	6.086
LoA	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
BoA	0.000	0.000	0.001	0.000	0.000	1.000	0.000	0.000	0.000
PH	0.009	-0.001	0.032	-0.000	-0.111	1.111	-0.111	15.203	45.609

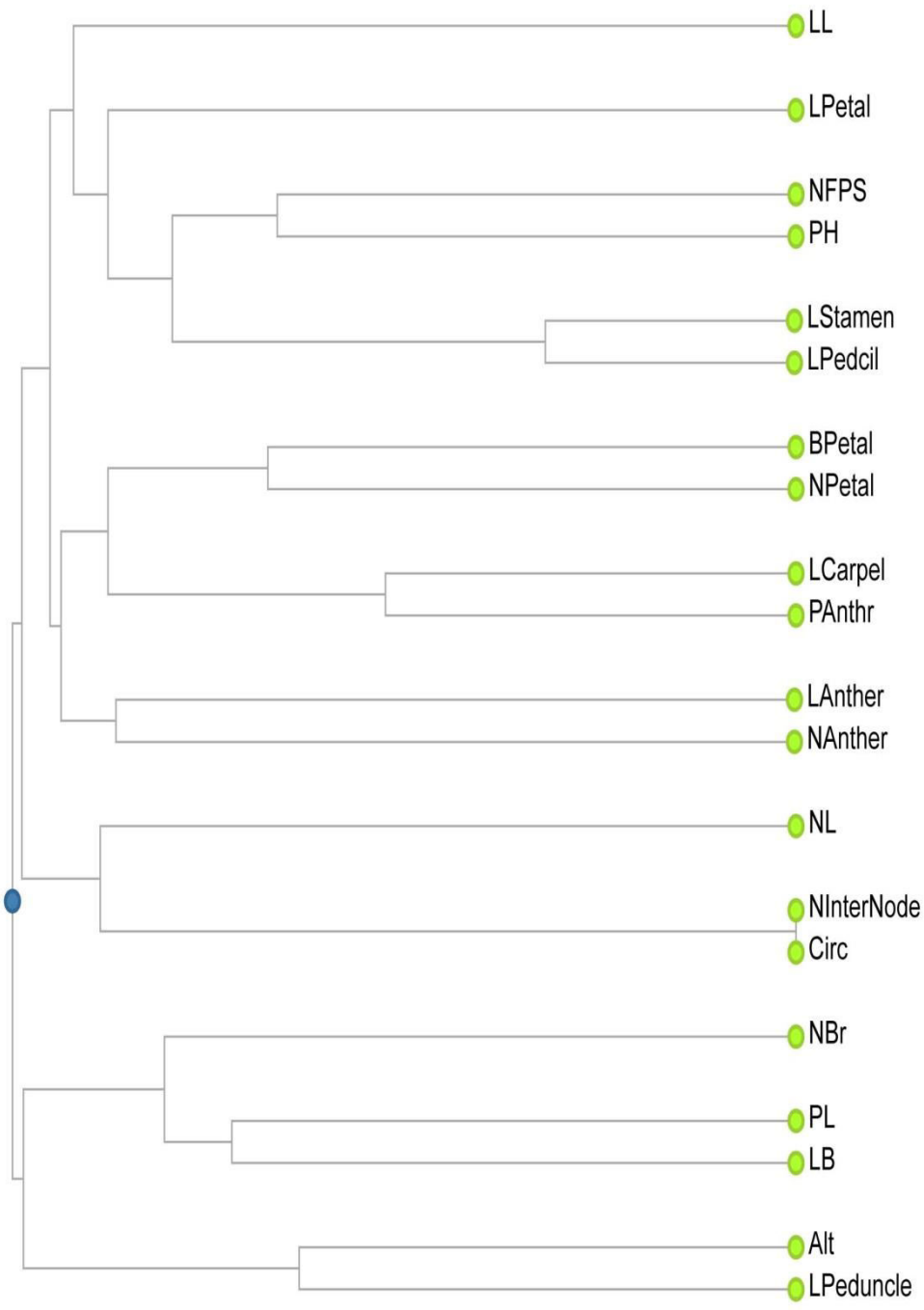


Fig. 17. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 3112 masl of Kiphire. (Cophenetic Correlation coefficient (CP) = 0.9288).

Table 41. Mean ± S.E., S.D. and Variance Calculations of morphogenetic traits of *Rhododendron* at an altitude of 3430 masl of Kiphire.

Morphological parameters	N	Mean		Std. Deviation	Variance
	Statistic	Statistic	Std. Error	Statistic	Statistic
NT	124	62.5000	3.22749	35.93976	1.292E3
PH	124	8.1611	.38439	4.28041	18.322
NBr	124	7.2419	.18724	2.08506	4.347
Circ	124	5.9054E2	5.89931E2	6569.18905	4.315E7
NoIn	124	6.2661	.18785	2.09183	4.376
NL	124	1.3041	.11856	1.32026	1.743
LL	124	13.6798	.51372	5.72059	32.725
LB	124	7.5266	.28052	3.12369	9.757
PtlL	124	2.0846	.08712	.97013	.941
LPdl	124	.3601	.01054	.11739	.014
NFPS	124	14.3226	.62423	6.95110	48.318
LPcl	124	2.2171	.03224	.35897	.129
NoP	124	7.2984	.11450	1.27502	1.626
LoP	124	3.9927	.11675	1.30004	1.690
BoP	124	1.7685	.04261	.47445	.225
NoA	124	14.7419	.22023	2.45238	6.014
LoS	124	2.6488	.05157	.57426	.330
LoA	124	.3561	.03886	.43275	.187
BoA	124	.1669	.00476	.05303	.003
LoC	124	3.5556	.08434	.93915	.882
Alt	124	3.4309E3	.40838	4.54752	20.680
Valid N (listwise)	124				

Table 42. Analysis of Variance (ANOVA) Calculations of morphogenetic traits of *Rhododendron* at an altitude of 3430 masl of Kiphire.

		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	1413.411	32	44.169	4.959	.000
	Within Groups	944.075	106	8.906		
	Total	2357.486	138			
Nbr	Between Groups	316.395	32	9.887	2.661	.000
	Within Groups	393.836	106	3.715		
	Total	710.230	138			
Circ	Between Groups	1.032E9	32	3.224E7	.798	.764
	Within Groups	4.281E9	106	4.039E7		
	Total	5.313E9	138			
NoIn	Between Groups	320.088	32	10.003	2.707	.000
	Within Groups	391.711	106	3.695		
	Total	711.799	138			
NL	Between Groups	61.726	32	1.929	1.221	.224
	Within Groups	167.460	106	1.580		
	Total	229.186	138			
LL	Between Groups	2081.243	32	65.039	2.922	.000
	Within Groups	2358.996	106	22.255		
	Total	4440.238	138			
LB	Between Groups	668.145	32	20.880	3.478	.000
	Within Groups	636.317	106	6.003		
	Total	1304.462	138			
PtlL	Between Groups	82.378	32	2.574	5.618	.000
	Within Groups	48.570	106	.458		
	Total	130.948	138			
LPdl	Between Groups	.795	32	.025	2.520	.000
	Within Groups	1.045	106	.010		
	Total	1.840	138			
NFPS	Between Groups	2566.345	32	80.198	2.478	.000
	Within Groups	3430.188	106	32.360		
	Total	5996.532	138			

LPcl	Between Groups	1.968	32	.062	.457	.993
	Within Groups	14.254	106	.134		
	Total	16.222	138			
NoP	Between Groups	119.876	32	3.746	4.582	.000
	Within Groups	86.671	106	.818		
	Total	206.547	138			
LoP	Between Groups	96.078	32	3.002	2.496	.000
	Within Groups	127.531	106	1.203		
	Total	223.609	138			
bOp	Between Groups	11.919	32	.372	2.389	.000
	Within Groups	16.526	106	.156		
	Total	28.445	138			
NoA	Between Groups	488.107	32	15.253	5.927	.000
	Within Groups	272.814	106	2.574		
	Total	760.921	138			
LoS	Between Groups	24.556	32	.767	4.228	.000
	Within Groups	19.240	106	.182		
	Total	43.796	138			
LoA	Between Groups	4.238	32	.132	.745	.829
	Within Groups	18.852	106	.178		
	Total	23.089	138			
BoA	Between Groups	.175	32	.005	3.171	.000
	Within Groups	.183	106	.002		
	Total	.358	138			
LoC	Between Groups	50.104	32	1.566	2.413	.000
	Within Groups	68.773	106	.649		
	Total	118.877	138			

Table 43. Pearson correlation (2 tailed) for association of morphogenetic traits of *Rhododendron* at an altitude of 3430 masl of Kiphire.

	NT	PH	NBr	Circ	N Inter Node	NL	LL	LB	PL	L Peduncle	NFPS	L Pedcil	N Petal	L Petal	B Petal	N Anther	L Stamen	L Anther	P Anthr	L Carpel	Alt
NT	1	.511**	-.140	.029	-.159	-.028	.333**	.312**	.579**	.356**	.316**	.075	.445**	.477*	.330**	.425**	.481**	-.008	.380**	.320**	-.637**
PH		1	.452**	.085	-.471**	.230*	.769**	.752**	.496**	.572**	.639**	.224**	.793**	.563**	.681**	.783**	.589**	.206*	.593**	.605**	-.618**
NBr			1	-.097	.997**	-.089	-.371**	-.371**	-.246**	-.224*	-.344**	-.141	-.394**	-.225*	-.322**	-.407**	-.309**	-.133	-.231**	-.273**	.308**
Circ				1	-.098	-.006	.094	.083	.001	.108	.100	.021	.050	.091	.025	.046	-.031	-.031	.022	.033	-.058
NoIn					1	-.087	-.391**	-.391**	-.267**	-.243**	-.359**	-.143	-.414**	-.239**	-.339**	-.429**	-.326**	-.137	-.245**	-.290**	.320**
NL						1	.178*	.164	.113	.008	.124	-.179*	.098	.106	.060	.123	.173	.125**	.189*	.121	-.089
LL							1	.954**	.572**	.667**	.718**	.240**	.852**	.546**	.746**	.821**	.642**	.143	.583**	.666**	-.447**
LB								1	.578**	.682**	.724**	.222*	.860**	.567**	.705**	.844**	.666**	.185*	.575**	.695**	-.449**
PtlL									1	.433**	.494**	.142	.559**	.405**	.516**	.561**	.563**	.090	.455**	.454**	-.447**
L Pdl										1	.593**	.275**	.765**	.676**	.656**	.714**	.762**	.166	.519**	.739**	-.412**
NFPS											1	.300**	.758**	.494**	.589**	.759**	.578**	.194*	.533**	.536**	-.518**
L Pcll												1	.340**	.044	.256**	.295**	.156	-.009	.089	.074	-.079
NoPl													1	.672**	.790**	.932**	.760**	.175	.625**	.782**	-.509**
LoPl														1	.533**	.621**	.695**	.171	.414**	.680**	-.375**
BoP															1	.733**	.672**	.094	.617**	.670**	-.413**
LoS																1	.712**	.160	.578**	.723**	-.519**
LoC																	1	.174	.542**	.774**	-.468**
NoA																		1	.279**	.196*	-.184*
LoA																			1	.560**	-.507**
BoA																				1	-.377**
Alt																					1

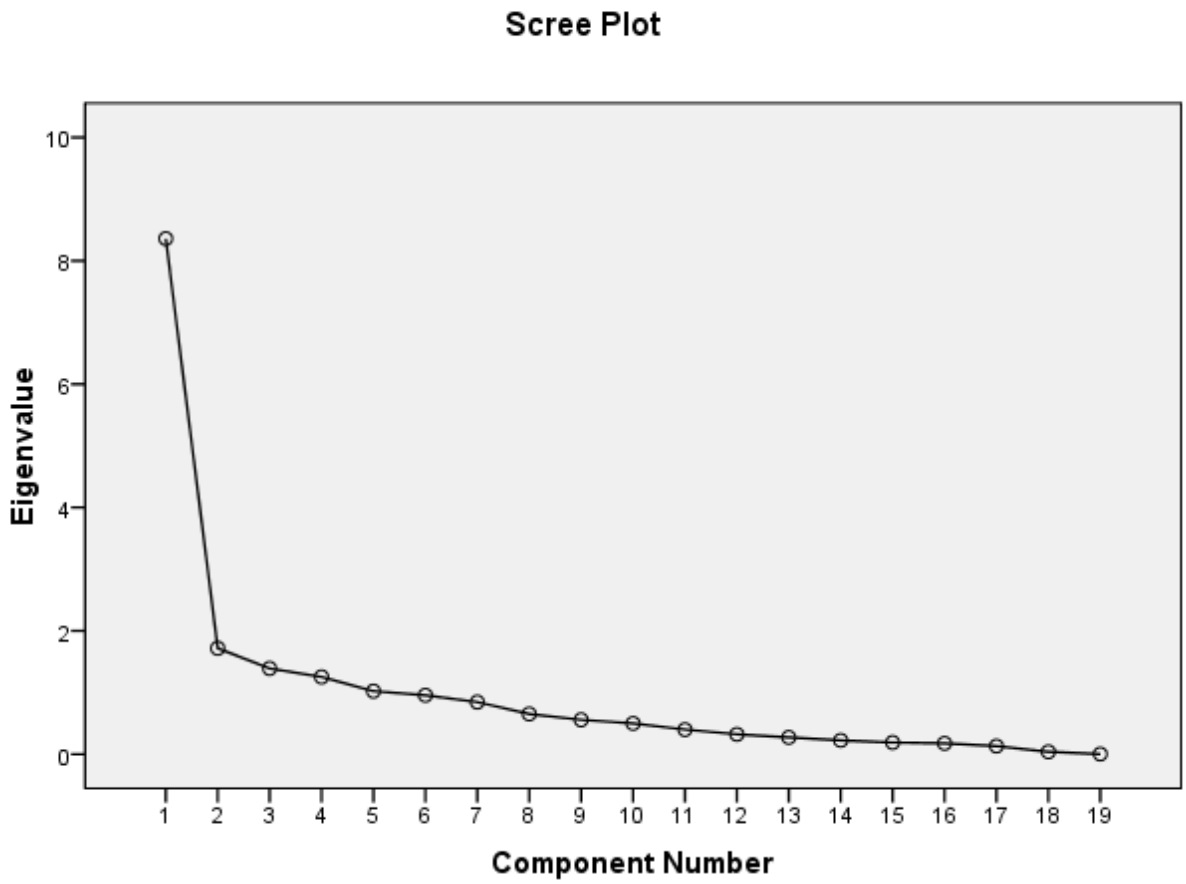


Fig. 18. Scree plot estimation to explain total variation in *Rhododendron* at an altitude of 3430 masl of Kiphire.

Table 44. Principal component analysis (PCA) of morphogenetic traits of *Rhododendron* at an altitude of 3430 masl of Kiphire.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Components	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.360	44.000	44.000	8.360	44.000	44.000	7.304	38.441	38.441
2	1.717	9.035	53.035	1.717	9.035	53.035	2.773	14.594	53.035
3	1.390	7.314	60.350						
4	1.252	6.588	66.938						
5	1.022	5.378	72.315						
6	.955	5.029	77.344						
7	.845	4.446	81.790						
8	.652	3.432	85.222						
9	.557	2.931	88.152						
10	.499	2.628	90.780						
11	.399	2.099	92.878						
12	.322	1.694	94.573						
13	.271	1.426	95.999						
14	.223	1.176	97.175						
15	.189	.997	98.172						
16	.175	.922	99.094						
17	.131	.690	99.784						
18	.039	.203	99.988						
19	.002	.012	100.000						

Table 45. Phenotypic and Genotypic variance components (Heritability Environmentability, Repeatability, Genotypic and Phenotypic coefficients) of morphogenetic traits of *Rhododendron* at an altitude of 3430 masl of Kiphire.

Morphological parameters	Vp	Vg	Ve	Vg×e	H2	E	R	GCV	PCV
PH	1611.824	1410.642	603.548	851390.157	0.875	0.125	529.090	60.093	64.236
NBr	21.930	18.896	9.104	172.029	0.861	0.139	8.706	53.264	57.382
Circ	2.692	1.485	3.623	5.380	0.551	0.449	2.550	16.829	22.658
NoIN	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
NL	2.785	1.585	3.602	5.709	0.569	0.431	2.619	20.092	26.633
LL	0.799	0.261	1.615	0.421	0.326	0.674	0.853	39.178	68.548
LB	29.410	22.095	21.947	484.918	0.751	0.249	17.239	34.363	39.645
PtlL	9.419	7.364	6.165	45.399	0.781	0.219	5.601	36.057	40.779
LPdl	1.133	0.979	0.464	0.454	0.864	0.136	1.264	47.478	51.076
N FPS	0.011	0.008	0.010	0.000	0.727	0.273	0.727	24.845	29.133
L Pcl	41.948	30.860	33.264	1026.527	0.735	0.265	25.207	38.787	45.222
NoP	0.028	-0.018	0.138	-0.002	-0.642	1.642	-0.714	6.051	7.547
LoP	1.887	1.607	0.841	1.351	0.851	0.149	1.567	17.370	18.822
BoP	1.340	0.928	1.237	1,147	0.692	0.308	1.548	24.131	28.997
LoS	0.186	0.133	0.160	0.021	0.715	0.285	0.827	20.627	24.393
LoC	0.357	0.295	0.186	0.054	0.826	0.174	0.977	20.511	22.564
NoA	1.449	0.445	3.013	1.340	0.307	0.693	1.231	18.764	33.860
LoA	7.782	6.899	2.649	18.275	0.886	0.114	3.234	17.818	18.924
BoA	0.069	0.008	0.183	0.001	0.115	0.885	0.130	25.124	73.786
PH	0.002	0.002	0.002	0.000	1.000	0.000	1.000	26.940	26.940

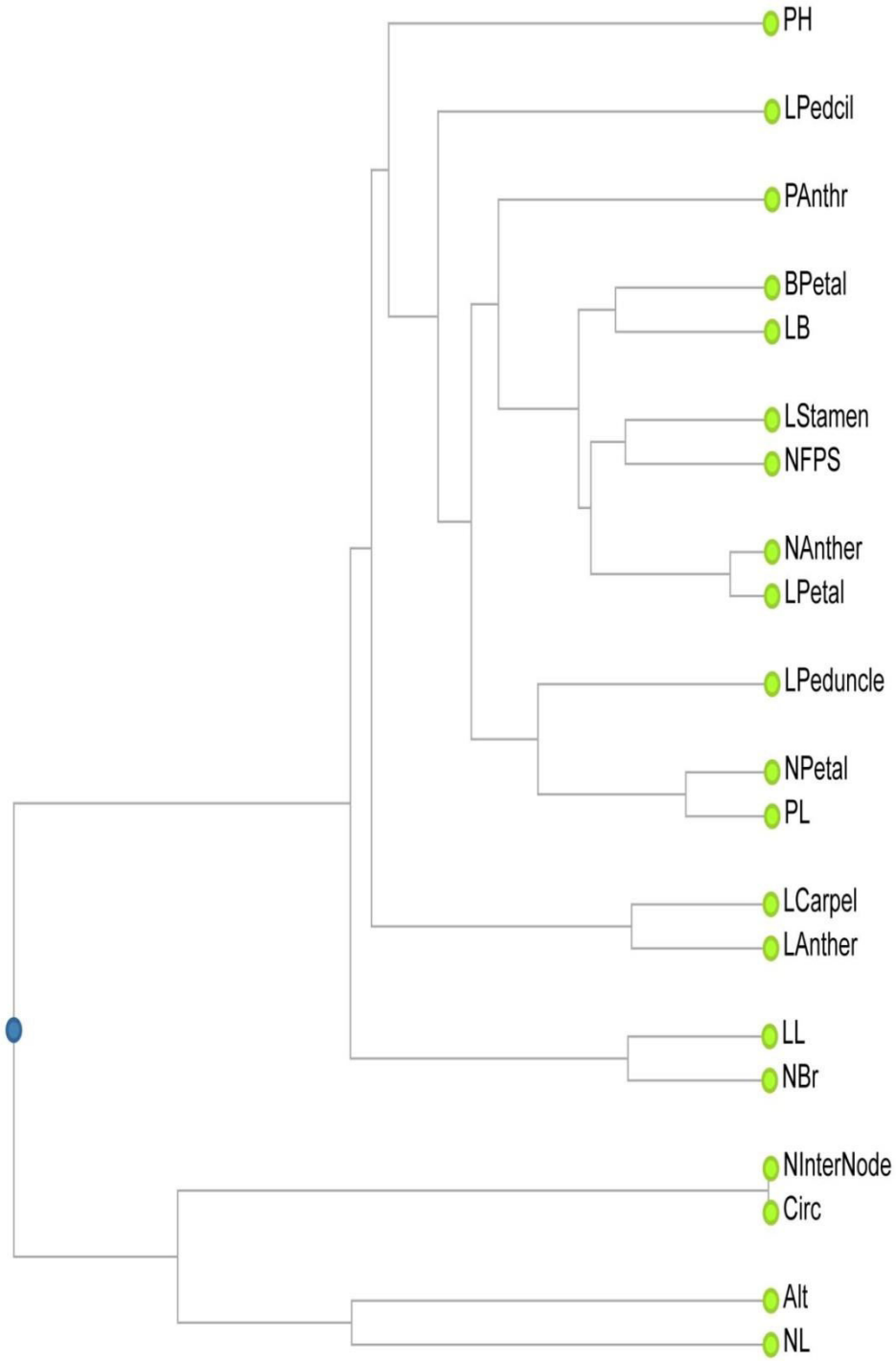


Fig. 19. UPGMA based on Pearson Correlation of morphogenetic traits of Rhododendrons of 3430 masl of Kiphire. (Cophenetic Correlation coefficient (CP) = 0.8914).

Table 46. Altitudinal observation of *Rhododendron* species and their density.

Altitude (masl)	*R.macabeanum*	*R.trifolium*	*R. formosum*	*R.arboreum*	*density/0.25 hectare*
Wokha					
1780	-	-	-	18	4.5~ 5
1854	-	-	-	14	3.5~ 4
1952	-	-	-	45	11.25~ 11
Kohima					
1653	-	-	-	33	8.25~ 8
2015	-	-	-	33	8.25~ 8
2284	-	-	83	178	65.25~ 65
Kiphiri					
2688	36	-	9	115	65.75~ 66
3112	101		12	16	32.25~ 32
3430	111	27	1	-	34.75~ 35
density/0.25 hectare	62	6.75~ 7	26.25~ 26	113	

Table 47. Altitudinal diversity of *Rhododendron.*

	Wokha	Kohima	Kiphire
Taxa (**Altitude**)	**3**	**3**	**3**
Individuals	77	327	428
Dominance D	0.4292	0.6574	0.3361
Simpson 1-D	**0.5708**	**0.3426**	**0.6639**
Shannon H	**0.9636**	**0.6428**	**1.095**
Evenness_ e^H/S	0.8737	0.634	0.996

Brillouin	0.9077	0.6269	1.08

	R.macabeanum	*R.trifolium*	*R.formosum*	*R.arboreum*
Menhinick	0.3419	0.1659	0.145	
Margalef	0.4604	0.3454	0.3301	
Equitability	0.8771	0.5851	0.9963	
Fisher alpha	0.6214	0.4562	0.4353	
Berger- Park	0.5844	0.7982	0.3738	
Chao-1	3	3	3	

Table 48. *Rhododendron* (species wise) diversity at three altitudes.

Taxa (**Altitude**)	**1**	**1**	**2**	**3**
Individuals	248	27	105	452
Dominance D	1	1	0.6688	0.4044
Simpson 1-D	**0**	**0**	**0.3312**	**0.5956**
Shannon H	**0**	**0**	**0.5133**	**0.9933**
Evenness_ e^H/S	1	1	0.8354	0.9
Brillouin	0	0	0.4909	0.9797
Menhinick	0.0635	0.1925	0.1952	0.1411
Margalef	0	0	0.2149	0,3771
Equitability			0.7406	0.9041
Fisher alpha	0.1327	0.2045	0.3505	0.4313
Berger- Park	1	1	0.7905	0.5398
Chao-1	1	1	2	3

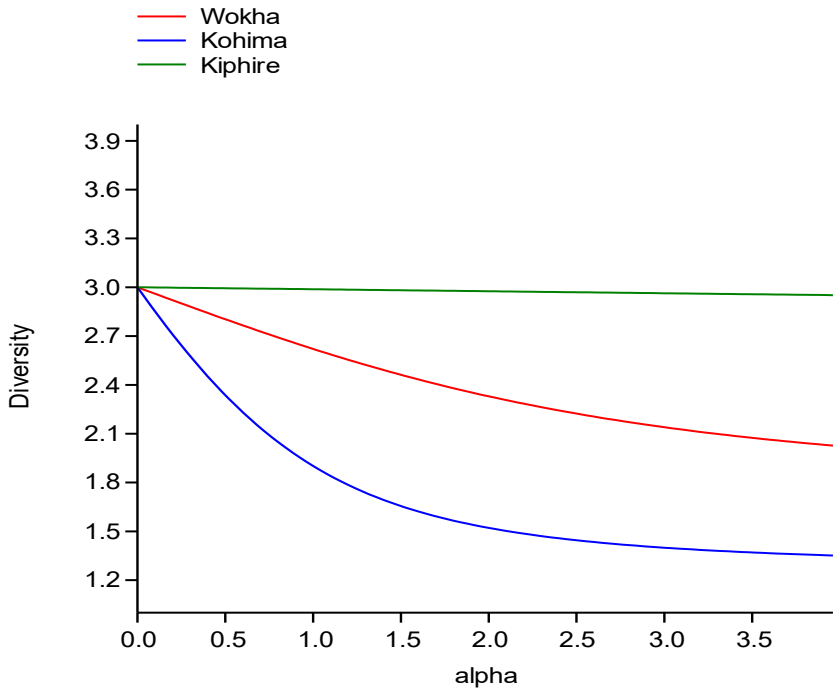


Fig. 20. Altitudinal diversity of *Rhododendron.*

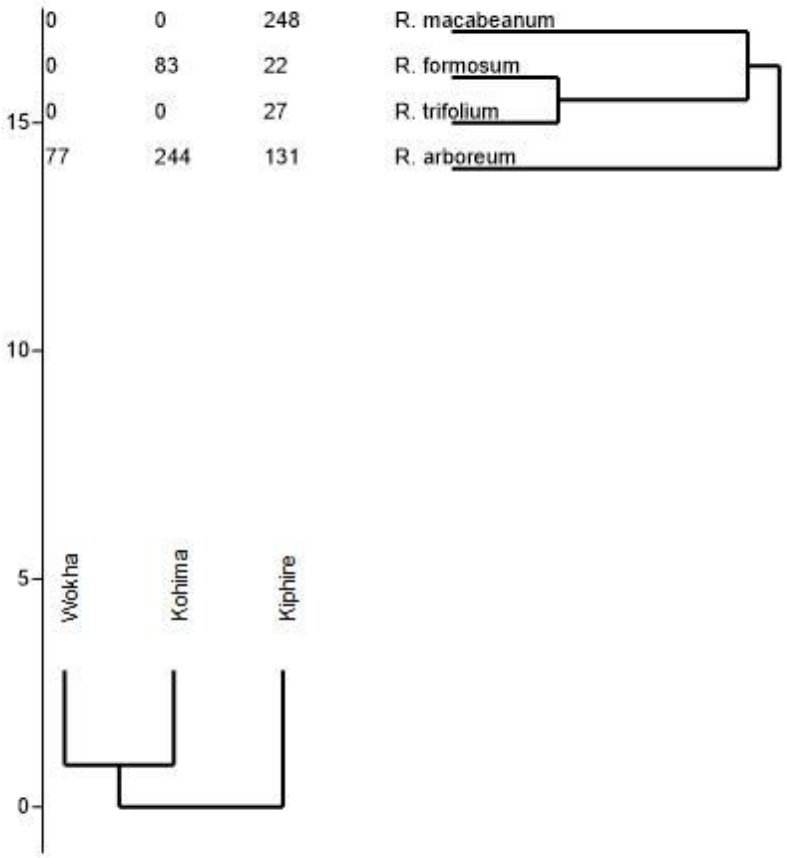


Fig. 21. Two way cluster analysis (Euclidean paired group) between altitude and *Rhododendron* species.

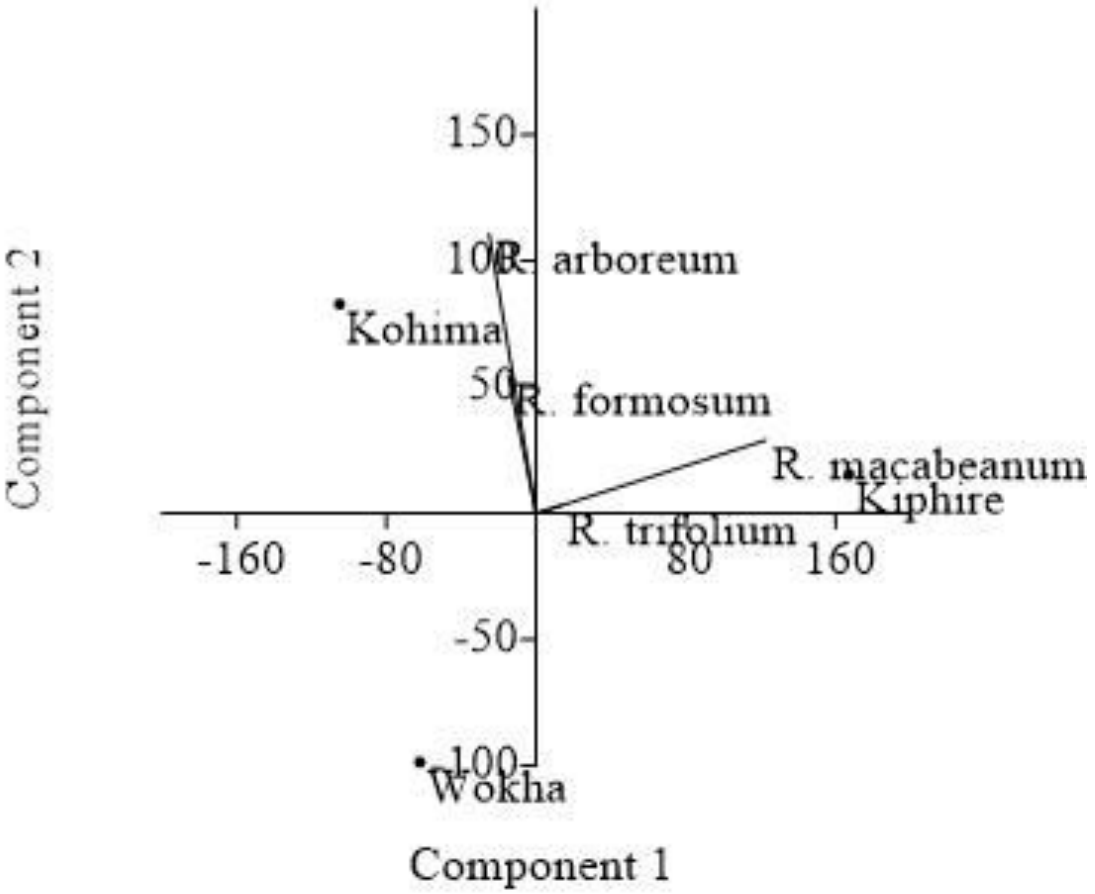


Fig. 22. Principal Component Analysis (biplot) between three districts and *Rhododendron* species.

(a)

(b)

Fig.23. *Rhododendron arboreum*, a) flower; and b) twig with beautiful flowers.

(a)

(b)

Fig.24. *Rhododendron formosum*, a) flower; and b) twig with beautiful flowers.

(a)

(b)

Fig.25. *Rhododendron triflorum*, a) flower; and b) branches with flower and leaf.

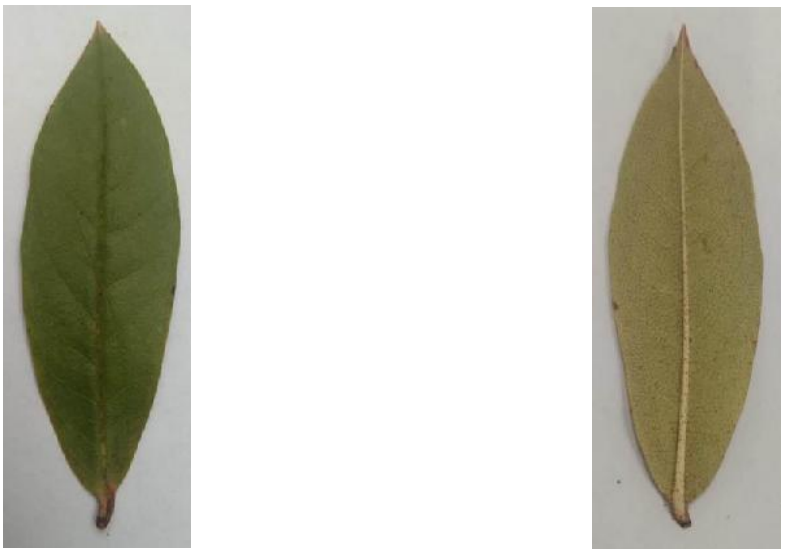
(a).

(b).

Fig.26. *Rhododendron macabeanum*, a) flower; and b) twig with beautiful flowers.

(a) (b)

Fig.27. *Rhododendron arboreum*, Leaf, a) Ventral surface; and b) Dorsal surface



(a) (b)

Fig.28. *Rhododendron formosum*, Leaf, a) Ventral surface; and b) Dorsal surface

(a) (b)

Fig.29. *Rhododendron triflorum*, Leaf, a) Ventral surface; and b) Dorsal surface

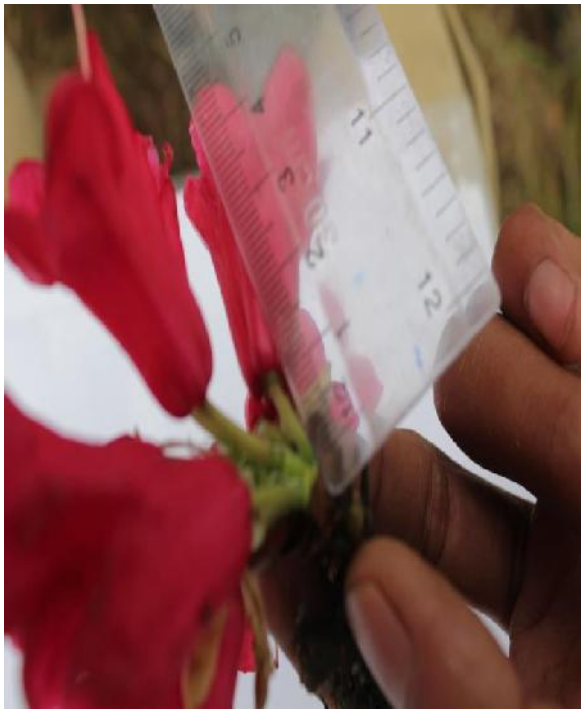
(a) (b)

Fig.30. *Rhododendron macabeanum*, Leaf, a) Ventral surface; and b) Dorsal surface

(a)

(b)

(c)



(d)

Fig.31. Field work at Mt. Tiyi, Wokha. Measurements (a) Quadrate, (b) Plant Height, (c) Petal Length, and (c) Length of Pedicel.

(a) **(b)**

(b) **(d)**

Fig.32. Field work at Mt. Puliebadze, Kohima. Measurements (a) Leaf Length, (b) Leaf Breadth, (c) Circumference, and (d) Length of Anther.

(a)

(b)

(c)

Fig.33. Field work at Mt. Saramati, Kiphire. Measurements (a) Number of trees, (b) Number of Flowers (c) Leaf Length, and (d) Altitude.

REFERENCES

Abebe, T., Wiersum, K. F., Bongers, F. 2009. Spatial and temporal variation in crop diversity in agro forestry home gardens of southern Ethiopia. *Agro forestry system* **78**:309-322.

Alelign, A., Teketay, D., Yemshaw, Y. and Edwards, S. 2007. Diversity and status of Regeneration of Woody Plants on the Peninsula of Zegie, Northwestern Ethiopia. *Tropical ecology* **48**(1): 37-49.

Arnaud-Haond, S., Teixeira, S., Massa, S., Billot, C., Saenger, P., Coupland, G., Duarte, C. and Serrao, E. 2006. Genetic structure at range edge: low diversity and high inbreeding in Southeast Asian mangrove (*Avicennia marina*) populations. *Molecular Ecology* **15**(12): 3515-3525.

Arora, R., Marian, C. O. and Krebs, S. L. 2003. Dehydrin variability among *rhododendron* species: a 25-kDa dehydrin is conserved and associated with cold acclimation across diverse species. *New Phytologist* **161**:773-780.

Atak, C., Celik, O. and Acik, L. 2011. Genetic analysis of *Rhododendron* mutants using random amplified polymorphic DNA (RAPD). *Pakistan Journal of Botany* **43**(2): 1173-1182.

Ayalew, A., Debebe, T. and Worku, A. 2011. Prevalance and risk factors of intestinal parasites among Delgi school children , North Gondar, Ethiopia, *Journal Parasitol Vector Biology* **3**(5): 75-81

Bhattacharya, D. and Sanjappa, M. 2008. *Rhododendron* habitats in India. *Journal of American Rhododendron Society* **62**(1): 14-18.

Bhattacharyya, D. 2011. *Rhododendron* species and their uses with special reference to Himalayas–a review. *Assam University Journal of Science and Technology* **7** (1): 161-167.

Burton, G. W. 1952. Quantitative inheritance in grasses. *Proceedings International Grassland Congress* **1**: 277-283.

Byers, S. G., Parsons, Y. and Hoffmann, A. A. 2009. Effect of altitude on the genetic structure of an Alpine grass, *Poa hiemata*. *Annals Botany* **103** :885-889.

Byers, D. 2008. Components of phenotypic variance. *Nature Education* **1**(1): 161.

Campbell, D. R. 2004. Natural selection in Ipomopsis hybrid zones: implications for ecological speciation. *New Phytologist* **161**(1): 83-90.

Campbell, D. R., Galen, C. and Wu, C. A. 2005. Ecophysiology of first and second generation hybrids in a natural plant hybrid zone. *Oecologia* **144**(2): 214-225.

Census, 2011. The twelve districts of Nagaland and their capitals, areas and elevations. (www.nagaland.nic.in)

Chamberlain, D. F. 1982. A revision of *Rhododendron* II. Subgenus *Hyemanthes*. *Notes Royal Botanical Garden Edinburg* **39**: 209-486.

Chamberlain, D. F. and Rae, S. J. 1990. "A revision of *Rhododendron* IV. Subgenus *Tsutsusi*." *Edinburgh Journal of Botany* **47**: 89-200.

Chamberlain, D. F., Milne, R. I., Abbott, R. J. and Wolff, K. 1999. Hybridization among sympatric species of *Rhododendron* (Ericaceae) in Turkey: morphological and molecular evidence. *American Journal of Botany* **86**(12): 1776-1785.

Chen, C., He, W., Nassirou, T. Y., Zhou, W., Yin, y., Dong, X., Rao, Q., Shi, H., Zhao, W., Efisue, A., Jin, D. 2016. Genetic Diversity and Phenotypic Variation in an Introgression Line Population Derived from an interspecific Cross between *Oryza glaberrima* and *Oryza sativa*. *PLoS ONE* **11**(9): eo161746.

Cullen, J. 1980. A revision of *Rhododendron* II. Subgenus *Hymenanthes*. *Notes Royal Botanical Garden Edinburgh* **39**(I): 1-207.

de Milleville, R. (2002). The Rhododendrons of Nepal. Himalayan Books, Katmandu, Nepal, pp.136.

Earl, D. A. and vonHoldt B.M. 2012. Structure Harvester: a website and program for visualizing structure output and implementing the Evanno method. *Conservation Genetic Resources* **4**: 359-361.

Espinosa, C. I. and Cabrera, O. 2011. What factors affect diversity and species composition of endangered Tumbesian Dry Forests in Southern Ecuador? *Tropical Biology and Conservation* **43**(1): 15-22.

Falconer, D. S. 1981. Introduction to quantitative genetics, 2nd Edition, Longmans Group Ltd.,London, pp.1-133.

Falconer, D. S. and Mackay, T.F.C. 1996. Introduction to Quantitative Genetics. 4th Edition, Addison Wesley Longman, Harlow.

Faria, R. and Navarro, A. 2010. Chromosomal speciation revisited: rearranging theory with pieces of evidence. *Trends in Ecology and Evolution* **25**(11):660-669.

Ghosh, R. B. and Samaddar, U. P. (1989). The Rhododendrons of the north-east India. *Journal of Economic and Taxonomic Botany* **13**(1):205-220.

Gibbs, D., Chamberlain, D. and Argent, G. 2011. The red List of Rhododendrons. Botanic Gardens Conservation International, Richmond, p. 128.

Goetsch, L., Ecker,t A. J. and Hall, B. D. 2005. The Molecular Systematic of *Rhododendron* (Eracaceae): A Phylogeny Based Upon RPB2 Gene Sequences. *Systematic Botany* **30**(3):616-626.

Hadado, T. T., Rau, D., Bitchhhi E. and Papa R. 2010. Adaptation and diversity along an altitudinal gradient in Ethiopian barley (*Hordeum vulgare* L.) landraces revealed by molecular analysis. *BMC Plant Biology* **10**(1): 121.

Henderson, I. R. and Salt, D, E. 2017. Natural genetic variation and hybridization in plants. *Journal of Experimental Botany* **68**(20): 5415-5417.

Jalata, Z., Ayana, A. and Zeleke, H. 2011. Variability, Heritability and genetic advance for some yield and yield related traits in Ethiopian Barley (*Hordeum vulgare* L.) Landraces and crosses. *International Journal of Plant Breeding and Genetics* **5**(1): 44-52.

Joshi, A. P. and Sharma, N. 2005. Flower power. *Rhododendron* is a health freak's delight. *Science and Environment Fortnightly, Down To Earth* **14**(3): 52.

Judd, W. S. and Kron, K. A. 1995. A revision of *Rhododendron* VI. subgenus *Pentanthera* (sections Sciadorhodion, Rhodora and Viscidula). *Edinburgh Journal of Botany* **52**: 1-54.

Jump, A. S., Hunt, J. M., Martínez-Izquierdo, J. A. and Penuelas, J. 2006. Natural selection and climate change: temperature-linked spatial and temporal trends in gene frequency in *Fagus sylvatica*. *Molecular Ecology* **15**(11): 3469-3480.

Kandedmir, G. E., Kandedmir, I. and Kaya, Z. 2004. Genetic variation in Turkish red pine (*pinus brutianTen*) seed stands as determined by RAPD markers. *Silvae Genetica* **53**:169-174.

Kant, A. 2004. Wildlife (the northeast travel special). *Sanctuary Asia* **24**: 67-84.

Kharwal, A. D. and Rawat, D. S. 2013. Ethnobotanical studies and distribution of different *Rhododendron* species in Himachal Pradesh, India. *Plant Sciences Feed* **3**: 46-49.

Koniarski, M. and Matysiak, B. 2013. Growth and development of potted *Rhododendron* cultivars 'Catawbiense Boursault' and 'Old Port' in response to regulated deficit irrigation. *Journal of Horticultural Research* **21**(1): 29-37.

Kron, K. A. 1993. A revision of *Rhododendron* section *Pentanthera*. *Edinburgh Journal of Botany* **50:** 249-364.

Lawrence, E. J., Griffin, C. and Henderson, I. R. 2017. Modification of meiotic recombination by natural variation in plants. *Journal of Experimental Botany* **68**: 5471-5483.

Levin, D. A. 2000. The origin, expansion, and demise of plant species. Oxford University, Print on Demand.

Li, Y., Yan, H.F. and Ge, X.J. 2012. Phylogeographic analysis and environmental niche modeling of widespread shrub *Rhododendron simsii* in China reveals multiple glacial refugia during the last glacial maximum. *Journal Systematic and Evolution* **50**(4): 362-373.

Li, Z., Lanying, Z. and Yongqing, W. 2008. Genetic Diversity and Relationship of *Rhododendron* species based on RAPD Analysis. *American Eurasian Journal of Agriculture and Environmental Sciences* **3**(4): 626-631.

Linnaeus, C. 1753. Species Plantarum, London. **1**: pp. 392.

Liu, X. Y., Shen, X.Q. and Zhang, Y. H. 2010. "Genetic relationship of nine hardy Rhododendrons by ISSR marker", *Acta Agriculturae Boreali-Occidentalis Sinica* **7**: 89-92.

Liu, Y., Zhang, L., Liu, Z., Luo, K., Chen, S. and Chen, K. 2012. Species identification of *Rhododendron* (Eraceae) using the chloroplast deoxyribonucleic acid PsbA-trnH genetic marker; A publication of phcog. *Net Pharmacognosy Magazine* **8(**29): 22-36.

Long, C. L., Wang, X. Q. and Huang, Y. 2009. Isolation and Characterization of Twenty-four Microsatellite Loci for *Rhododendron decorum* Franch. *Horticultural Science* **44**(7):2028-2030.

Mabberley, D. J. 2008." Mabberley's plant-book: A portable dictionary of plants, their classifications and uses,"2nd Edition, Cambridge University Press, Cambridge.

Mao, A. A. 2010. The genus *Rhododendron* in north-east India. *Botanica Orientalis: Journal of Plant Science* **7**: 26-34.

Mao, A. A. and Gogoi, R. 2007. Rediscovery of a critically endangered endemic *Rhododendron*. *Indian Forestry* **133**(12): 1699-1702.

Mao, A. A. and Gogoi, R. 2012. Rhododendrons of Manipur and Nagaland, India. *NeBIO-An International Journal of Environment and Biodiversity* **3**(1): 1-10

Mao, A. A., Gogoi, R. and Apang, O. 2009. Studies on *Rhododendron* species of Mayodia, Lower Dibang Valley, Arunachal Pradesh, India. *Bulletin of Arunachal Forest Research* **25**(1&2): 93-99.

Mao, A. A., Singh K.P. and Hajra, P. K. 2002. "Rhododendrons," In: N. P. Singh and D. K. Singh, Eds., Floristic Diversity and Conservation Strategies in India, BSI, Calcutta, pp. 2167-2202.

Mather, K. and Jinks, J. L. 1971. Biometric Genetics. Second edition. Chapman, London.

Mekonen, T., Ayele, B. and Ashagrie, Y. 2015. Woody Plant Species Diversity, Structure and Regeneration Status of Woynwuha Natural Forest, North West Ethiopia. *Asian Journal of Ethnopharmacology and Medicinal Foods* **1**(1): 3-5.

Ohkawa, T., Kitamura, K., Takasu, H. and Kawano, S. 2006. Genetic variation in *Fagus multinervis Nakai* (Fagaceae), a beech species endemic to Ullung Island, South Korea. *Plant Species Biology* **21**(3): 135-145.

Ohsawa , T. and Ide, Y. 2008. Global patterns of genetic variation in plant species along vertical and horizontal gradients on mountains. *Global Ecology and Biogeography* **17**(2): 152-163.

Okubo, H., Tagane, S. and Hiramatsu, M. 2008. Hybridization and asymmetric introgression between *Rhododendron eriocarpum* and *Rhododendron indicum* on Yakushima Island, southwest Japan. *Journal of Plant Research* **121**:387-395.

Paul, A., Khan, M. L., Arunachalam, A., and Arunachalam, K. (2005). Biodiversity and conservation of Rhododendrons in arunachal pradesh in the indo-burma biodiversity hotspot. *Current Science* **89**(4): 623-634.

Philipson, M.N. and Philipson W.R. 1956. A preliminary synopsis of the Genus *Rhododendron. Notes Royal Botanical Garden Edinburgh* **40**(1): 225-227.

Piersma, T. and Drent, J. 2003. Phenotypic flexibility and the evolution of organismal design. *Trends in Ecology and Evolution* **18**: 228-233.

Pigliucci, M. 2001. Phenotypic plasticity: beyond nature and nurture. 1st ed., John Hopkins University Press: Baltimore.

Pogorzelec, M ., Glebocka, K., Hawrylak-nowak, B. and Parzymies,M. 2014. Reproduction and diversity of the endangered *Salix lapponum* L. populations in Eastern Poland. *Turkish Journal of Botany* **38**: 1239-1247.

Pornon, A., Scaravage, N. E., Thomas, P. and Taberlet, P. 2000. Dynamics of genotypic structure in clonal *Rhododendron ferrugineum* (Eraceace) populations. *Molecular Ecology* **9**: 1099- 1111.

Pradhan, U. C. 1985. A preliminary enumeration of Rhododendrons of the Indian region. Part 1. *Himalayan Plant Journal* **3**(8): 110-123.

Pradhan, U. C. and Lachungpa, S. T. 1990. Sikkim-Himalayan Rhododendrons. Primulaceae Books, Kalimpong, Darjeeling, India.

Praveen, T. K., Razdan, R. and Satheesh, H. 2008. Effect of the aqueous extract of *Scoparia Dulcis* L. on CCL_4 induced cytochrome P_{450} damage in rats. *Pharmacologyonline* **3**: 8311-836.

Runions, C. J. and Geber, M. A. 2000. Evolution of the self-pollinating flower in *Clarkia xantiana* (Onagraceae). I. Size and development of floral organs. *American Journal of Botany* **87**(10): 1439-1451.

Sastry, A. R. K. and Hajra, P. K. 1983. "Rare and endemic species of *Rhododendron* in India-A preliminary study". In: S. K. Jain and R. R. Rao, An Assessment of threatened plants of India: BSI, Calcutta, pp. 222-231.

Schneller, J. and Liebst, B. 2007. Patterns of variation of a common fern (*Athyrim filix-femina*; woodsiaccae): Population structure along and between altitudinal gradients. *American Journal of Botany* **94**:965-971.

Seeni, S., Kuttapetty, M., Pillai P. and Varghese, R. 2014. Genetic diversity analysis in disjunct populations of *Rhododendron arboreum* from the temperate and tropical forests of Indian subcontinent corroborate Satpura hypothesis of species migration. *Biologia* **69**(3): 311-322.

Sharma, A., Poudel, R. C., Li, A., Xu, J. and Guan, K. 2014. Genetic diversity of *Rhododendron delavayi var. delavayi* (CB Clarke) Ridley inferred from nuclear and chloroplast DNA: implications for the conservation of fragmented populations. *Plant systematic and evolution* **300**(8): 1853-1866.

Sharma, J. R. 1988. Statistical and biometrical techniques in plant breeding. New Age International Limited Publishers, New Delhi, p.432.

Shaw, R. G. 1987. Maximum likelihood approaches applied to the Quantitative Genetics of Natural Populations. *Evolution* **41**(4): 812-826.

Shivasubramanian, S. and Menon, N. 1973. Heterosis and inbreeding depression in rice. *Madras Agricultural Journal* **60**: 1139-1144.

Singh, K. K., Kumar, S., Rai, L. K. and Krishna, A. P. 2003. *Rhododendron* conservation in Sikkim Himalaya. *Current Science* **85**: 602-606.

Sochor, M., Vasut, R. J, Bartova, E., Majesky, L. and Mracek, J. 2013. Can gene flow among populations counteract the habitat loss of extremely fragile biotopes? An example from the population genetic structure in *Salix daphnoides*. *Tree Genetics Genomes* **9**: 1193-1205.

Srivastava, P. 2012. *Rhododendron arboreum*: An overview. *Journal of Applied Pharmaceutical Science* **02**(01): 158-162.

Stocklin, J., Kuss, P. and Pluess, A. R. 2009. Genetic diversity, phenotypic variation and local adaptation in the alpine landscape: case studies with alpine plant species. *Botanica Helvetica* **119**(2): 125-133.

Sun H., Zha, H. G. and Milne R. I. 2010. Asymmetric hybridization in *Rhododendron agastum*: A hybrid taxon comprising mainly F_1s in Yunnan, China. *Annals of Botany* **105**(1): 89-100.

Taberlet, P., Escaravage, N., Questiau, S., Poronon, A. and Doche, B. 1998; Clonal diversity in a *Rhododendron ferrugineum* L. (Ericaceae) population inferred from AFLP markers; *Molecular Ecology* **7**: 975-982.

Thiel-Egenter, C., Gugerli, F., Alvarez, N., Brodbeck, S., Cieslak, E., Colli, L., Englisch, T., Gaudenl, M., Gielly, L. and Korbecka, G. 2009. Effects of species traits on the genetic diversity of high-mountain plants: a multi-species study across the Alps and the Carpathians. *Global Ecology and Biogeography* **18**(1): 78-87.

Truong, C., Palme, A. E. and Felber, F. 2007. Recent invasion of the mountain birch Betula pubescens ssp. *tortuosa* above the tree line due to climate change: genetic and ecological study in northern Sweden. *Journal of evolutionary biology* **20**(1): 369-380.

Ward, K. F. 1949. Plant hunting in Manipur. *Journal Royal Horticultural Society* **74**: 288-295.

Ward, K. F. 1960. Pilgrimage for Plants. George G. Harrap and Co. Ltd., London.

Watt, G. 1890. Forests of Manipur. *Indian Forestry* **14**:291-339 and 387.

Watt, G. 1892. Dictionary of economic products of India, pp.492-495.

Wei, H., Fu, Y. and Arora, R. 2005. Intron-flanking EST–PCR markers: from genetic marker development to gene structure analysis in *Rhododendron*. *Theoretical and applied genetics* **111**(7): 1347-1356.

Wroblewska, A. 2013. High genetic diversity within island-like peripheral populations of *Pedicularis sceptrum-carolinum*, a species with a northern geographic distribution. *Annales Botanici Fennici* **50**: 289-299.

Wu, C.I. 2001. The genic view of the process of speciation. *Journal of Evolutionary Biology* **14**: 851-865.

Census, 2011. The twelve districts of Nagaland and their capitals, areas and elevations. (www.nagaland.nic.in)

Xia, T., Chen, S., Chen, S., Zhang, D., Zhang, D., Gao, Q. and Ge, X. 2007. ISSR analysis of genetic diversity of the Qinghai-Tibet Plateau endemic *Rhodiola chrysanthemifolia* (Crassulaceae). *Biochemical Systematics and Ecology* **35**: 209-214.

Yan, X. B., Gao, Y. X., Zhao, C., Liu, F. Y and Lu, B.R. 2009. Intra-population genetic diversity of two wheatgrass species along altitude gradients on the Qinghai Tibetan Plateau: Its implication for conservation and utilization. *Conservation Genetics* **10**: 359-367.

Yang, J., Ma, Y., Milne, R. I. and Zhang, C. 2010. Unusual patterns of hybridization involving a narrow endemic *Rhododendron* species (Ericaceae) in Yunnan, China. *American Journal of Botany* **97**(10): 1749-1757.

Yumnam, J.Y. 2008. "Rhododendrons in Meghalaya Need Attention," *Current Science* **95(**7): 817-818.

Zhang, J. L., Zhang, C. Q., Gao, L. M., Yang, J. B. and Li, H. T. 2007. Natural hybridization origin of *Rhododendron agastum* (Ericaceae) in Yunnan, China: inferred from morphological and molecular evidence. *Journal of plant research* **120**(3): 457-463.

Zhao, W., Fei, Y., Xing, M., Fan, R.J., Luo, S. and Chen, X. 2012. Genetic diversity analysis of *Rhododenron aureum Georgia* (Ericaceae) located on Changbai Mountain using ISSR and RAPD marker. *Plant systematic and Evolution* **298**: 921-930.

List of Paper Publication

Kumar, S., Kithan, N. A. and Jamir, N. S. 2018. Altitudinal morphogenetic traits variation of Rhododendrons. *EurAsian Journal of BioSciences* **12**: 321-324.

Kumar, S., Kithan, N. A. and Jamir, N. S. 2018. Repeatability, Heritability and Environmentability of certain Quantitative traits Rhododendrons. *Journal of Cytology and Genetics* **19**: 7-15.

List of Paper/Poster Presented in Seminars/Conferences

1.' Altitudinal morphogenetic traits variation of Rhododendrons': ICPEP-6, Sixth International Conference on Plants & Environmental Pollution Organized by International Society of Environmental Botanists (ISEP) & CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow-226001, India. November 27-30, 2018.

2. 'Repeatability, Heritability and Environmentability of certain Quantitative traits Rhododendrons': National Symposium on Current Trends and Future Prospects in Plant Science Research, Centenary Year Celebration, February 1-3, 2019. Centre of Advanced Study, Department of Botany, Institute of Science, Banaras Hindu University, Varanasi-221005.

List of Seminars/Conferences attended

1.National Workshop on 'Scientific Writing, Research Communication and IPR Issues' Organized by Institutional Biotech Hub & Department of Botany Nagaland University, Lumami 798627, Nagaland. August 28-29, 2014.

2.National Worship on Applications of Biotechnology Tools and Bioinformatics' Jointly Organized by Institutional Biotech Hub, Department of Botany & Bioinformatics Infrastructure Facility Centre Nagaland University, Lumami 798627, Nagaland. March 30- April 04, 2015.

3. National Conference of Stakeholders on Conservation, Cultivation, Resource Development and Sustainable Utility of Medicinal Plants of North-Eastern India. March 6-7, 2019. Jointly Organized by Department of Botany, Nagaland University, Lumami Nagaland & Society for Conservation and Resource Development of Medicinal Plants (SMP), New Delhi.