GENETIC DIVERGENCE IN KIRIYAT

(*Andrographis paniculata* Nees)

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"GENETIC DIVERGENCE IN KIRIYAT (*Andrographis paniculata* Nees)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

%	-	per cent
&	-	and
ANOVA	-	Analysis of Variance
DAS	-	Days After Sowing
DAT	-	Days After Transplanting
CD (0.05)	-	Critical Difference at 5 % level
cm	-	centimeter
m	-	meter
d.f	-	degrees of freedom
et al.	-	and co-workers/co-authors
Fig.	-	Figure
g	-	gram
FYM	-	Farm Yard Manure
GCV	-	Genotypic Coefficient of Variation
PCV	-	Phenotypic Coefficient of Variation
ECV	-	Environmental Coefficient of Variation
GAM	-	Genetic Advance as percentage of Mean
H^2	-	Heritability
V_G	-	Genotypic Variance
V_P	-	Phenotypic Variance
V_E	-	Environmental Variance
i.e.	-	that is
KAU	-	Kerala Agricultural University
SE	-	Standard Error
viz.	-	namely

INTRODUCTION

1. INTRODUCTION

Kiriyat (*Andrographis paniculata* Wall. Ex Nees) which is commonly known as King of Bitters (as the whole plant is extremely bitter in taste) belongs to family Acanthaceae. It is widely distributed in the tropical and subtropical regions of Asia and South East Asia. In India, the herb is found growing in Madhya Pradesh, Chhattisgarh, Odisha, Maharashtra, Assam, Bihar, West Bengal, Uttar Pradesh, Tamil Nadu and Kerala (Pandey and Mandal, 2010). In traditional Chinese, Unani and Indian systems of medicine, it is widely used to treat a variety of ailments due to its hepato-protective, hypoglyceamic, anti-bacterial, analgesic, anti-inflammatory, vermicidal and antipyretic properties.

As per Indian Pharmacopoeia, fresh and dried leaves as well as juice obtained by crushing the whole plant are the official drug (Pharmacopoeia, 1955). About twenty six ayurvedic formulations contain kiriyat as an ingredient. In traditional medicines against leprosy, gonorrhea, scabies, boils, skin eruptions, malaria and seasonal fevers this plant is the main component as it cools and relieves internal heat, pain and inflammation (Handa *et al.*, 1986; Madav *et al.*, 1995). The plant is also well known for its antioxidant, antimicrobial activity (Singha *et al.*, 2003) and its "blood purifying" capacity (Kabeeruddin, 1937).

Andrographolide, a diterpene lactone with a molecular formula, $C_{20}H_{30}O_5$ is the principal therapeutic component in the plant which makes it bitter (Saxena *et al.*, 1998). Along with this, another three lactones namely deoxyandrographolide, neoandrographolide and deoxydidehydro andrographolide are also present in kiriyat. Usually the plant is given in the form of infusion, decoction or powder, either alone or in combination with other medicinal plants. Nowadays kiriyat is used as a cheaper substitute for Chirayata (*Swertia chirayita* (Roxb.) an endangered plant of the Himalayan region. In international markets also it is fetching good attention as it is an

important ingredient in different medicines for treating cancer (Zhao *et al.,* 2008) and HIV infections (Calabrese *et al.,* 2000).

Andrographis genus consists of twenty eight species, of which few are medicinally important and kiriyat (*Andrographis paniculata,* 2n=50) is the most popular species. Although the plant is an annual (Mishra *et al.,* 2007; Sharma *et al.,* 2009) the different ecological and climatic conditions caused the plant to be introduced as a perennial (Prathanturarug *et al.,* 2007). It is an erect herb possessing quadrangular stem, leaves simple, petiolate, lanceolate, opposite and glabrous with slightly undulate margin, acuminate apex with a tapering base. Inflorescence is a terminal panicle or raceme. Flowers are small, complete, bisexual, zygomorphic, pentamerous and pedicillate. Corolla is white with purple spots with hairy outer surface. Calyx tube bears glandular hairs and consists of 5 sepals. Androecium consists of 2 stamens which are epipetalous and gynoecium is syncarpous with superior ovary containing many ovules in axile placentation and a single style with bifid stigma. Fruits are simple, dry dehiscent with marked central depression along the septa. Capsules are erect, linear or oblong, containing numerous seeds and are yellowish-brown in colour (Mishra *et al.,* 2007; Sharma *et al.,* 2009). The plant is mainly self pollinated as it is self compatible (Lattoo *et al.*, 2006), but outcrossing to the extent of 28 per cent has been reported (Sabu, 2002).

Although kiriyat is the main constituent in many Ayurvedic formulations and traditional drugs and also the estimated demand of this drug in our country alone is 1000 tons year^{-1}; its commercial cultivation is not yet practiced. In current situation, the plant is collected from forest areas and hence a wide variation in the total extractives could be seen among the plants collected from different ecosystems i.e., ecotypes (Raina *et al.,* 2013). As there is a huge demand for the plant, farmers can get better remuneration by cultivating the crop. Moreover trade in international markets requires drugs with uniform potency. Crop improvement in kiriyat is thus the

need of the hour. High yielding stable cultivars are imperative to meet the requirements of the drug industry. A thorough look at the germplasm is a prerequisite for crop breeding.

Therefore, the present study was aimed to determine genetic divergence of the germplasm and to identify the superior ecotypes of *kiriyat* in terms of herbage yield and quality which can be further used for crop improvement programmes.

The present investigation was undertaken with the following objectives:

1. To assess the genetic variability present in the natural ecotypes of Kiriyat (*Andrographis paniculata* Nees) collected from different sources.
2. Identifying the best ecotype in terms of herbage yield and total extractive.
3. To identify the nature of relationship among the yield and yield contributing characters
4. To understand the cause and effect relationship among the yield contributing traits

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present investigation on "Genetic divergence in kiriyat (*Andrographis paniculata* Nees)" is reviewed under different aspects. Since literature on kiriyat is scarce, the literature available on other medicinal plants with respect to various aspects is also reviewed here.

2. 1 VARIABILITY

Variability for different characters is a pre-requisite for the effective selection of genotypes from a population. A brief review on works related with variability for different characters in kiriyat (*Andrographis paniculata*) are presented here.

By studying different ecotypes of *Andrographis paniculata* collected from different parts of Asia, Padmesh *et al.* (1999) determined the intraspecific variability and found that total extractives from the different accessions exhibit significant variability.

On an evaluation with ten accessions of kiriyat, Paul (2000) concluded that there exists high variability for stem and leaf characters and also for total plant dry weight.

Misra *et al.* (2001) evaluated twenty two genotypes of *A. paniculata* from various parts of India for genetic variation in biomass yield and yield components by considering characters such as plant height, leaf length and width, leaf/stem ratio, and herbage yield and found that genotypes differed significantly.

An experiment with fifty four accessions of kiriyat collected from different parts South Asia was conducted by Sabu *et al.* (2001) and reported that there is a moderate level of genetic variation existing among kiriyat accessions.

In another study with thirty genotypes of *A. paniculata* collected from various regions of India, revealed significant genetic variation among the accessions for different plant traits along with the andrographolide content and total extractives (Misra *et al.*, 2003).

Maison *et al.* (2005) studied intraspecific variation in twenty five accessions of *A. paniculata* collected from different locations of Thailand and reported that there was significant variation among the accessions with respect to total extractives.

After evaluating the genetic diversity among twenty eight accessions of kiriyat, Prathanturarug *et al.* (2007) reported that there was a wide variability in herbage yield, dry weight and total extractives among the accessions.

Comparative analysis of genetic diversity in *Andrographis paniculata* by Lattoo *et al.* (2008) using analysis of variance revealed significant differences in all the metric traits. He also concluded that there is sufficient diversity among them the accessions for total extractive.

In kiriyat, range of number of leaves seedling^{-1} (75 Days After Sowing-DAS) and seedling shoot length (75 DAS) were reported to be from 19.43 to 5.00 and 8.67 cm to 2.18 cm respectively, which indicated availability of wide variation for these characters (Panwar, 2009).

Sharma *et al.* (2009) conducted variability studies on a collection of fifteen *A. paniculata* genotypes from Chhattisgarh and adjoining states and found wide variations in yield components, andrographolide content as total extractives among the genotypes.

Andrographis paniculata collections from five different locations of Madhya Pradesh and Chhattisgarh were evaluated by Pandey and Mandal (2010) and found that growth characteristics were not significantly different but the total extractive was

significantly different among the germplasm collections. They observed the ranges of characters like plant height (60.20- 52.3 cm), leaf length (6.22- 5.84 cm), leaf width (1.98- 1.83 cm) etc.

Morphological variation and variation in total extractive of kiriyat were studied by Minz and Koche (2012) after collecting different accessions of *Andrographis paniculata* from different provinces of Chhattisgarh and they reported that there is a wide variation in metric characters along with the total extractives.

Sharma and Singh (2012) assessed genetic variability of twenty germplasm of *A. paniculata* and concluded that yield contributing characters showed significant variations among the accessions. They also revealed that the genetic advance were high for dry weight of herb plant^{-1}, fresh weight of herb plant^{-1} and total extractive.

Evaluation on important yield contributing biometric observations recorded from twenty four accessions collected from different regions of five districts of Chhattisgarh indicated that kiriyat accessions had wide range of genetic variation which could be exploited for germplasm improvement (Minz *et al.*, 2013).

Raina *et al.* (2013) studied thirty germplasm collections of *A. paniculata* and the result showed that there is a wide variability among the accessions for total extractable content on dry weight basis. Superior genotypes with high total extractive as andrographolide content were also identified.

Characterization and evaluation of forty four accessions of *A. paniculata* for nine important traits *viz.*, plant height, number of primary and secondary branches, leaf length, leaf width, herbage yield and total extractives was done by Kumar *et al.* (2014) and found that highest variability was for herbage yield (fresh weight basis) and for total extractives.

In a study conducted with different accessions of *A. paniculata* Devi (2016) reported that genotypes from different eco- geographical regions were grouped in different clusters which indicated there was no correlation between geographical and genetic diversity in kiriyat. Considerable divergence was observed for the character total extractive which contributed maximum to total genetic diversity. Days to 50 percent flowering and number of tertiary branches plant^{-1} were other two important characters that contributed to the total divergence.

Nagvanshi and Tirkey (2016) investigated genetic diversity in *A. paniculata* using twenty four genotypes by using analysis of variance and revealed that the collected accessions have significant difference among characters such as days to 50 per cent flowering, number of secondary branches, number of tertiary branches, leaf width, collar girth, plant duration, fresh and dry herbage yield.

Manjesh *et al.* (2016) reported that variability for qualitative traits was found to be limited after studying the genetic variability using twenty two genotypes of *A. paniculata* collected from different parts of India with respect to morphological traits, yield, total extractives in terms of andrographolide content.

2. 2 COEFFICIENT OF VARIATION

Comparison of variability among different characters can be made in terms of coefficient of variation which is a unit free measurement of variation.

Misra *et al.* (1998a) studied coefficients of variation for six quantitative characters in thirty seven accessions of ashwagandha (*Withania somnifera*) and found that dry root yield was having highest phenotypic and genotypic coefficients of variation which was followed by plant canopy and the trait, plant height was having the lowest.

After studying the pattern of genetic variation for different traits in kiriyat accessions, Misra *et al.* (2001) recorded highest phenotypic and genotypic coefficient of variation for dry biomass yield followed by leaf/stem ratio and plant height; while these values were lowest for leaf length.

From a genetic divergence study using eighty three genotypes of turmeric collected from different parts of India, Verma *et al.* (2014) reported that both genotypic and phenotypic coefficient of variations were highest for number of tertiary rhizomes plant^{-1} followed by number of tillers/clump and number of secondary rhizomes plant^{-1}.

Genetic variability for nine yield attributing characters among thirty two accessions of *Withania somnifera* was studied (Yadav *et al.*, 2007) and concluded that the phenotypic and genotypic coefficient of variation was highest for root diameter and lowest for fresh weight of berries.

After evaluating fifteen sweet basil (*Ocimum basilicum*) genotypes collected from different parts of our country, Ibrahim *et al.* (2011) estimated PCV and GCV for all characters and found that PCV was higher than GCV indicating the influence of environment over the character. It was noticed that highest PCV was estimated for stem dry weight, oil content, oil yield and linear growth.

Sharma and Singh (2012) assessed genetic variability of twenty germplasm of *A. paniculata* and observed that the magnitude of phenotypic coefficients of variations were higher than genotypic coefficient of variations. Dry weight of plant was found to have highest PCV (20.23 %) and GCV (19.24 %). Medium range of values were observed for the following characters, i.e., for total extractive, PCV and GCV were 16.52 and 16.44 respectively, in the case of number of primary branches plant^{-1} it was 14.14 (PCV) and 7.34 (GCV) and for leaf length 11.62 (PCV) and 9.73 (GCV).

Raina *et al.*, (2013) reported that the coefficient of variation was highest (42-53 %) for *A. paniculata* accessions from Orissa. This indicated that diverse accessions of *A. paniculata* for total extractives occurring in this state would provide scope for germplasm improvement.

After evaluating forty four accessions of *A. paniculata* for nine important traits i.e., plant height, number of primary and secondary branches, leaf length, leaf width, herbage yield and total extractives, Kumar *et al.* (2014) reported that highest variability was for herbage yield on fresh weight basis (CV=16.95 %) and the coefficient of variation for total extractives was 13.34 % .

Singh *et al.* (2014) estimated PCV and GCV of some yield attributing characters in ashwagandha accessions and reported that PCV is slightly higher than GCV for all traits studied which indicated influence of environment over expression of traits. Root diameter and volume were the characters with high GCV and PCV which indicated the genetic variation for these characters in the genotypes studied. Coefficient of variation was highest for seed yield plant^{-1} while it is lowest for biological yield plant^{-1}.

Yield contributing characters in kiriyat such as herbage dry weight, total extractives, number of tertiary branches plant^{-1}, herbage fresh weight and plant height exhibited high GCV and PCV which indicated scope for yield improvement. For characters like stem diameter, leaf length, number of secondary branches, days to 50 percent flowering, and leaf width moderate GCV and PCV were recorded (Devi, 2016).

Phenotypic expression of the 24 accessions of kiriyat considered for study was influenced by environment, as PCV value was higher than the GCV for all the biometric characters under study. Number of tertiary branches exhibited highest GCV (49.72) and PCV (50.10) followed by dry and fresh herbage yields. For characters

like plant height, number of secondary branches and collar girth, GCV and PCV were moderate. Low GCV and was observed for characters such as days to 50 percent flowering and leaf length (Nagvanshi and Tirkey, 2016).

2. 3 HERITABILITY AND GENETIC ADVANCE

Heritability in broad sense refers to the genetic variation present in the population in relation to the total observed variance. Genetic advance is a measure of genetic gain under selection.

High heritability along with high genetic advance is important for effective selection with respect to phenotypic performance. The estimation of broad sense heritability and genetic advance for different characters by different workers is reviewed below.

Misra *et al.* (1998a) studied heritability of six quantitative characters in 37 accessions of ashwagandha (*Withania somnifera*) and found that all the economic characters under study showed high heritability among which the highest was for plant canopy while the lowest for root length. Genetic advance (as percentage of mean) was highest for plant canopy and lowest for plant height.

Paul (2000) reported high heritability for all the characters related to herbage yield and andrographolide in terms of total extractives.

Heritability in the broad sense and the corresponding genetic advance were high for plant height and dry matter yield of kiriyat which indicated that these trait were governed by additive gene effect with low environment effect and there by offering a scope for genetic improvement by exercising selection. Other biometric characters were moderately heritable with moderate to low genetic advance indicating non additive gene effects (Mishra *et al.*, 2001).

By studying thirty genotypes of *A. paniculata,* Misra *et al.* (2003) reported that stem diameter and dry biomass yield exhibited high heritability and with high genetic advance. Hence it was concluded that these traits were governed by additive gene effects and the environmental influence over expression of these traits was negligible.

Kumar *et al.* (2008) studied genetic variability and correlation of nine yield determining factors in 32 genotypes of ashwagandha (*Withania somnifera*). Even if all the characters exhibited high heritability, number of berriesplant-1 showed highest and biological yield possessed lowest value. Genetic advance was highest for root diameter and berry yield had the lowest value.

Genetic variability for nine yield attributing characters among thirty two accessions of *Withania somnifera* was studied and found that all characters showed high heritability among which number of berries per plant was with highest value and for biological yield possessed the lowest value. Genetic advance was highest for the trait, root diameter and it was lowest for berries yield plant^{-1} (Yadav *et al.,* 2008).

On evaluating fifteen genotypes of sweet basil (*Ocimum basilicum*) Ibrahim *et al.* (2011) reported that highest broad sense heritability was for stem dry weight and herb dry weight which indicated the efficiency for their selection. The expected genetic advance for stem dry weight was 4.159 and that for linear growth was 10.313. Additive gene effect resulted in high genetic advance and heritability (broad sense) estimates for linear growth, stem dry weight, herb dry weight and oil content.

Sharma and Singh (2012) assessed genetic variability of twenty germplasm of *A. paniculata* and found that heritability was high for total extractive content (99.0 %) followed by fresh weight (98.0 %) and dry weight (90.0 %). Characters such as leaf length, days to 50 percent flowering and plant height were found to have a moderate heritability of 70.0 %, 67.0 % and 54.0 % respectively. The study also

revealed the genetic advance for characters like fresh weight plant^{-1} (50.61) and dry weight plant^{-1} (18.96). The expected genetic advance in percent of mean were high for dry weight, fresh weight and total extractive with values 37.67 %, 37.20 % and 33.70 % respectively.

In a study conducted to estimate genetic variability parameters in *A. paniculata* Nagvanshi (2014) reported that highest heritability estimated was 98.8 % for number of tertiary branches followed by 97.3 % for fresh herbage yield, 95.3 % for dry herbage yield, 89.1 % for days to 50 percent flowering, 88.0% for collar girth, 87.5 % for plant height, 67.5 % for leaf width and 63.1 % for number of secondary branches. Heritability for leaf length was only 22.1 %. These values of heritability indicated negligible influence by environment on phenotypes. Genetic advance (% mean) was moderate for collar girth, leaf width, number of secondary branches and days to 50 percent flowering with values of 29.44 %, 26.08 %, 20.39 % and 10.90 % respectively. Characters like leaf length and plant height had low genetic advance since they are governed by non additive gene action and so, heterosis breeding may be useful. High heritability as well as high genetic advance was observed for the characters like number of tertiary branches, dry and fresh herbage yields and plant height on per plant basis.

Estimation of heritability and genetic advance for different characters in ashwagandha (*Withania somnifera*) was carried out by Singh *et al*, (2014). Heritability (86.52 %) and genetic advance (55.88 %) for root diameter was highest among the characters studied. From this result they concluded that the additive gene action was predominant for these characters and so, selection may be very effective for these characters.

Verma *et al.* (2014) after evaluating eighty three genotypes of turmeric reported that high heritability was observed for number of leaves shoot^{-1} followed by

number of tertiary rhizomes plant^{-1}. Genetic advance was also high for these two characters which indicated the efficiency of selection over these economic characters.

In a study conducted with *A. paniculata* high heritability was recorded for the characters as days to 50 percent flowering (99 %), total extractives (99 %), plant height (98 %), herbage dry weight (98 %), herbage fresh weight (96 %), leaf length (84 %), number of secondary branches plant^{-1}(79 %) and stem diameter (63 %). Low heritability was observed for leaf width (11 %). High genetic advance (as % of mean) was observed for plant height (36.44 %), days to 50 percent flowering (33.94 %) and herbage dry weight (20.69 %); while it was moderate for herbage fresh weight (19.95 %) and low for number of secondary branches plant^{-1} (9.43 %), leaf length (2.36 %), stem diameter (0.76 %), total extractives (0.74 %) and leaf width (0.12 %) (Devi, 2016).

2. 4 ASSOCIATION OF CHARACTERS

Study of character association helps the breeder in fixing selection criteria for parental lines, such that selections will be effective in isolating the plants with desired combination of characters. Phenotypic correlation is the correlation of phenotypic values and is subjected to changes in the environment. It measures the environment deviation together with non-additive gene action. Genotypic correlation is the correlation of breeding value. Hence, knowledge of association between different characters is highly essential for planning a successful breeding programme.

2. 4. 1 Correlation Coefficient Analysis

A thorough understanding of correlation between yield and its component traits is essential for choosing the character for selection.

Genotypic and phenotypic correlations in ashwagandha were estimated by studying thirty six early generation selections from F_2 population obtained after wide

crosses and seven genotypes. It was found that root yield was exhibiting significant and positive correlation with plant height and number of branches (Kandalkar *et al.*, 1993).

Laxminarayan and Mukund (2003) conducted correlation studies in a collection of thirty different genotypes of ashwagandha collected from different states of India and reported that leaf length had significantly positive correlation with root yield, while collar diameter had a significant and positive correlation with root diameter.

Root yield plant^{-1} was significantly and positively associated with all component characters except for number of seeds berry^{-1} after evaluating thirty two genotypes of ashwagandha (*Withania somnifera)* Kumar *et al.* (2008) .

Yadav *et al.* (2008) investigated correlation among nine economical traits in thirty two genotypes of ashwagandha (*Withania somnifera*) and reported that root yield plant^{-1} was significantly and positively correlated with all other traits except for number of seeds/ berry.

After investigating correlations between yield parameters using ashwagandha (*Withania somnifera* Dunal) cv. Jawahar Asgandh-20, Kubsad *et al.* (2009) revealed the positive correlation between harvest index and dry root yield plant^{-1}. They also reported that plant height and dry matter plant^{-1} also exhibited a significant positive correlation.

Thirty four genotypes of African marigold (*Tagetes erecta* L.) collected from different parts of South India for investigating correlations between flower yield plant^{-1} and some important biometric traits. The results revealed that number of branches, flower diameter, flower size, flower weight; number of flowers plant^{-1}and xanthophylls content had positive and significant correlation with flower yield plant^{-1}. But, flower yield plant^{-1} was significantly and negatively associated with days

to first flowering. Therefore, indirect selection on the basis of characters such as number of branches plant^{-1}, days to first flowering, flower diameter, flower size, flower weight, number of flowers plant^{-1} and xanthophyll content would improve flower yield plant^{-1}. (Karuppaiah and Kumar, 2010).

Correlation studies conducted in ten Ajowan (*Carum copticum* L.) accessions from different regions of Iran revealed the existence of significant relationship between most of the economic characters under study, i.e. there was a significant and positive association between number of branches and number of umbels; plant height and number of umbellets; number of umbels and number of umbellets and biological yield and plant height. But, ripening period length had a significant negative association with single plant yield (Dalkani *et al.*, 2011).

The correlation analysis using thirty one genotypes of safed musli *(Chlorophytum borivilianu)* by Haque *et al.* (2011) with respect to the dependent character, root yield and seven independent yield determining characters indicated that there was a significant positive correlation between root yield and characters such as leaf number, leaf length and finger number.

Kumar *et al.* (2012) conducted correlation studies among a collection of 20 germplasm lines of *Ocimum* spp. and reported that for all the characters value of genotypic correlations were higher than phenotypic correlation values. Days to maturity was negatively correlated with herb yield while plant height was having a significant positive association with herb yield but negatively related with oil content and oil yield.

In an experiment with 280 crosses obtained from seven accessions of *Andrographis paniculata,* Valdiani *et al.* (2012) reported that there was a significant positive correlation between herbage yield and dry weights of shoot and leaf on per plant basis. It was also noticed that a positive correlation existed between total

extractives and leaf dry weight and leaf/stem ratio. But there was a negative correlation between shoot dry weight and total extractives.

Correlation between yield contributing biometric characters of *A. paniculata* was studied by Nagvanshi (2014) using 257 accessions. It was found that fresh herbage yield plant^{-1} had a significant positive correlation with plant height and dry herbage yield, but was negatively correlated with collar girth.

Verma *et al.* (2014) after evaluating eighty three genotypes of turmeric reported that the rhizome yield showed highly significant and positive correlation with weight of fresh rhizome followed by weight of mother rhizome and number of primary rhizomes (on per plant basis).

A correlation study conducted by Devi (2016) in 136 kiriyat accessions revealed that there was a significant positive relation between dry herbage weight and fresh herbage weight, plant height, stem diameter (cm) and number of secondary branches. But the total extractive was having a significant negative correlation with dry herbage yield.

2. 5 PATH COEFFICIENT ANALYSIS

Wright (1921) developed a statistical device called Path coefficient analysis which helps in partitioning of the correlation coefficients into direct and indirect effects of independent variable on dependent variable. As dry yield is a dependent character influenced by several factors, selection based on simple correlation without considering the component characters is not effective. Hence, path analysis is of much importance in any plant breeding programme. Correlation in combination with path analysis would give a better insight into cause and effect relationship between different pairs of characters.

Kandalkar *et al.* (1993) did path coefficient analysis in ashwagandha using thirty six early generation selections from F_2 population obtained after wide crosses and 7 genotypes. The result indicated the highest positive direct was exerted by plant height and indirect effect by number of branches on root yield. Hence, root yield can be improved through selection for high plant height and number of branches.

The path coefficient analysis for six quantitative characters using thirty seven accessions of ashwagandha (*Withania somnifera*) revealed that the characters, root diameter and root length contributed highest amount of direct and indirect contributions to root yield and hence it may form a good selection criterion for improvement of root yield (Misra *et al.*, 1998a).

Kumar *et al.* (2008) conducted path coefficient analysis with a collection of thirty two genotypes in association with nine economically important characters of ashwagandha (*Withania somnifera)*. Results indicated that highest direct and indirect contribution to root yield was determined by its root length and diameter and so, selection favouring long root and high root girth would improve yield.

Yadav *et al.* (2008) did path coefficient analysis using thirty two genotypes of ashwagandha (*Withania somnifera*) and reported that highest direct contribution to root yield was by root length and that root diameter made the highest indirect contribution to root yield. Hence, indirect selection for root length and root diameter would improve root yield.

Path coefficient analysis was conducted in Ajowan (*Carum copticum* L.) accessions in relation with the following characters like plant height, stem diameter, ripening period, number of umbels, number of leaflet, leaf length etc. and it revealed that all the characters had high direct effects on plant yield, of which plant height and umbel number exhibited high positive direct effects on single plant yield but leaflet number and ripening period had negative direct effects on plant yield. This suggested

that indirect selection over low number of leaflet and short ripening period may improve plant yield. Leaflet number exhibited a high indirect effect on single plant yield through plant height (Dalkani *et al.*, 2011).

Ibrahim *et al.* (2011) carried out path analysis of growth characters of sweet basil (*Ocimum basilicum*) with oil yield and revealed that herb dry weight had maximum positive direct effect on oil yield followed by oil content and leaf dry weight. But, the characters like number of primary branches, linear growth, leaf and stem dry weights had a negative direct effect on oil yield.

The path analysis in some yield contributing traits of *Ocimum* spp. revealed that there was a positive direct effect by herb yield and number of leaves per plant towards oil yield. Therefore, indirect selection based on number of leaves plant^{-1} would result in improvement on oil yield (Kumar *et al.*, 2012).

Sangwan *et al.* (2013) conducted path analysis in twenty six accessions of ashwagandha (*Withania somnifera)* and the study reported that total extractable content had highest positive direct effect on fresh root yield. Therefore, an effective selection for the character root weight would improve total extractable contents in genotypes.

Nagvanshi (2014) did the path coefficient analysis with 257 accessions of *A. paniculata* and revealed that characters like collar girth, number of secondary branches, dry herbage yield, plant height, days to 50 percent flowering and leaf width was not affected by the any other component character or environment. Hence, it was concluded that these factors had direct effects on herbage yield. Among the biometric characters, collar girth had highest significant positive direct effect in association with fresh herbage yield and the lowest positive direct effect was for number of tertiary branches. In the case of leaf length, there was a high negative direct effect on fresh herbage yield.

After performing path coefficient analysis in eight three genotypes of turmeric Verma *et al.* (2014) reported there was a high positive direct effect for fresh rhizome weight per plant followed by number of leaves shoot^{-1} over rhizome yield and this indicated the scope for indirect selection for improved yield based on number of leaves shoot^{-1}.

Path analysis in *A. paniculata* established that herbage fresh weight exhibited highest positive direct effect on herbage dry weight along with number of tertiary branches, plant height, leaf length and width. But, stem girth, number of secondary branches, total extractable content and days to 50 percent flowering were reported to have negative direct effects on herbage fresh weight (Devi, 2016).

2. 6 GENETIC DIVERGENCE:

D^2 statistics (Mahalanobis, 1936) measures divergence between populations. By assessing the genetic divergence between populations this technique indirectly help us in selecting desirable parents for crossing programme.

Misra *et al.* (1998b) evaluated the genetic divergence for six yield contributing characters among thirty seven accessions of ashwagandha (*Withania somnifera*) collected from different parts of India using Mahalanobis D^2 statistics. Based on D value, eight clusters were obtained and five genotypes, WS-1, WS-9, WS-20, WS-36 and WS-24 exhibited greater diversity from each other. Hence, crosses such as WS-1 × WS-9 or WS 1 × WS-24 would be the most productive material for exploiting heterosis in ashwagandha.

Jain *et al.* (2007) studied genetic divergence using Mahalanobis D^2 statistics in a collection of fifty five Ashwagandha (*Withania somnifera*) genotypes collected from different eco-geographic regions of India and based on the D^2 value genotypes were included in ten clusters. Highest inter-cluster distance was between cluster II

and IX (222.00) and lowest (33.02) was between clusters I and II. Fifteen genotypes were included in cluster I which was the largest group while cluster II and III contained nine genotypes. By selecting parents from cluster II and cluster IX hybridization programme would be more efficient in exploiting hybrid vigour.

Using Mahalanobis D^2 analysis genetic variability among thirty two genotypes of ashwagandha (*Withania somnifera*) was assessed by Yadav *et al.* (2007). They grouped the genotypes into five clusters in relation with D^2 value. The genotypes were randomly distributed into different clusters indicating the absence of any association between genotypes of the same agro-ecological condition. Genotypes in clusters II, IV and V were diverse and having higher mean values for all the characters studied and so parents for hybridization would be selected from these clusters in order to get high yielding recombinants.

Genetic divergence among eight genotypes of *Asparagus racemosus* obtained from different geographical regions of Uttarakhand was evaluated with the aid of Mahalanobis D^2 statistic after considering characters like shoot length, number of shoots, no. of fingers, length of single finger, fresh weight of single finger, dry weight, fresh root yield etc. On the basis of D^2 value, genotypes were grouped into four clusters among which cluster I and III was having the highest inter-cluster distance which indicated the presence of appreciable amount of diversity among the genotypes and it was concluded that genotypes from these two clusters can be selected as parents for hybridization programme (Gupta *et al.*, 2008).

Lattoo *et al.* (2008) assessed genetic diversity of fifty three kiriyat (*A. paniculata*) accessions from five eco-geographical regions in India following D^2 statistics and reported that there was significant difference in all the metric traits and inter-cluster distances indicating that there was considerable genetic diversity among the accessions. Based on D^2 values, the fifty three accessions got classified into five clusters. 31 accessions were included in cluster I, cluster II with 9, cluster III

contained 6, 2 in cluster IV and 5 accessions were included in cluster V. Genotypes in cluster III and V had wide diversity since inter-cluster divergence (6.85) between these two clusters was the highest.

Twenty one genotypes of basil (*Ocimum* spp.) obtained from different parts of India were grouped into five clusters based on D^2 values. Clusters I and II contained maximum genotypes (5) and least was in cluster IV (3). As the intra-cluster distance was maximum for cluster IV, it was concluded that genotypes in this cluster were more diverse. The inter-cluster distance was maximum between cluster I and IV (D2=5.461) which indicated that selection of genotypes from these clusters would result in heterosis (Sahu *et al.*, 2008)

Singh *et al.*, (2009) studied genetic divergence in isabgol (*Plantago ovata*) with the aid of D^2 statistics. Based on D^2 values they grouped eighty accessions of isabol into 7 clusters. Inter-cluster distances were higher than the intra cluster distances indicating the wide genetic variation among the clusters. Cluster I was included with 57 genotypes which was the largest cluster followed by cluster II (13). Highest intra-cluster distance is for cluster I i.e. 78.43. Maximum inter-cluster distance was between clusters IV and V.

Twenty accessions of *Nardostachys jatamansi* were evaluated for assessing the genetic diversity and based on D^2 values the accessions were grouped in three clusters. The inter-cluster distance was ranged from 3.84 to 12.24 among which maximum inter-cluster distances was observed between clusters 1 and 3 and so accessions included in these clusters were more diverse (Chauhan *et al.*, 2011).

Haque *et al.* (2011) conducted D^2 analysis for estimating genetic divergence in thirty one genotypes of safed musli *(Chlorophytum borivilianu)* after considering nine biometric characters. Based on the D^2 value, eight clusters of genotypes were obtained. Cluster VIII (nine genotypes) was having highest intra-cluster distance,

while highest inter-cluster distance was between cluster II and III. From the study they concluded that geographical diversity was not necessarily related with genetic diversity.

Evaluation of genetic variability in *A. paniculata* was done by Benoy *et al.* (2012) with the aid of D^2 statistic and reported inter-cluster distance was higher than intra-cluster distance which indicated the existence of greater diversity among the germplasm studied.

Priya *et al.* (2013) studied genetic diversity with a collection of fifty one genotypes of betel vine (*Piper betle*) for seven characters using Mahanalobis D^2 statistic and they grouped the genotypes into six clusters. Cluster I, the largest group contained twenty four genotypes. Cluster V and Cluster VI exhibited maximum inter cluster distance while the intra-cluster distance was maximum in Cluster II indicating the close relationship among the genotypes included in the cluster. Selections of parents from clusters with high inter and intra cluster distance will result in hybrids with greater vigour.

Thirty seven castor genotypes from different parts of India were used for assessing genetic divergence using D^2 statistics and these thirty seven genotypes were grouped into fourteen clusters. Cluster VI was the largest cluster with eighteen genotypes. Clusters VI and XIV was having the maximum inter cluster distance (D=30.42) which represented a wide genetic diversity among the genotypes studied. (Pachpute *et al.*, 2013).

Genetic diversity of *Andrographis paniculata* was studied by Wijarat *et al.* (2013) after collecting fifty three accessions from five eco-geograpic regions of India and reported that there was a great extent in genetic diversity for total extractive and andrographolide content among the genotypes studied.

Twenty one accessions of chilli were evaluated by Hasan *et al.* (2014) to assess genetic diversity in the species. Based on D^2 values for seven quantitative characters the genotypes were grouped into 6 clusters. Highest intra-cluster distance was observed in cluster I and genotypes included in clusters IV and V were having wide diversity as the inter-cluster distance between them was the highest among others (931.61).

Genetic diversity in Ashwagandha [*Withania somnifera* (L.)] was studied by Mishra (2014) after collecting forty five genotypes all over India and by using Mahalanobis D^2 statistic. After analysis, six clusters were obtained in which the maximum diversity was reported between cluster II and VI and genotypes from these clusters having high inter-cluster distance as parents in breeding programmes is highly beneficial.

Singh *et al.* (2014) grouped twenty one genotypes of ashwagandha (*Withania somnifera*) into five clusters after evaluating their diversity using D^2 statistic. Largest clusters were cluster II and cluster IV which included 5 genotypes. Intra- cluster distance was highest between cluster III and cluster I (6.779) and the lowest was between cluster IV and V (3.478). Highest intra cluster distance was observed for cluster III (3.324). High intra-cluster distance indicated a wider genetic diversity between genotypes that would result in an effective selection for crop improvement.

Genetic divergence among eighty three genotypes of turmeric collected from different parts of India was studied using D^2 statistic and on the basis of D value, 10 clusters were obtained. Cluster V was the largest cluster which contained 18 genotypes while cluster II was the smallest group with 2 genotypes. Cluster II exhibited maximum intra-cluster distance and cluster IX had maximum inter-cluster distance which was followed by cluster I (Verma *et al.*, 2014).

Mahanalobis D^2 statistics was carried out for the estimation of genetic variation among forty accessions of ashwagandha (*Withania somnifera*) and on the basis of D^2 values, 6 clusters were obtained. Cluster I was included with thirty genotypes and was the largest group. Highest inter-cluster distance was between cluster II and cluster VI, followed by the distance between clusters II and III. Intra cluster distance was maximum in cluster III and minimum in cluster I (Joshi *et al.,* 2015).

Devi (2016) carried out evaluation of genetic diversity using 136 genotypes of *A. paniculata* and based on D^2 value the genotypes were grouped into twelve clusters. 47 genotypes were included in the cluster, i.e. cluster III. Inter-cluster distance was highest between cluster VII and X (1882.208) while intra-cluster distance was highest for cluster XI (531.957). From the study it was concluded that the genotypes from different region were independent of their genetic origin.

Evaluation of genetic variability in G*arcinia gummi – gutta* in Central Kerala was done by Manivannan *et al.* (2016) with 120 genotypes of garcinia. Based on D^2 value, 7 clusters were obtained. Inter-cluster distance was higher than intra-cluster distance which indicated the existence of greater diversity among the germplasm studied.

Twenty four kiriyat accessions were evaluated by Nagvanshi and Tirkey, 2016 using D^2 statistic and they obtained 5 clusters among which the cluster II had the largest number of accessions (7) while cluster V contained the least number (1). Cluster III and IV showed wider diversity among the groups as the inter cluster distance between these two clusters was the highest. The highest intra cluster distance was observed for cluster II. As the inter cluster distance was higher than intra cluster distance, it was concluded that there was a wide range of variability among the genotypes and thus there exist scope for plant improvement.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram during 2015-2017 to estimate the genetic divergence in kiriyat (*Andrographis paniculata* Nees). The experimental field was situated at a latitude and longitude of 8.4344^0 N and 76.9917^0 E respectively and found to have an average annual rainfall of 1835 mm with an average temperature of 27^0 C.

3.1 MATERIALS

The experimental materials consisted of thirty accessions of kiriyat, collected from different parts of India namely Gujarat, Karnataka, Kerala and Tamil Nadu and evaluated. The details of the accessions are given in Table 1.

3.2 METHODS

3.2.1 Design and Layout

The experiment was conducted in a Randomized Block Design with three replications adopting a spacing of 45 cm x 30 cm. Twenty plants were maintained in each treatment per replication.

3.2.2 Sowing and Cultural Operations

Seeds were sown in seed trays during May 2016 and seedlings were transplanted to the main field forty five days after sowing at the rate of one seedling per pit after incorporating farm yard manure. Irrigation was scheduled twice in a week during dry spell. Weeding was done once in forty five days interval as a good agricultural practice.

Table 1. List of kiriyat genotypes (*Andrographis paniculata* Nees)

Accession No	Place of collection	Accession No	Place of collection
A_1	Chithradurga, Karnataka	A_{16}	Alanalloor, Palakkad
A_2	Tala Kaveri, Karnataka	A_{17}	Mannuthy, Thrissur
A_3	Coimbatore, Tamil Nadu	A_{18}	Anand Kalmegh 1, Anand, Gujarat
A_4	Killikulam, Tamil Nadu	A_{19}	Kundapura , Karnataka
A_5	Cherpulassery, Palakkad	A_{20}	Pulppally, Wayanad
A_6	Padannakkad, Kasargode	A_{21}	Thamarassery, Calicut
A_7	Kottakkunnu, Malappuram	A_{22}	Puthukad, Thrissur
A_8	Anand local 1, Gujarat	A_{23}	Thalasserry, Kannur
A_9	Vellayani, Thiruvananthapuram	A_{24}	Kottiyam, Kollam
A_{10}	Aruvipuram, Thiruvananthapuram	A_{25}	Sreekandapuram, Kannur
A_{11}	Marthandam, Tamil Nadu	A_{26}	North Paravur, Ernakulam
A_{12}	Kayamkulam, Alappuzha	A_{27}	Anand Local 2, Gujarat
A_{13}	Mandya, Karnataka	A_{28}	Vaikkom, Kottayam
A14	Kottakkal, Malappuram	A_{29}	Ranni, Pathanamthitta
A15	Nilambur, Malappuram	A_{30}	Aranmula, Pathanamthitta

3.2.3 Biometric Observations

From each accession, five plants were randomly selected as observational plants and the average was recorded. Observations were recorded for seedling height at 15 days after transplanting (DAT) (cm), number of leaves seedling^{-1}, days to 50 percent flowering, number of primary branches, number of secondary branches, leaf length (cm), leaf width (cm), stem girth (cm), leaf/stem ratio, plant height, herbage yield (fresh weight) (g), yield plant^{-1} (dry weight) (g), duration and total extractives (quality parameter) (%).

3.2.3.1 Seedling Height (15 DAT) (cm)

The height of the seedling at 15 DAT was measured from ground level up to the tip of the main shoot and expressed in centimeters.

3.2.3.2 Number of Leaves Seedling^{-1}

Total number leaves seedling^{-1} was counted from the five randomly selected plants and mean value was recorded.

3.2.3.3 Days to 50 Percent Flowering

The number of days taken for the flowering of 50 per cent of the plants in each plot was counted.

3.2.3.4 Number of Primary Branches

At the time of flowering, branches produced by the main stem were counted from all the five observational plants.

Plate 1. General view of experimental field

a)

b)

3.2.3.5 Number of Secondary Branches

At the time of flowering, branches borne on the primary branches were counted.

3.2.3.6 Leaf Length (cm)

The average length of five mature leaves with pedicel at the time of flowering were randomly selected from the 5th secondary branch on the 5th primary branch of observational plants were calculated and expressed in centimeters.

3.2.3.7 Leaf Width (cm)

The average width of five mature leaves from the five randomly selected plants from which the length was observed was taken at the time of flowering and expressed in centimetres.

3.2.3.8 Stem Girth (cm)

At the time of flowering, stem girth of observational plants were measured at the collar region and expressed in centimeters.

3.2.3.9 Leaf/Stem ratio

Immediately after harvest, leaves of five randomly selected plants were removed from stem. Stem and leaves plant^{-1} were weighed separately and ratio was calculated (weight of leaves/weight of stem).

3.2.3.10 Duration

It was recorded as numbers of days from date of sowing to the date at which seeds became mature.

Plate 2. Kiriyat plant

a

b

c

d

a) Shoot tip b) Inflorescence c) Pods d) Whole plant

3.2.3.11 Plant Height

The height of the plant was measured in centimeters as the maximum height of the plant obtained from the base to the tip of the top most primary branch at the time of harvest.

3.2.3.12 Herbage Yield (g)

Weight of whole plant was taken from the five randomly selected plants immediately after harvest and the average was recorded.

3.2.3.13 Yield Plant^{-1} (g)

The observational plants were washed and shade dried for 10 days and then kept separately in paper envelope for oven drying at 50^0 C for 24 hours. The dried plant was then weighed separately and average was noted.

3.2.3.14 Total Extractives (%)

Oven dried plants were finely powdered and 100 grams of sample was taken from each accession for soxhlet extraction using acetone as the solvent.

3.3 STATISTICAL ANALYSIS

3.3.1 Analysis of Variance (ANOVA)

The analysis of variance (Panse and Sukhatme, 1967) was carried out for all biometric characters recorded from the field evaluation for comparison among the ecotypes and to estimate variance components as given below.

Sources of variation	Degrees of freedom	Sum of squares	Mean square	F ratio
Replications	t-1	SSR	MSR	MSR/MSE
Treatment	r-1	SST	MST	MST/MSE
Error	(r -1)(t -1)	SSE	MSE	
Total	rt-1	TSS		

Where,

r = number of replications

t= number of treatments

SSR =sum of squares for replications

MSR=mean squares for replication

SST =sum of squares for treatments

MST=mean squares for treatments

SSE =sum of squares for error

MSE=mean squares for error

TSS = Total sum of squares

Critical difference (CD) = $t\alpha\sqrt{\frac{2\times MSE}{r}}$

Where,

tα = table value of students' distribution at error degrees of freedom

α = level of significance (5 % or 1 %).

3.3.2 Estimation of Genetic Parameters

3.3.2.1 Genetic Components of Variance

Phenotypic and genotypic components of variances were estimated for each character, by equating the expected value of mean squares (MS) to the respective variance components (Jain, 1982). Based on this, the following components of variance were estimated.

i. Genotypic variance (V_G) $\quad V_G = \frac{MST - MSE}{r}$

i. Phenotypic variance (V_P) $\quad V_P = V_G + V_E$

iii. Environmental variance (V_E), $V_E = MSE$

3.3.2.2 Coefficients of Variation

On the basis of estimates of components of variances namely, genotypic, phenotypic and environmental the coefficients of variation for all the characters were calculated and were expressed in percentage.

i. Genotypic coefficient of variation, $GCV = \sqrt{\frac{V_G}{\overline{X}}} \times 100$

ii. Phenotypic coefficient of variation, $PCV = \sqrt{\frac{V_P}{\overline{X}}} \times 100$

Iii. Environmental coefficient of variation, $ECV = \sqrt{\frac{V_E}{\overline{X}}} \times 100$

Where, $\overline{X}$ = grand mean

Based on the value of coefficients of variation, different categories of range of variation were followed as reported by Sivasubramanian and Menon (1973).

Low : Less than 10 %

Moderate : 10 to 20 %

High : More than 20 %

3.3.2.3 Heritability

Proportion of genotypic variance to the total observed variance in the total population is referred as heritability in the broad sense. It was calculated and expressed in percentage (Allard, 1999).

$$\text{Heritability, } H^2 = \frac{V_G}{V_P} \times 100$$

Range of heritability estimates were categorized by Johnson *et al.* (1955) as

Low : Less than 30 %

Medium : 30 to 60 %

High : Above 60 %

3.3.2.4 Genetic advance

Genetic advance refers to the expected genetic gain or improvement in the next generation by selecting superior individuals under certain amount of selection pressure. Genetic advance was estimated using the heritability estimates by the following formula (Fehr *et al.*, 1987).

$$GA = k.H^2\sqrt{V_P}$$

Where k= Standardized selection differential (2.06 at 5 % selection intensity).

For visualizing the relative utility of genetic advance among the characters, genetic advance as percent of mean was also estimated.

$$\text{GA as percent of mean} = \frac{GA}{\overline{X}} \times 100$$

The range of genetic advance as percent of mean was classified according to Johnson *et al.* (1955).

Low	:	Less than 10 %
Moderate	:	10-20 %
High	:	More than 20 %

3. 3. 3 Correlation Analysis

Character association refers to the association of characters which estimates the magnitude and direction of change of one character with respect to the change in another character.

Genotypic and phenotypic correlation coefficients were calculated using the formulae suggested by Falconer (1964).

$$\text{Genotypic coefficient of correlation } (r_G) = \frac{COV_G\,(X, Y)}{\sqrt{V_P\,(X).V_P\,(Y)}}$$

$$\text{Phenotypic coefficient of correlation } (r_P) = \frac{COVp\,(X, Y)}{\sqrt{V_G\,(X).V_G\,(Y)}}$$

Where, COV_P (X,Y) and COV_G (X,Y) respectively denotes the phenotypic and genotypic co-variances between the two traits X and Y. V_P(X) and V_G(X) denotes the phenotypic and genotypic variance for X and V_P(Y) and V_G(Y) indicate the phenotypic and genotypic variance for Y respectively.

3. 3. 4 Path Analysis

Path analysis is a standardized partial regression coefficient which explains cause and effect relationship among the variables (Wright, 1960). It measures the direct effect of one independent variable upon dependent variable and other independent variables. It divides correlation coefficients into components of direct and indirect effects (Dewey and Lu, 1959). This method permits the breeder to identify relatively important components of a variable, on the basis of their direct and indirect influences.

The set of equations obtained from the path diagram were solved to get the information on the direct and indirect contribution of the casual factors on the effect.

The residual effect is computed as $R = 1 - (r_{Y1}.P_{Y1} + r_{Y2}.P_{Y2} + ... + r_{Yn}.P_{Yn})$

$$R = 1 - \sum(r_{Yi}.P_{Yi})$$

Where 'r' is the correlation between various traits and the direct effect of X_1 on Y is P_{12} and so on. Indirect effect of X_1 on Y depends on other correlated factors.

The direct and indirect effects were classified based on the scale given by Lenka and Mishra (1973).

>1.0	–	Very high
0.3 - 0.99	–	High
0.2 – 0.29	–	Moderate
0.10- 0.19	–.	Low
0.00 – 0.09	–	Negligible

3. 3. 5 D^2 Analysis

The assessment of genetic variability present among different genotypes is one of the potent tools of measuring genetic divergence in various breeding materials. Genetic diversity arises due to geographical separation or due to genetic barriers of crossability. The genetic divergence of the ecotypes was studied using Mahalanobis D^2 statistic. The D^2 statistic measures the forces of differentiation at intracluster and intercluster levels. The genotypes were grouped into distinct clusters using their relative distances from each other (D^2 values).The accessions were clustered by Tocher's method.

RESULTS

4. RESULTS

Thirty genotypes of kiriyat (*Andrographis paniculata* Nees) were evaluated for various biometric characters. The field experiment was conducted for the evaluation of kiriyat genotypes and clustering them using Mahanalobis D^2 statistic. The results of present study are presented in this chapter.

4.1 ANALYSIS OF VARIANCE

Analysis of variance (Table 2) revealed that there was a significant differences among the thirty genotypes for all the biometric characters considered and these characters were seedling height (15 DAT) (cm), number of leaves seedling^{-1} (15 DAT), days to 50 percent flowering, number of primary branches, number of secondary branches, leaf length (cm), leaf width (cm), stem girth (cm), leaf/stem ratio, duration, plant height (cm), herbage yield (fresh weight) (g), yield plant^{-1} (dry weight) (g) and total extractives (%).

4.2 MEAN PERFORMANCE OF ACCESSIONS

From the mean value obtained for various biometric characters, it was observed that there was considerable variation among all the thirty genotypes for the characters under study (Table 3).

Seedling height (15 DAT) ranged from 7.53 to 13.70 cms. The highest value was recorded for accession A_{10} (Aruvippuram) which was statistically on par with A_7 (13.27 cm), A_{18} (13.20 cm), A_{14} (13.17 cm) and A_5 (13.13 cm). The seedling height was lowest for the accession A_{16} (Alanalloor). However, accessions A_2 (7.57 cm), A_4 (7.63 cm), A_{12} (7.87 cm), A_6 (8.03 cm) and A_{29} (8.13 cm) were statistically on par with it.

Table 2. Analysis of variance of 14 characters in thirty genotypes of kiriyat

Sl. No.	Characters	Mean square		
		Genotypes	Replication	Error
1	Seedling height (15 DAT) (cm)	12.70**	1.16	0.16
2	Number of leaves seedling^{-1} (15 DAT)	10.96**	6.21	2.25
3	Days to 50 percent flowering	606.73**	5.06	9.27
4	Number of primary branches	73.67**	5.70	3.05
5	Number of secondary branches	429.38**	5.57	6.15
6	Leaf length (cm)	20.93**	0.33	1.81
7	Leaf width (cm)	1.52**	0.06	0.02
8	Stem girth (cm)	1.66**	0.01	0.01
9	Leaf/stem ratio	0.16**	0.02	0.01
10	Duration (days)	176.43**	3.93	8.29
11	Plant height (cm)	765.46**	3.94	2.86
12	Herbage yield (g)	1550.27**	39.54	309.25
13	Yield plant^{-1} (g)	120.75**	3.54	3.92
14	Total extractives (%)	10.63**	0.30	0.66

** Significant at 1 percent level

* Significant at 5 percent level

Number of leaves seedling^{-1} (15 DAT) was highest for the accession A_{15} (Nilambur) (12.33) which was statistically on par with accessions A_{10} (11.67), A_{27} (11.33), A_{14} (10.67), A_{18} (10.67), A_{23} (10.67) and A_7 (10.33). The accession A_1 (Chithradurga) (5.67) had the lowest number of leaves seedling^{-1}. Accessions A_{19} (6.00), A_{17} (6.00), A_{16} (6.00), A_{25} (6.00), A_{12} (6.33), A_8 (6.67), A_{26} (6.67), A_2 (7.00), A_4 (7.00), A_{13} (7.00), A_{22} (7.00) and A_{30} (7.00) were statistically on par with it.

Days to 50 percent flowering was maximum for the accession A_{16} (Alanalloor) (142.33) which was statistically on par with A_{17} (141.67), A_{13} (141.00), A_{29} (140.00), A_{21} (139.67) and A_{26} (137.33). A_{10} (Aruvipuram) (98.67) was the earliest and was statistically on par with A_{23} (100.67), A_7 (101.00), A_{28} (102.67) and A_{24} (103.33).

The number of primary branches ranged from 14.33 to 32.33. Accession A_{10} (Aruvipuram) had the highest number of primary branches. However, accessions A_{27} (32.00), A_{18} (31.33) and A_{28} (29.67) were statistically on par with it. It was least for A_3 (Coimbatore) and A_{16} (Alanalloor). Accessions A_1 (17.00) and A_{11} (16.33) were statistically on par with A_3 and A_{16}.

Maximum number of secondary branches was recorded for accession A_{14} (Kottakkal) (155.67). None of the accessions was statistically on par with accession A_{14}. Minimum value was recorded for accession A_{25} (Sreekandapuram) (34.29) and was found to be statistically on par with accessions A_{23} (34.33), A_{30} (34.33), A_{13} (35.00), A_2 (35.33), A_{16} (35.33), A_{28} (35.33), A_1 (36.67), A_{29} (38.66), A_{20} (40.33) and A_{11} (41.66).

Mean value of leaf length ranged from 2.63 to 10.47 cms, i.e., it was highest for accession A_1 (Chithradurga) and A_{26} (9.26 cm), A_{27} (9.10 cm), A_{13} (9.06), A_{17} (9.06), A_{29} (8.70 cm), A_{12} (8.63 cm) and A_{19} (8.03 cm) were statistically on par with it. Lowest leaf length was reported for accession A_9 (Vellayani) which was

Table 3. Mean performance of thirty kiriyat accessions

Accession	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
A1	8.50	5.67	135.67	17.00	36.67	10.47	2.57	1.15	0.30	59.57	65.80	20.06	210.33	2.35
A2	7.57	7.00	127.67	20.67	35.33	7.60	2.20	0.85	0.30	41.20	61.23	18.68	200.67	4.47
A3	10.27	7.33	133.67	14.33	58.67	7.73	2.47	1.58	0.29	45.40	56.90	17.21	205.33	3.08
A4	7.63	7.00	123.67	27.67	46.00	7.57	1.73	0.90	0.45	38.33	61.67	18.80	194.33	4.85
A5	13.13	8.67	117.00	27.00	140.33	2.90	1.00	3.07	0.81	94.53	120.40	36.72	192.33	10.37
A6	8.03	7.33	122.00	26.67	47.33	4.37	1.03	1.53	0.35	47.73	71.53	21.81	197.67	9.83
A7	13.27	10.33	101.00	21.00	117.33	2.73	0.77	2.71	0.82	106.97	117.34	36.81	189.00	13.02
A8	12.30	6.67	118.00	26.00	59.67	4.10	1.50	2.32	0.78	44.87	95.78	32.64	200.67	9.11
A9	9.73	7.67	105.67	24.33	140.67	2.63	0.63	1.93	0.81	59.83	96.63	29.47	193.00	12.10
A10	13.70	11.67	98.67	32.33	145.00	2.97	0.67	2.76	0.85	105.43	137.25	37.79	182.67	13.59
A11	8.63	9.00	113.67	16.33	41.67	3.00	0.77	1.22	0.81	58.87	74.90	21.35	203.00	11.45
A12	7.87	6.33	131.67	24.00	47.33	8.63	2.47	2.44	0.28	48.60	65.96	18.61	210.33	7.66
A13	8.47	7.00	141.00	20.00	35.00	9.07	2.63	0.97	0.32	39.30	66.60	19.18	213.00	3.61
A14	13.17	10.67	106.33	29.33	155.67	3.13	1.23	2.96	0.93	104.60	127.22	37.58	198.33	13.05
A15	11.80	12.33	127.00	25.00	76.33	2.77	0.83	2.13	0.42	77.93	85.15	26.93	205.33	11.21
A16	7.53	6.00	142.33	14.33	35.33	7.33	2.40	0.97	0.32	41.77	57.77	17.83	212.00	2.52
A17	12.10	6.00	141.67	27.33	45.67	9.07	2.03	2.12	0.59	59.37	93.61	29.91	204.00	2.56
A18	13.20	10.67	109.33	31.33	95.33	3.17	1.17	2.25	0.86	96.57	107.27	33.51	203.00	11.80
A19	8.90	6.00	133.67	20.67	47.67	8.03	2.10	0.97	0.32	41.77	63.15	19.18	206.33	5.42
A20	8.63	7.67	125.33	26.00	40.33	5.63	1.37	2.54	0.50	78.63	103.40	31.55	205.00	8.32

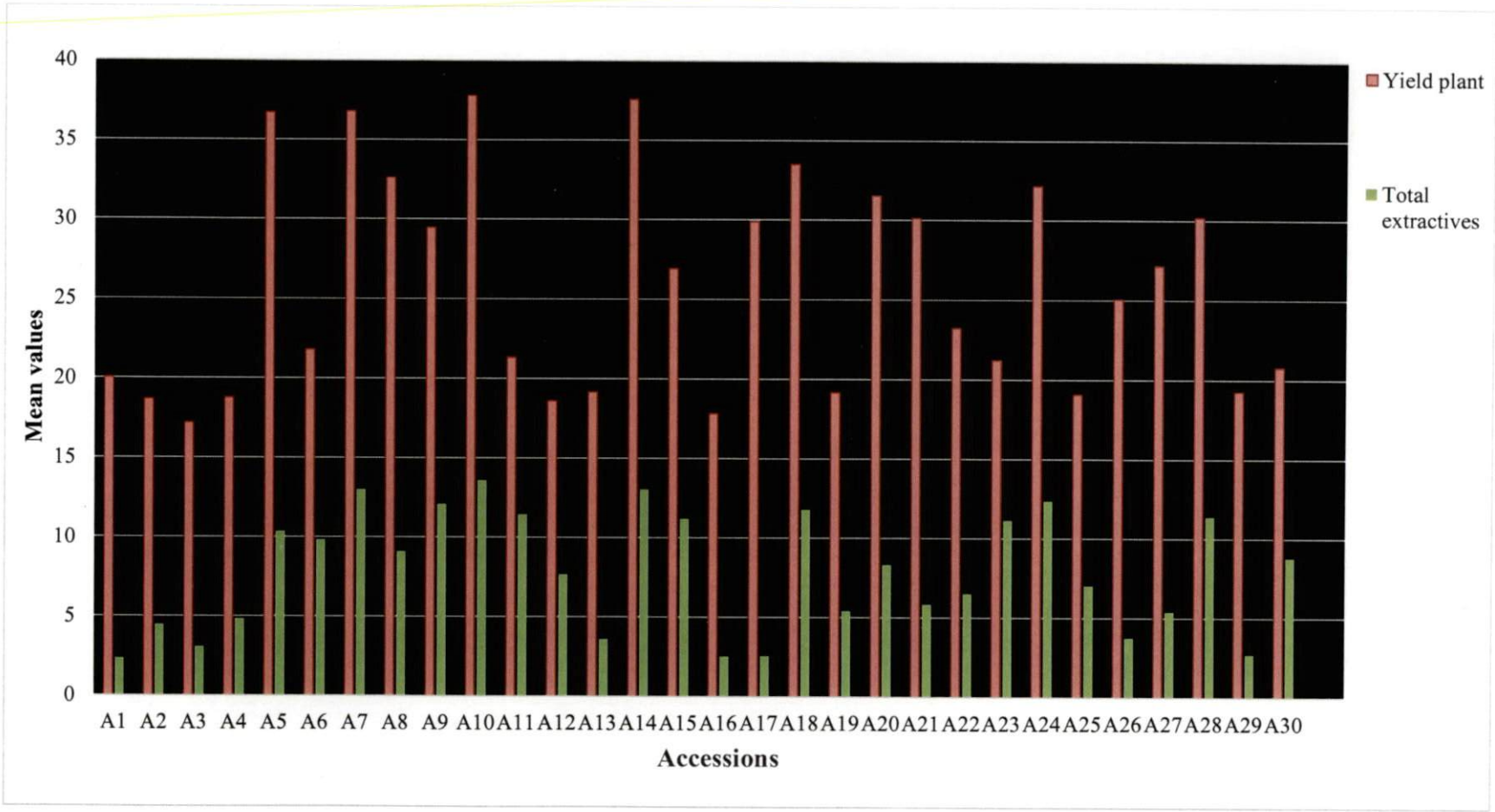
X1 Seedling height (15 DAT)(cm)
X2 Number of leaves seedling^{-1} (15 DAT)
X3 Days to 50 percent flowering
X4 Number of primary branches
X5 Number of secondary branches
X6 Leaf length (cm)
X7 Leaf width (cm)
X8 Stem girth (cm)
X9 Leaf/stem ratio
X10 Plant height (cm)
X11 Herbage yield (g)
X12 Yield plant^{-1} (g)
X13 Duration (days)
X14 Total extractives (%)

(Continued)

Accession	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
A21	10.60	8.67	139.67	21.33	49.67	7.47	2.50	1.83	0.68	68.23	95.26	30.14	210.00	5.83
A22	8.23	7.00	129.00	27.33	47.00	6.70	1.87	1.76	0.37	40.50	78.02	23.24	208.33	6.51
A23	11.00	10.67	100.67	24.00	34.33	2.83	1.20	1.89	0.57	70.43	64.98	21.23	195.33	11.16
A24	11.90	8.00	103.33	28.33	75.33	2.67	0.73	2.74	0.91	100.73	107.22	32.18	202.00	12.39
A25	10.03	6.00	127.33	25.00	34.29	6.73	2.67	1.18	0.40	50.87	59.50	19.09	210.33	7.03
A26	9.50	6.67	137.33	20.33	45.00	9.27	2.77	1.61	0.30	38.83	82.20	25.07	210.33	3.76
A27	12.23	11.33	137.00	32.00	71.67	9.10	2.07	2.64	0.79	98.17	89.07	27.17	212.67	5.40
A28	8.30	7.67	102.67	29.67	35.33	3.17	1.83	1.82	0.90	41.73	99.10	30.23	200.33	11.40
A29	8.13	8.33	140.00	29.00	38.67	8.70	2.40	0.57	0.77	44.43	66.50	19.27	207.67	2.72
A30	9.33	7.00	122.33	25.67	34.33	6.57	1.93	0.62	0.29	39.37	68.2	20.8	211.00	8.81
Mean	10.12	8.08	123.15	24.47	64.59	5.71	1.72	1.80	0.58	62.82	84.52	25.80	203.14	7.85
C.V. (genotypic)	20.20	21.10	11.46	19.83	59.45	47.66	41.13	41.17	43.31	38.5	26.57	26.46	4.73	47.98
S.E.	0.33	1.22	2.49	1.43	5.53	1.10	0.13	0.06	0.09	1.38	14.36	0.78	2.35	0.66
C.D. (5%)	0 .65	2.45	4.97	2.85	11.07	2.20	0.25	0.12	0.18	2.76	28.72	1.56	4.70	1.32

X1 Seedling height (15 DAT)(cm)
X2 Number of leaves seedling^{-1} (15 DAT)
X3 Days to 50 percent flowering
X4 Number of primary branches
X5 Number of secondary branches
X6 Leaf length (cm)
X7 Leaf width (cm)
X8 Stem girth (cm)
X9 Leaf/stem ratio
X10 Plant height (cm)
X11 Herbage yield (g)
X12 Yield plant^{-1} (g)
X13 Duration (days)
X14 Total extractives (%)

Fig. 1. Mean performance of thirty kiriyat accessions for yield plant^{-1} and total extractives (%)



statistically on par with A_{24} (2.67 cm), A_7 (2.73 cm), A_{15} (2.77 cm), A_{23} (2.83 cm), A_5 (2.90 cm), A_{10} (2.96 cm), A_{11} (3.00 cm), A_{14} (3.13 cm), A_{18} (3.16 cm), A_{28} (3.16 cm), A_8 (4.10 cm) and A_6 (4.36 cm).

Among thirty genotypes, average leaf width exhibited significant variation with a range of 0.63 cm to 2.77 cm. A_{26} (North Paravur) had maximum leaf width which was statistically on par with A_{25} (2.67 cm), A_{13} (2.63 cm) and A_1 (2.57 cm). A_9 (Vellayani) was reported with minimum leaf width and was statistically on par with A_{10} (0.67 cm), A_{24} (0.73 cm), A_7 (0.77 cm), A_{11} (0.77 cm) and A_{15} (0.83 cm).

The average stem girth was maximum for A_5 (Cherpulassery) (3.07 cm) and was statistically on par with A_{14} (2.96 cm). The minimum stem girth was observed for accession A_{29} (Ranni) (0.57 cm). The accession A_{30} (Aranmula) (0.62 cm) was statistically on par with A_{29}.

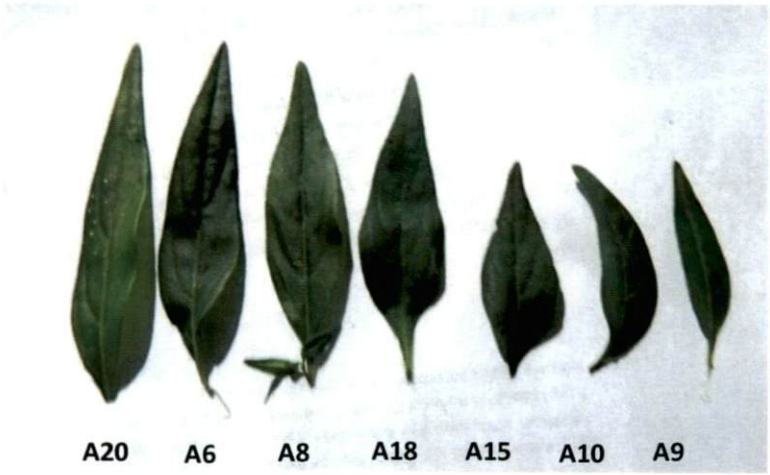
Accession A_{14} (Kottakkal) (0.93) exhibited the highest leaf/stem ratio. A_{24} (0.91) and A28 (0.90) were statistically on par with A_{14}. A_{12} (Kayamkulam) (0.28) was noticed with lowest leaf/stem ratio which was statistically on par with A_3 (0.29), A_{30} (0.29), A_1 (0.30), A_2 (0.30), A_{26} (0.30), A_2 (0.30), A_{19} (0.32), A_{13} (0.32), A_{16} (0.32), A_6 (0.35), A_{22} (0.37), A_{25} (0.40), A_{15} (0.42) and A_4 (0.45).

Significant variation was observed for herbage yield which ranged from 56.90 g to 137.25 g. Highest herbage yield was recorded for accession A_{10} (Aruvipuram). A_{14} (127.22), A_5 (120.40) and A_7 (117.30) were statistically on par with accession A_{10}. A_3 (Coimbatore) recorded minimum herbage yield (g) and was statistically on par with A_{16} (57.77), A_{25} (59.50), A_2 (61.23), A_4 (61.66), A_{19} (63.15), A_{23} (64.98), A_1 (65.80), A_{12} (65.96), A_{29} (66.50), A_{13} (66.60), A_{30} (68.20), A_6 (71.53), A_{11} (74.90), A_{22} (78.02), A_{26} (82.20) and A_{15} (85.14).

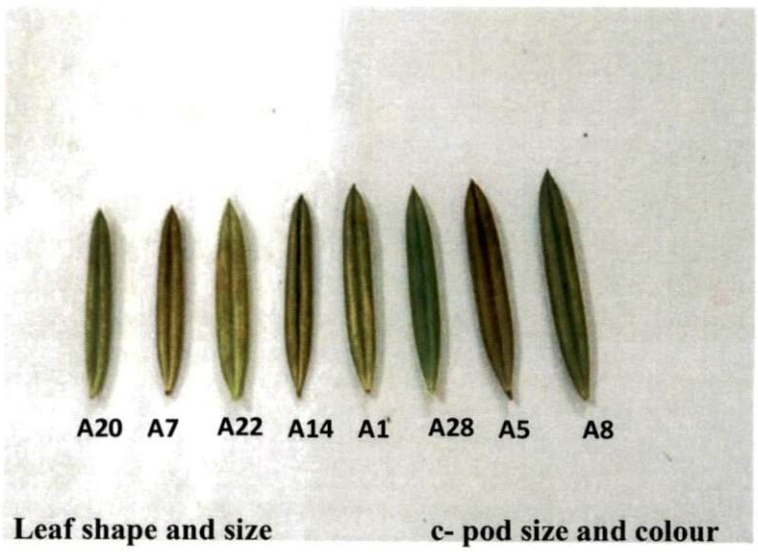
Plate 3. Variability in leaf and pods among kiriyat accessions

a

b



c



a- Leaf colour b- Leaf shape and size c- pod size and colour

Range obtained for the character, yield plant^{-1} was from 17.21 g to 37.79 g. The accession A_{10} (Aruvipuram) had maximum yield plant^{-1} which was statistically on par with A_{14} (37.58 g), A_7 (36.81 g) and A_5 (36.72 g); while A_3 (Coimbatore) recorded minimum yield plant^{-1}. A_{16} (17.83 g), A_{12} (18.61 g) and A_2 (18.68 g) were statistically on par with accession A_3.

Average duration of plant exhibited a range between 182.67 and 213.00 days. The earliest accession was A_{10} (Aruvipuram) with an average duration of 182.67 days and no other accession was statistically on par with it. A_{13} (Mandya) was recorded the longest duration and was statistically on par with A_{27} (212.67), A_{16} (212.00), A_{30} (211.00), A_1 (208.33), A_{12} (210.33), A_2 (210.33), A_{26} (210.00) and A_{21} (210.00).

Among the thirty accessions, average total extractives (%) exhibited significant variation with a range of 13.59 to 2.35. Total extractives were highest for A_{10} (Aruvipuram). A_{14} (13.05) and A_7 (13.02) and were statistically on par with A_{10}. It was minimum for the A_1 (Chithradurga) and was statistically on par with A_{16} (2.51), A_{17} (2.55), A_{29} (2.72), A_3 (3.08) and A_{13} (3.61).

4.3 VARIABILITY STUDIES

Phenotypic and genotypic coefficients of variations for fourteen traits were obtained and the results are presented in Table 4.

4.3.1 Phenotypic Coefficient of Variation

The phenotypic coefficient of variation (PCV) ranged from 5.07 (duration) to 60.03 (number of secondary branches). Highest PCV was for number of secondary branches (60.03) followed by total extractives (50.86), leaf length (48.72), leaf/stem ratio (44.30), leaf width (42.10), stem girth (41.36), plant height (38.68), herbage yield (31.77), yield plant^{-1} (31.76), number of leaves seedling^{-1} (15 DAT) (28.09), number of primary branches (21.07) and seedling height (15 DAT) (20.58). Days to

Plate 4. Selected superior kiriyat accessions

ARUVIPPURAM

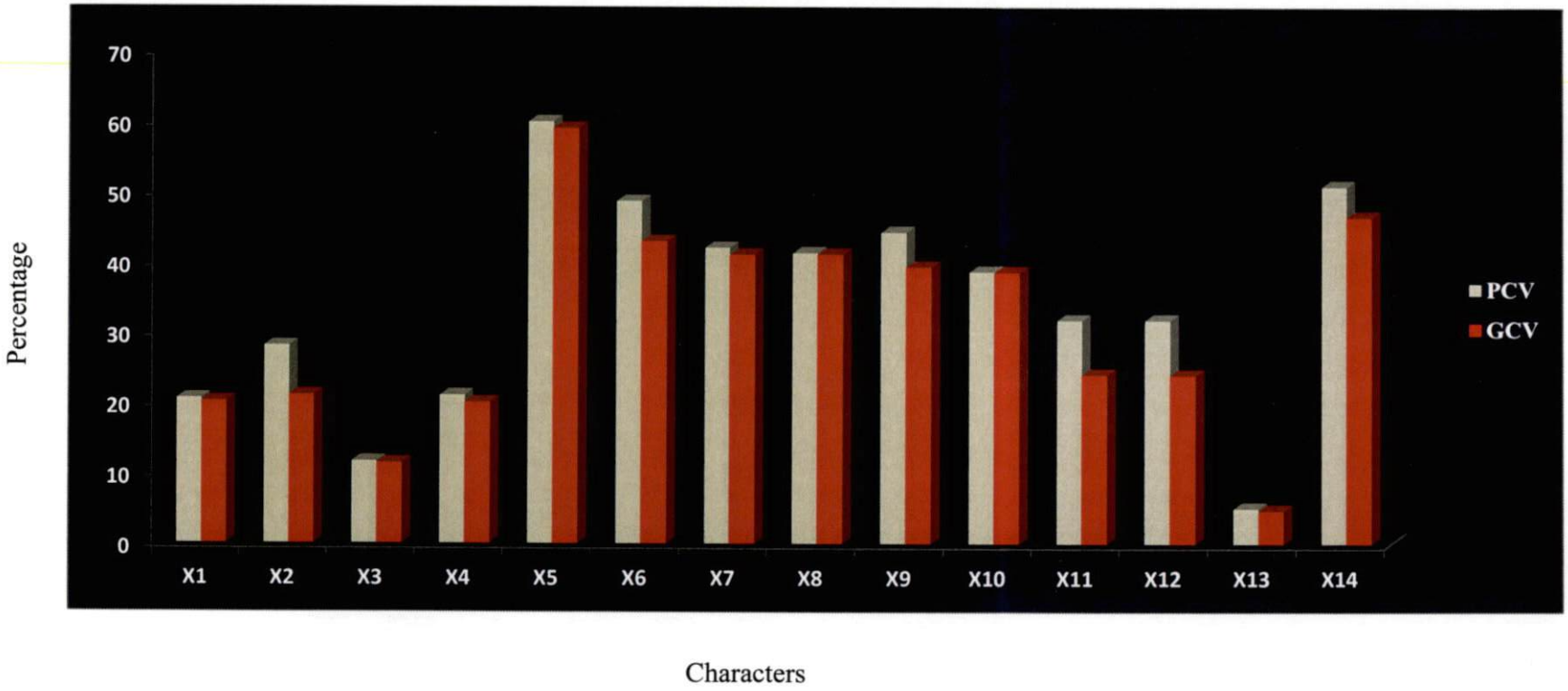
KOTTAKKAL

KOTTAKKUNNU

Table 4. Genetic parameters

Character	Variance		Coefficient of variation		Heritability (%)	Genetic advance (% of mean)
	Phenotypic	Genotypic	PCV	GCV		
Seedling height (15 DAT) (cm)	4.34	4.18	20.58	20.19	96.33	40.85
Number of leaves seedling^{-1} (15DAT)	5.13	2.90	28.09	21.09	56.39	32.64
Days to 50 percent flowering	208.42	199.15	11.72	11.46	95.55	23.08
Number of primary branches	26.58	23.54	21.07	20.05	88.55	38.44
Number of secondary branches	1465.13	1419.58	60.03	59.09	96.87	119.80
Leaf length (cm)	8.18	6.37	48.72	43.01	77.91	78.20
Leaf width (cm)	0.52	0.49	42.10	41.13	95.46	82.79
Stem girth (cm)	0.55	0.54	41.36	41.17	99.06	84.41
Leaf/stem ratio	0.06	0.04	44.30	39.34	78.85	71.97
Plant height (cm)	590.39	587.53	38.68	38.59	89.52	79.30
Herbage yield (g)	722.92	413.67	31.76	24.03	57.22	37.44
Yield plant^{-1} (g)	67.39	38.23	31.77	23.93	56.73	45.30
Duration (days)	64.33	56.04	5.07	4.74	87.11	9.10
Total extractives (%)	3.98	3.32	50.86	46.48	83.51	87.50

Fig. 2. PCV (%) and GCV (%) for fourteen characters in kiriyat accessions



PCV- Phenotypic Coefficients of Variation

GCV- Genotypic Coefficients of Variation

X1	Seedling height (15 DAT)(cm)	X8	Stem girth (cm)
X2	Number of leaves seedling^{-1} (15 DAT)	X9	Leaf/stem ratio
X3	Days to 50 percent flowering	X10	Plant height (cm)
X4	Number of primary branches	X11	Herbage yield (g)
X5	Number of secondary branches	X12	Yield plant^{-1} (g)
X6	Leaf length (cm)	X13	Duration (days)
X7	Leaf width (cm)	X14	Total extractives (%)

50 percent flowering (11.72) exhibited moderate level of PCV whereas, duration (5.07) exhibited low PCV.

4.3.2 Genotypic coefficient of variation

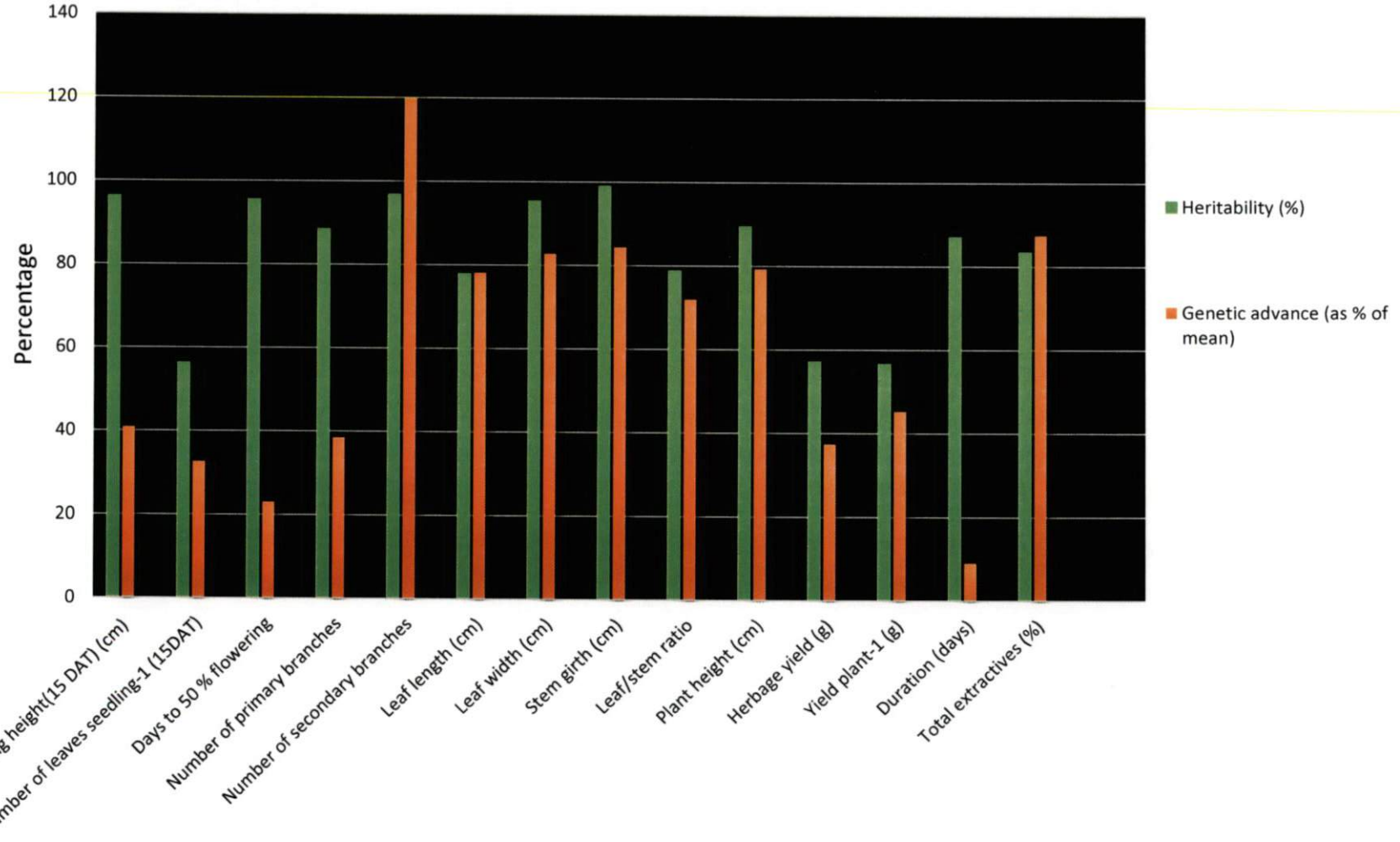
Genotypic coefficient of variation (GCV) ranged from 4.74 (duration) to 59.09 (number of secondary branches). Highest GCV was observed for number of secondary branches (59.09) followed by total extractives (46.48), leaf length (43.01), stem girth (41.17), leaf width (41.13), leaf/stem ratio (39.34), plant height (38.59), herbage yield (24.03), yield plant^{-1} (23.93), number of leaves seedling^{-1} (15 DAT) (21.10), number of primary branches (20.05) and seedling height (15 DAT) (20.19). Days to 50 percent flowering (11.46) exhibited moderate level of GCV whereas, duration (4.73) exhibited low GCV.

4. 4 HERITABILITY AND GENETIC ADVANCE

Heritability (in broad sense) was high for all the characters under study except number of leaves seedling^{-1} (15 DAT), herbage yield and yield plant^{-1}. (Table 4). The highest heritability was obtained for stem girth (99.06 %) followed by number of secondary branches (96.87 %), seedling height (15 DAT) (96.33 %), days to 50 percent flowering (95.55 %), leaf width (95.46 %), plant height (89.52 %), number of primary branches (88.55 %), duration (87.11 %), total extractives (83.51 %), leaf/stem ratio (78.85 %), leaf length (77.91 %), while moderate heritability was observed for herbage yield (57.22 %), yield plant^{-1} (56.73 %) and number of leaves seedling^{-1} (15 DAT) (56.39 %).

All the characters exhibited high genetic advance (as % of mean) except duration (9.10 %) which exhibited low genetic advance. The highest estimate was obtained for number of secondary branches (119.80 %) followed by total extractives (87.50 %), stem girth (84.41 %), leaf width (82.79 %), plant height (79.30 %), leaf

Fig. 3. Heritability (%) and Genetic Advance (% mean) for fourteen characters in kiriyat accessions



length (78.2 %), leaf/stem ratio (71.97 %), yield plant^{-1} (45.3 %), seedling height (15 DAT) (40.85 %), number of primary branches (38.44 %), herbage yield (37.44 %), number of leaves seedling^{-1} (15DAT) (32.64 %) and days to 50 percent flowering (23.08 %).

4. 5 ASSOCIATION ANALYSIS

4.5.1 Correlation Coefficient Analysis

The correlation between different traits was computed as genotypic, phenotypic and environmental correlation coefficients and presented here under.

4.5.1.1 Genotypic correlation coefficient

The genotypic correlation coefficients are given in Table 5.

Highly significant positive correlation was recorded between yield plant^{-1} and herbage yield (0.980) followed by leaf/stem ratio (0.867), stem girth (0.840), seedling height (15 DAT) (0.810), plant height (0.786), number of secondary branches (0.761), total extractives (0.686), number of leaves seedling^{-1} (15DAT) (0.605) and number of primary branches (0.553). The association was significantly negative with leaf length (-0.651) followed by leaf width (-0.632), days to 50 percent flowering (-0.594) and duration (-0.586).

Seedling height (15 DAT) showed highly significant positive correlation with herbage yield (0.862) followed by plant height (0.825), yield plant^{-1} (0.810), stem girth (0.764), leaf/stem ratio (0.755), number of leaves seedling^{-1} (15DAT) (0.744), number of secondary branches (0.725), total extractives (0.553) and number of primary branches (0.441). It had negative association with leaf length (-0.533) followed by leaf width (-0.508), days to 50 percent flowering (-0.468) and duration (-0.456).

Table 5. Genotypic correlation coefficients

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.000	0.744**	-0.468**	0.441**	0.725**	-0.533**	-0.508**	0.764**	0.755**	0.825**	0.862**	0.810**	-0.456**	0.553**
X2		1.000	-0.581**	0.523**	0.644**	-0.682**	-0.685**	0.608**	0.751**	0.851**	0.716**	0.605**	-0.503**	0.732**
X3			1.000	-0.403**	-0.589**	0.933**	0.815**	-0.495**	-0.687**	-0.543**	-0.659**	-0.594**	0.787**	-0.939**
X4				1.000	0.384**	-0.361**	-0.388**	0.477**	0.535**	0.439**	0.610**	0.553**	-0.347**	0.454**
X5					1.000	-0.613**	-0.659**	0.689**	0.675**	0.734**	0.907**	0.761**	-0.709**	0.656**
X6						1.000	0.949**	-0.548**	-0.799**	-0.568**	-0.826**	-0.651**	0.757**	-0.870**
X7							1.000	-0.557**	-0.690**	-0.632**	-0.702**	-0.632**	0.776**	-0.898**
X8								1.000	0.718**	0.807**	0.927**	0.840**	-0.457**	0.625**
X9									1.000	0.790**	0.836**	0.867**	-0.547**	0.675**
X10										1.000	0.897**	0.786**	-0.480**	0.643**
X11											1.000	0.980**	-0.646**	0.661**
X12												1.000	-0.586**	0.686**
X13													1.000	-0.675**
X14														1.000

X1 Seedling height (15 DAT)(cm)
X2 Number of leaves seedling^{-1} (15 DAT)
X3 Days to 50 percent flowering
X4 Number of primary branches
X5 Number of secondary branches
X6 Leaf length (cm)
X7 Leaf width (cm)
X8 Stem girth (cm)
X9 Leaf/stem ratio
X10 Plant height (cm)
X11 Herbage yield (g)
X12 Yield plant^{-1} (g)
X13 Duration (days)
X14 Total extractives (%)

* significant at 5% level
** significant at 1% level

Number of leaves seedling^{-1} (15DAT) was noticed with highly significant positive correlation with plant height (0.851) followed by leaf/stem ratio (0.751), seedling height (15 DAT) (0.744), total extractives (0.732), herbage yield (0.716), number of secondary branches (0.644), stem girth (0.608), yield plant^{-1}(0.605) and number of primary branches (0.523). But, it exhibited negative association with leaf width (-0.685) followed by leaf length (-0.682), days to 50 percent flowering (-0.581) and duration (-0.503).

Days to 50 percent flowering had highly significant positive correlation with leaf length (0.933) followed by leaf width (0.815) and duration (0.787); but it was correlated negatively with total extractives (-0.939) followed by leaf/stem ratio (-0.687), herbage yield (-0.659), yield plant^{-1} (-0.594), number of secondary branches (-0.589), number of leaves seedling^{-1} (15DAT) (-0.581), plant height (-0.543), stem girth (-0.495), seedling height (15 DAT) (-0.468) and number of primary branches (-0.403).

It was observed that highly significant positive correlation existed between number of primary branches and herbage yield (0.610) followed by yield plant^{-1} (0.553), leaf/stem ratio (0.535), number of leaves seedling^{-1} (15DAT) (0.523), stem girth (0.477), total extractives (0.454), seedling height (0.441), plant height (0.439) and number of secondary branches (0.384). But, it exhibited negative association with days to 50 percent flowering (-0.403), leaf width (-0.388), leaf length (-0.361) and duration (-0.347).

Number of secondary branches exhibited positive correlation with herbage yield (0.907) followed by yield plant^{-1} (0.761), plant height (0.734), seedling height (0.725), stem girth (0.689), leaf/stem ratio (0.675), total extractives (0.656), number of leaves seedling^{-1} (15DAT) (0.644) and number of primary branches (0.384). But, it exhibited negative association with duration (-0.709) followed by leaf width (-0.659), leaf length (-0.613) and days to 50 percent flowering (-0.403).

Highly significant negative correlation was noticed between leaf length and total extractives (-0.870) followed by herbage yield (-0.826), leaf/stem ratio (-0.799), number of leaves seedling^{-1} (15DAT) (-0.682), yield plant^{-1} (-0.651), number of secondary branches (-0.613), plant height (-0.568), stem girth (-0.548), seedling height (-0.533) and number of primary branches (-0.361), while a positive association had been noticed with leaf width (0.949) followed by days to 50 percent flowering (0.933) and duration (0.757).

Leaf width possessed negative correlation with total extractives (-0.898) followed by herbage yield (-0.702), leaf/stem ratio (-0.690), number of leaves seedling^{-1} (15DAT) (-0.685), number of secondary branches (-0.659), yield plant^{-1} (-0.632), plant height (-0.632), stem girth (-0.557), seedling height (-0.508) and number of primary branches (-0.388), but it had positive correlation with leaf length (0.949) followed by days to 50 percent flowering (0.815) and duration (0.776).

Stem girth showed highly significant positive correlation with herbage yield (0.927) followed by yield plant^{-1} (0.840), plant height (0.807), seedling height (0.764), leaf/stem ratio (0.718), number of secondary branches (0.689), total extractives (0.625), number of leaves seedling^{-1} (15DAT) (0.608), and number of primary branches (0.477); but it had highly significant negative association with duration (-0.457) followed by leaf width (-0.557), leaf length (-0.548) and days to 50 percent flowering (-0.495).

It was noticed that leaf/stem ratio had highly significant positive correlation with yield plant^{-1} (0.867) followed by herbage yield (0.836), plant height (0.790), seedling height (0.755), number of leaves seedling^{-1} (15DAT) (0.751), stem girth (0.718), number of secondary branches (0.675), total extractives (0.675) and number of primary branches (0.535). It had negative association with leaf length (-0.799), leaf width (-0.690), days to 50 percent flowering (-0.687) and duration (-0.547).

Highly significant positive correlation was observed between plant height and herbage yield (0.897) followed by number of leaves seedling^{-1} (15DAT) (0.851), seedling height (0.825), leaf/stem ratio (0.807), stem girth (0.807), yield plant^{-1} (0.786), number of secondary branches (0.734), total extractives (0.643) and number of primary branches (0.439). But, it possessed negative association with leaf width (-0.632) followed by leaf length (-0.568), days to 50 percent flowering (-0.543) and duration (-0.480).

Herbage yield showed positive correlation with yield plant^{-1} (0.980) followed by stem girth (0.927), number of secondary branches (0.907), plant height (0.897), seedling height (0.862), leaf/stem ratio (0.836), number of leaves seedling^{-1} (15DAT) (0.716), total extractives (0.661) and number of primary branches (0.610). But, it exhibited negative association with leaf length (-0.826) followed by leaf width (-0.702), days to 50 percent flowering (-0.659) and duration (-0.646).

Highly significant negative correlation was observed between duration and number of secondary branches (-0.709) followed by total extractives (-0.675), herbage yield (-0.586), yield plant^{-1} (-0.586), leaf/stem ratio (-0.547), number of leaves seedling^{-1} (15DAT) (-0.503), plant height (-0.480), stem girth (-0.457), seedling height (-0.456) and number of primary branches (-0.347), but it had positive correlation with days to 50 percent flowering (0.787) followed by leaf width (0.776) and leaf length (0.757).

Total extractives exhibited high positive correlation with number of leaves seedling^{-1} (15DAT) (0.732) followed by yield plant^{-1} (0.686), leaf/stem ratio (0.675), herbage yield (0.661), number of secondary branches (0.656), plant height (0.643), stem girth (0.625), seedling height (0.553) and number of primary branches (0.454). But, it exhibited negative association with days to 50 percent flowering (-0.939) followed by leaf width (-0.898), leaf length (-0.870) and duration (-0.675).

4.5.1.2. Phenotypic Correlation Coefficient

The phenotypic correlation coefficients are presented in Table 6. Highly significant positive correlation was recorded between yield plant^{-1} with herbage yield (0.828) followed by stem girth (0.828), seedling height (15 DAT) (0.777), plant height (0.776), leaf/stem ratio (0.750), number of secondary branches (0.743), total extractives (0.615), number of primary branches (0.511) and number of leaves seedling^{-1} (15DAT) (0.463). The association was significantly negative with leaf width (-0.602) followed by leaf length (-568), days to 50 percent flowering (-0.568) and duration (-0.523).

Seedling height (15 DAT) showed significant positive correlation with plant height (0.808) followed by yield plant^{-1} (0.777), stem girth (0.746), number of secondary branches (0.700), leaf/stem ratio (0.668), herbage yield (0.637), number of leaves seedling^{-1} (15DAT) (0.542), total extractives (0.500) and number of primary branches (0.402). It had negative association with leaf width (-0.499) followed by days to 50 percent flowering (-0.457), leaf length (-0.451) and duration (-0.436).

Number of leaves seedling^{-1} (15DAT) was noticed with highly significant positive correlation with plant height (0.640) followed by seedling height (15 DAT) (0.542), total extractives (0.477), number of secondary branches (0.472), yield plant^{-1} (0.463), stem girth (0.450), leaf/stem ratio (0.453), herbage yield (0.399), and number of primary branches (0.302). But, it exhibited negative association with leaf width (-0.504) followed by leaf length (-0.456), days to 50 percent flowering (-0.409) and duration (-0.336).

Days to 50 percent flowering had highly significant positive correlation with leaf length (0.802) followed by leaf width (0.787) and duration (0.763). It was correlated negatively with total extractives (-0.864) followed by leaf/stem ratio (-0.619), yield plant^{-1} (-0.568), number of secondary branches (-0.557), plant height (-

Table 6. Phenotypic correlation coefficients

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1	0.542**	-0.457**	0.402**	0.700**	-0.451**	-0.499**	0.746**	0.668**	0.808**	0.637**	0.777**	-0.436**	0.500**
X2		1.000	-0.409**	0.302**	0.472**	-0.456**	-0.504**	0.450**	0.453**	0.640**	0.399**	0.463**	-0.336**	0.477**
X3			1.000	-0.369**	-0.557**	0.802**	0.787**	-0.486**	-0.619**	-0.528**	-0.522**	-0.568**	0.763**	-0.864**
X4				1.000	0.356**	-0.262	-0.350**	0.444**	0.486**	0.415**	0.476**	0.511**	-0.292**	0.415**
X5					1.000	-0.548**	-0.628**	0.677**	0.576**	0.723**	0.647**	0.743**	-0.645**	0.583**
X6						1.000	0.805**	-0.485**	-0.494**	-0.502**	-0.322**	-0.568**	0.601**	-0.734**
X7							1.000	-0.542**	-0.612**	-0.611**	-0.536**	-0.602**	0.720**	-0.805**
X8								1.000	0.631**	0.801**	0.699**	0.828**	-0.423**	0.569**
X9									1.000	0.699**	0.789**	0.750**	-0.494**	0.701**
X10										1.000	0.672**	0.776**	-0.444**	0.586**
X11											1.000	0.828**	-0.509**	0.699**
X12												1.000	-0.523**	0.615**
X13													1.000	-0.615**
X14														1.000

X1 Seedling height (15 DAT)(cm)
X2 Number of leaves seedling^{-1} (15 DAT)
X3 Days to 50 percent flowering
X4 Number of primary branches
X5 Number of secondary branches
X6 Leaf length (cm)
X7 Leaf width (cm)
X8 Stem girth (cm)
X9 Leaf/stem ratio
X10 Plant height (cm)
X11 Herbage yield (g)
X12 Yield plant^{-1} (g)
X13 Duration (days)
X14 Total extractives (%)

* significant at 5% level
** significant at 1% level

0.528), herbage yield (-0.522), stem girth (-0.486), seedling height (15 DAT) (-0.457), number of leaves seedling^{-1} (15DAT) (-0.409) and number of primary branches (-0.369).

It was observed that highly significant positive correlation existed between number of primary branches and yield plant^{-1} (0.511) followed by leaf/stem ratio (0.486), herbage yield (0.476), stem girth (0.444), total extractives (0.415), seedling height (0.402), plant height (0.415), number of secondary branches (0.356) and number of leaves seedling^{-1} (15DAT) (0.302). But, it showed negative association with days to 50 percent flowering (-0.369) followed by leaf width (-0.350).

Number of secondary branches exhibited positive correlation with yield plant^{-1} (0.743) followed by plant height (0.723), seedling height (0.700), stem girth (0.677), herbage yield (0.647), total extractives (0.583), leaf/stem ratio (0.576), number of leaves seedling^{-1} (15DAT) (0.472) and number of primary branches (0.356). But, it exhibited negative association with duration (-0.645) followed by leaf width (-0.628), days to 50 percent flowering (-0.557) and leaf length (-0.548).

Highly significant negative correlation was found between leaf length and total extractives (-0.734) followed by yield plant^{-1} (-0.568), number of secondary branches (-0.548), plant height (-0.502), leaf/stem ratio (-0.494), stem girth (-0.485), number of leaves seedling^{-1} (15DAT) (-0.456), seedling height (-0.451) and herbage yield (-0.322); while a positive association had been noticed with leaf width (0.805) followed by days to 50 percent flowering (0.802) and duration (0.601).

Leaf width possessed negative correlation with total extractives (-0.805) followed by number of secondary branches (-0.628), leaf/stem ratio (-0.612), yield plant^{-1} (-0.602), plant height (-0.611), stem girth (-0.542), herbage yield (-0.536), number of leaves seedling^{-1} (15DAT) (-0.504), seedling height (-0.499) and number

of primary branches (-0.350), but it showed positive correlation with leaf length (0.805) followed by days to 50 percent flowering (0.787) and duration (0.720).

Stem girth showed positive correlation with yield plant^{-1} (0.828) followed by plant height (0.801), seedling height (0.746), herbage yield (0.699), leaf/stem ratio (0.631), number of secondary branches (0.677), total extractives (0.569), number of leaves seedling^{-1} (15DAT) (0.450) and number of primary branches (0.444); but, it exhibited negative association with leaf width (-0.542) followed by leaf length (-0.485), days to 50 percent flowering (-0.486) and duration (-0.423).

It was noticed that leaf/stem ratio had highly significant positive correlation with herbage yield (0.789) followed by yield plant^{-1} (0.750), total extractives (0.701), plant height (0.699), seedling height (0.668), stem girth (0.631), number of secondary branches (0.576), number of leaves seedling^{-1} (15DAT) (0.453) and number of primary branches (0.486); while it exhibited negative association with days to 50 percent flowering (-0.619) followed by leaf width (-0.612), leaf length (-0.494) and duration (-0.494).

Highly significant positive correlation was observed between plant height and seedling height (0.808) followed by stem girth (0.801), yield plant^{-1} (0.776), number of secondary branches (0.723), leaf/stem ratio (0.699), herbage yield (0.672), number of leaves seedling^{-1} (15DAT) (0.640), total extractives (0.586) and number of primary branches (0.415). But, it exhibited negative association with leaf width (-0.612) followed by days to 50 percent flowering (-0.528), leaf length (-0.494) and duration (-0.444).

Herbage yield showed positive correlation with yield plant^{-1} (0.828) followed by leaf/stem ratio (0.789), stem girth (0.699), total extractives (0.699), plant height (0.672), number of secondary branches (0.647), seedling height (0.637), number of primary branches (0.476) and number of leaves seedling^{-1} (15DAT) (0.399). But,

there existed negative association with leaf width (-0.536) followed by days to 50 percent flowering (-0.522), duration (-0.509) and leaf length (-0.322).

Highly significant negative correlation was observed between duration and number of secondary branches (-0.645) followed by total extractives (-0.615), yield plant^{-1} (-0.523), herbage yield (-0.509), leaf/stem ratio (-0.494), plant height (-0.444), seedling height (-0.436), stem girth (-0.423), number of leaves seedling^{-1} (15DAT) (-0.336) and number of primary branches (-0.292); but it exhibited positive correlation with days to 50 percent flowering (0.763) followed by leaf width (0.720) and leaf length (0.601).

Total extractives exhibited high positive correlation with leaf/stem ratio (0.701) followed by herbage yield (0.699), yield plant^{-1} (0.615), plant height (0.586), number of secondary branches (0.583), stem girth (0.569), seedling height (0.500), number of leaves seedling^{-1} (15DAT) (0.477) and number of primary branches (0.415). It had highly significant negative association with days to 50 percent flowering (-0.864) followed by leaf width (-0.805), leaf length (-0.734) and duration (-0.615).

4. 6 PATH ANALYSIS

The direct and indirect effects of the component characters on yield plant^{-1} were estimated using path coefficient analysis (Table 7). The characters having high genotypic correlation with yield plant^{-1} viz., seedling height (15 DAT), number of leaves seedling^{-1} (15 DAT), days to 50 percent flowering, number of primary branches, number of secondary branches, leaf length, leaf width, stem girth, leaf/stem ratio, plant height, herbage yield and total extractives were selected.

Characters exhibiting positive direct effect on yield plant^{-1} were plant height (0.861) followed by herbage yield (0.824), days to 50 percent flowering (0.769),

Table 7. Path analysis (direct diagonal / indirect off diagonal)

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	Genotypic correlation co-efficiencies
X1	**0.336**	-0.864	-0.360	0.158	0.248	0.227	-0.118	-0.065	0.437	0.710	-0.354	0.456	0.810
X2	0.250	**-1.162**	-0.447	0.188	0.220	0.291	-0.159	-0.051	0.435	0.733	-0.294	0.603	0.605
X3	-0.157	0.676	**0.769**	-0.144	-0.201	-0.398	0.190	0.042	-0.398	-0.468	0.271	-0.774	-0.594
X4	0.148	-0.610	-0.310	**0.358**	0.131	0.154	-0.090	-0.040	0.310	0.379	-0.251	0.374	0.553
X5	0.244	-0.748	-0.453	0.138	**0.341**	0.261	-0.153	-0.058	0.391	0.632	-0.373	0.540	0.761
X6	-0.179	0.793	0.718	-0.129	-0.209	**-0.426**	0.221	0.046	-0.463	-0.489	0.339	-0.871	-0.651
X7	-0.171	0.796	0.627	-0.139	-0.225	-0.405	**0.233**	0.047	-0.399	-0.545	0.289	-0.740	-0.632
X8	0.257	-0.707	-0.381	0.171	0.235	0.234	-0.129	**-0.084**	0.416	0.695	-0.381	0.514	0.840
X9	0.254	-0.873	-0.528	0.192	0.230	0.341	-0.160	-0.061	**0.579**	0.681	-0.344	0.556	0.867
X10	0.277	-0.989	-0.418	0.158	0.251	0.242	-0.147	-0.062	0.458	**0.861**	-0.369	0.530	0.786
X11	0.060	-0.632	-0.307	0.119	0.198	0.151	-0.163	0.078	-0.484	0.773	**0.824**	0.365	0.980
X12	0.086	-0.350	-0.264	0.163	0.178	-0.200	-0.187	-0.152	0.191	0.540	0.272	**0.411**	0.686
Residual effect (R)								0.1715					

X1 Seedling height (15 DAT) (cm)
X2 Number of leaves seedling^{-1} (15 DAT)
X3 Days to 50 percent flowering
X4 Number of primary branches
X5 Number of secondary branches
X6 Leaf length (cm)
X7 Leaf width (cm)
X8 Stem girth (cm)
X9 Leaf/stem ratio
X10 Plant height (cm)
X11 Herbage yield (g)
X12 Total extractives(%)

leaf/stem ratio (0.579), total extractives (0.411), number of primary branches (0.358), number of secondary branches (0.341), seedling height (15 DAT) (0.336) and leaf width (0.233); while number of leaves seedling^{-1} (15 DAT) (-1.163) and leaf length (-0.426) had high negative direct effect on yield plant^{-1}.

Seedling height (15 DAT) exhibited high positive direct effect (0.336) on yield plant^{-1} and it had high positive indirect effect on yield plant^{-1} via plant height (0.710) and total extractives (0.456). Its genotypic correlation with yield was high and positive (0.810).

Number of leaves seedling^{-1} (15 DAT) had high and positive genotypic correlation (0.605) with yield plant^{-1}, but exhibited a very high negative direct effect (-1.162) on yield. It is due to its high negative indirect effect (-0.447) via days to 50 percent flowering, that accounts for the total correlation.

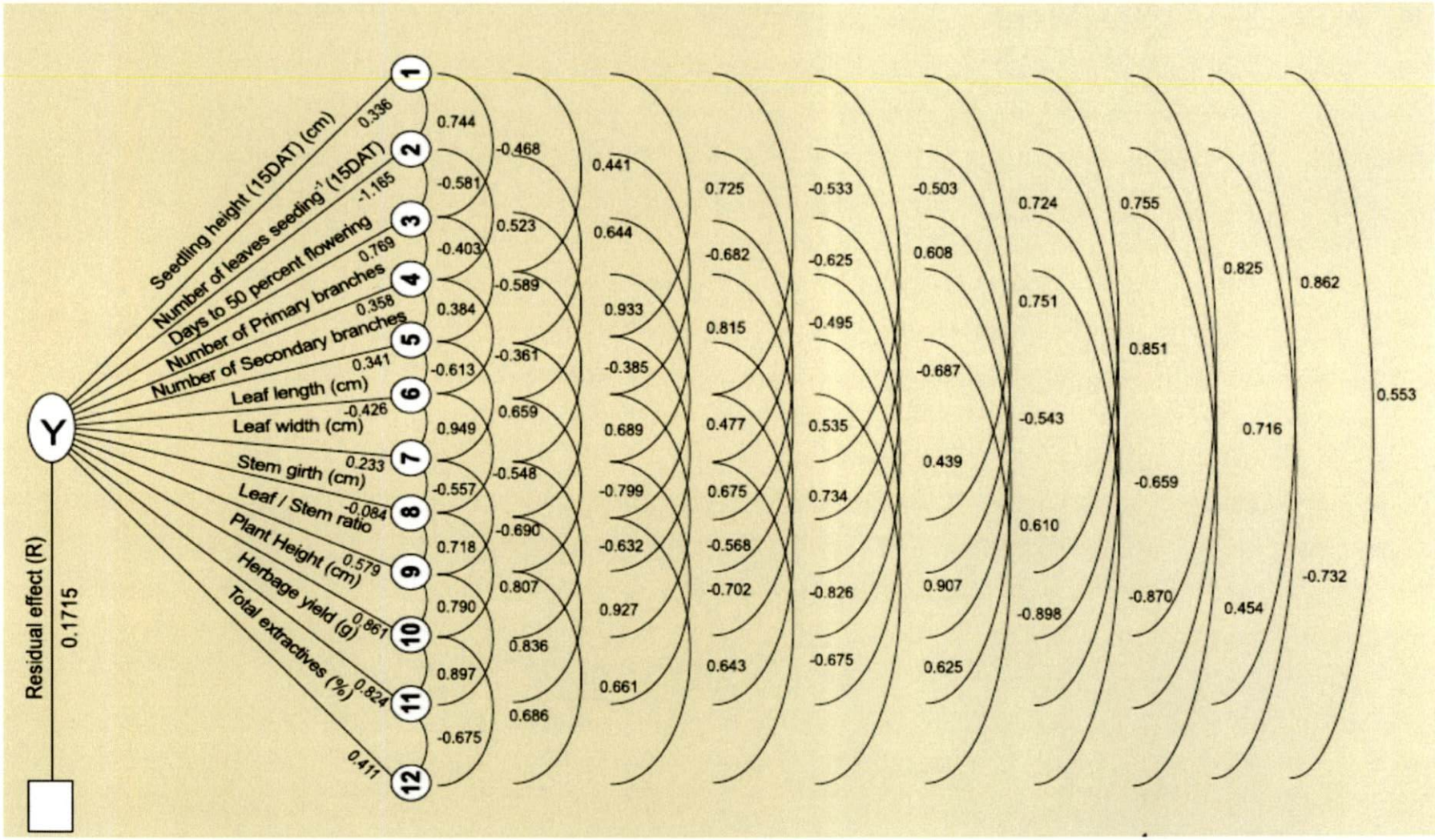
The genotypic correlation (-0.594) of days to 50 percent flowering on yield plant^{-1} was significantly negative. But, it had high positive direct effect (0.769); since it had high positive indirect effect via number of leaves seedling^{-1} (15 DAT) (0.6756).

Number of primary branches showed high positive direct effect (0.3584) and genotypic correlation (0.553) on yield plant^{-1}. It had high positive indirect effect on yield via characters such as plant height (0.3786), total extractives (0.3737) and leaf/stem ratio (0.3098).

Number of secondary branches had high positive direct effect (0.3410) and genotypic correlation (0.761) in association with yield plant^{-1}. It had high positive indirect effect on yield plant^{-1} via plant height (0.6321), total extractives (0.5402), leaf/stem ratio (0.3909) and herbage yield (0.3731).

Leaf length exhibited high negative genotypic correlation (-0.651) and direct effect (-0.4260) on yield plant^{-1}. It had high positive indirect effect through characters

Fig. 4. Path diagram showing direct and indirect effects of various characters on yield plant^{-1}



like number of leaves seedling^{-1} (15 DAT) (0.7926), days to 50 percent flowering (0.7176) and herbage yield (0.3390).

Leaf width was observed to have moderate positive direct effect (0.2325), but exhibited negative genotypic correlation (-0.632). It had high negative indirect effect on the same through total extractives (-0.7397), plant height (-0.5449), number of secondary branches (-0.4045) and leaf/stem ratio (-0.399) and this accounts for negative genotypic correlation.

The genotypic correlation (0.840) of stem girth on yield plant^{-1} was positive, but it had a low negative direct effect on yield plant^{-1} (-0.084); since it had high negative indirect effect via number of leaves seedling^{-1} (15 DAT) (-0.7070) and days to 50 percent flowering (-0.3809).

Leaf/stem ratio had high positive direct effect (0.5793) and genotypic correlation (0.867) in association with yield plant^{-1}. It had high positive indirect effect via plant height (0.6810), total extractives (0.5564) and number of secondary branches (0.3409).

Plant height exhibited high positive direct effect (0.8610) and genotypic correlation (0.786) on yield plant^{-1}. It had high positive indirect effect via total extractives (0.5299) and leaf/stem ratio (0.4579).

Herbage yield exhibited high positive genotypic correlation (0.980) and direct effect (0.8240) on yield plant^{-1}. It exerted high positive indirect effect via total extractives (0.365) and plant height (0.773).

Total extractives had found to have high positive direct effect (0.411) and genotypic correlation (0.686). It had high positive indirect effect via plant height (0.540).

The residual effect obtained was 0.1715.

Characters such as plant height, herbage yield, leaf/stem ratio, total extractives, number of primary branches and number of secondary branches were having high positive direct effect as well as high genotypic correlation coefficient.

4. 7. GENETIC DIVERGENCE ANALYSIS

Assessment of genetic divergence among thirty genotypes was carried out by using Mahanalobis D^2 statistic and the results obtained from the study are presented below.

The thirty accessions were grouped into seven clusters (Fig. 1).Cluster VII was the largest cluster with thirteen accessions followed by cluster VI with five accessions, cluster V which contained four accessions, clusters III and IV with two accessions each and cluster I was a solitary cluster with one accession (Table 8).

4.7.1. Cluster Means of the Characters

The cluster means for 14 characters are presented in Table 9.

Seedling height varied from 9.07 cm in cluster V to 13.29 cm in cluster VI. Maximum mean value for number of leaves seedling^{-1} (15 DAT) (10.40) was in cluster VI, while it was lowest (6.38) in cluster VII. The accession in cluster I exhibited earliest days to 50 percent flowering (105.66) while accessions in cluster IV was the latest (139.44) to flower. Cluster VI had maximum number of primary branches (28.19) and cluster VII had minimum mean (20.71). The maximum number of secondary branches (145.00) was observed in cluster I and the minimum (39.61) was for in cluster VII. The maximum leaf length (8.48 cm) was recorded in cluster IV and the minimum (2.28 cm) in cluster II. Leaf width varied from 2.65 cm in cluster VII to 0.63 in cluster I. Maximum stem girth was observed in cluster VI (2.75 cm)

Table 8. Clustering pattern

Clusters	Number of accessions	Accessions
I	1	A9
II	2	A15, A24
III	2	A8, A28
IV	3	A17, A21, A27
V	4	A6, A11, A20, A23
VI	5	A5, A7, A10, A14, A18
VII	13	A1, A2, A3, A4, A12, A13, A16, A19, A22, A25, A26, A29, A30.

Table 9. Cluster mean values of 14 biometric characters of thirty kiriyat accessions

Cluster means	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
Cluster I	9.73	7.66	105.66	24.33	145.00	2.63	0.63	1.92	0.68	59.83	96.63	29.47	193.00	12.10
Cluster II	11.85	10.16	115.16	26.66	74.166	2.28	0.78	2.43	0.68	89.33	96.92	29.56	158.67	11.80
Cluster III	10.30	7.16	110.33	27.83	48.66	3.53	1.66	2.06	0.84	43.30	103.07	31.43	155.50	10.26
Cluster IV	11.64	8.66	139.44	26.88	57.88	8.48	2.20	2.19	0.71	75.26	95.24	29.07	163.89	4.60
Cluster V	9.07	8.66	115.42	23.25	40.583	3.65	1.09	1.79	0.55	63.92	78.64	23.99	155.25	10.20
Cluster VI	13.29	10.40	106.47	28.19	132.26	2.74	0.96	2.75	0.88	101.60	119.58	36.48	148.07	12.36
Cluster VII	8.77	6.38	123.45	20.71	39.61	7.82	2.65	1.68	0.40	41.42	60.84	19.21	152.00	5.38

X1 Seedling height (15 DAT) (cm)
X2 Number of leaves seedling^{-1} (15 DAT)
X3 Days to 50 percent flowering
X4 Number of primary branches
X5 Number of secondary branches
X6 Leaf length (cm)
X7 Leaf width (cm)
X8 Stem girth (cm)
X9 Leaf/stem ratio
X10 Plant height (cm)
X11 Herbage yield (g)
X12 Yield plant^{-1} (g)
X13 Duration
X14 Total extractives (%)

and the minimum was in cluster VII (1.68 cm). The highest leaf/stem ratio was observed for cluster VI (0.88) and lowest was in cluster VII (0.40). The maximum plant height was reported in cluster VI (101.60 cm) while the minimum was in cluster VII (41.42 cm). Cluster VI showed maximum (119.58 g) herbage yield and the minimum was in cluster VII (60.84 g). Cluster VI reported the maximum yield plant^{-1} (36.48 g) while cluster VII exhibited the minimum (19.21 g). The early maturing (193.00) accession was included in cluster I, while cluster IV was with late maturing accessions (208.89). Cluster VI recorded the maximum (12.36 g) total extractives and the minimum was observed for cluster IV (4.60 g).

Cluster VI had the maximum cluster mean for seedling height (13.29 cm), number of leaves seedling^{-1} (15 DAT) (10.40), number of primary branches (28.19), stem girth (2.75 cm), leaf/stem ratio (0.88), plant height (101.60 cm), herbage yield (119.58 g) and total extractives (12.36 g). Hence, accessions in this cluster were found to be superior in terms of economic characters.

Cluster I was a solitary cluster with one accession (A9). The accession was noticed for its early maturing habit as it had minimum days to 50 percent flowering (105.66). It had highest number of secondary branches (145.00) along with high content of total extractives (12.10 g).

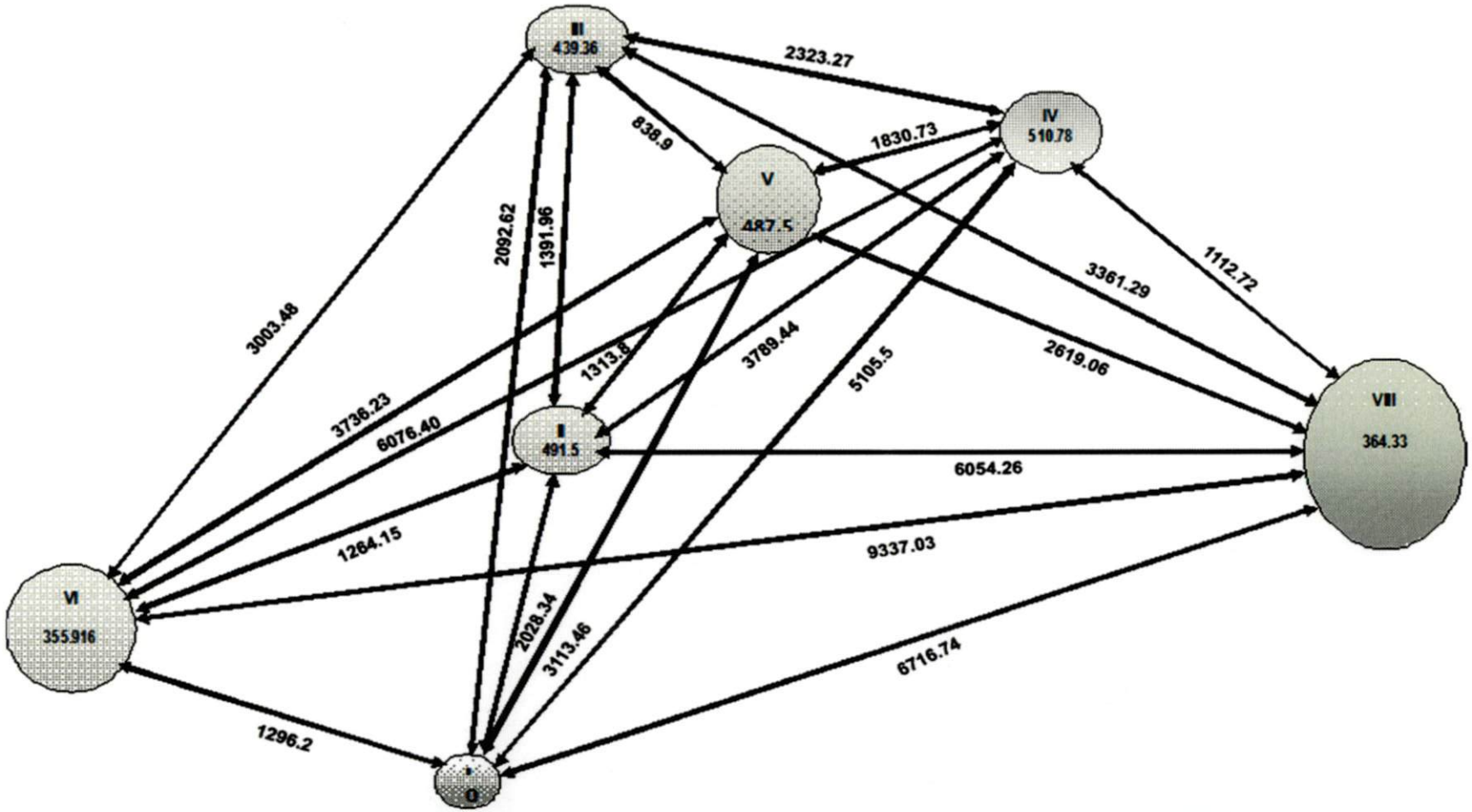
The average inter and intra cluster distances are presented in Table 10.

Highest inter cluster distance was observed between cluster VI and cluster VII (9337.03) followed by that between cluster I and cluster VII (6726.74), cluster IV and VI (6076.40), cluster II and VII (6054.26); I and IV (5105.60), cluster II and IV (3789.44), V and VI (3736.23), III and VII (3361.29) and the least was between V and III (838.90). Intra cluster distance highest for cluster IV (510.76) and least for cluster VI (355.92).

Table 10. Average intra and intercluster distances (D values)

Clusters	I	II	III	IV	V	VI	VII
I	0	2028.34	2092.65	5105.60	3113.46	1296.20	6726.74
II		491.50	1391.96	3789.44	1313.38	1264.15	6054.26
III			439.36	2323.27	838.90	3003.48	3361.29
IV				510.76	1830.73	6076.40	1112.72
V					487.50	3736.23	2619.06
VI						355.92	9337.03
VII							364.34

Fig. 5. Cluster diagram showing inter cluster distances and intra cluster distances



Genotypes included in cluster VI and cluster VII were highly divergent since the inter cluster distance between cluster VI and cluster VII was the highest. Since intra cluster distance was highest for cluster IV, diversity among the genotypes in cluster IV were high.

DISCUSSION

5. DISCUSSION

Variability is the prerequisite to any crop improvement programme. A thorough knowledge on the genetics of inheritance is crucial prior to any attempt at breeding. The present study thus forms an important pre-breeding link.

Kiriyat is a highly potential candidate for genetic improvement among the medicinal plants currently used and can easily fetch a good remuneration for the farmers at the same time the pharmaceutical industry is assured of good quality material.

Hence, the present investigation was carried out to study the genetic divergence in kiriyat and identifying the best ecotype in terms of herbage yield and quality in terms of total extractive using thirty kiriyat accessions.

The results obtained are discussed under here:-.

5.1 VARIABILITY STUDIES

5.1.1 Mean Performance of Accessions

There was noticeable difference among the thirty accessions for seedling height (15 DAT), number of leaves seedling^{-1} (15 DAT), days to 50 percent flowering, number of primary branches, number of secondary branches, leaf length, leaf width, stem girth, leaf/stem ratio, plant height, herbage yield, yield plant^{-1}, duration and total extractives. Misra *et al.* (2003), Prathanturarug *et al.* (2007), Raina *et al.* (2013) Kumar *et al.* (2014) and Nagvanshi and Tirkey (2016) reported the existence of wide variability for several biometric characters in kiriyat.

Seedling height (15 DAT) ranged from 7.53 to 13.70 cms which is in accordance with the report by Panwar (2009).

In the present investigation number of leaves seedling^{-1} (15 DAT) showed variation between 5.67 and 12.33. A significant difference for the character was earlier reported by Panwar (2009) in *A. paniculata*.

Days to 50 percentage flowering had a range from 142.33 days to 98.67 days. Paul (2000), Devi (2016) and Nagvanshi and Tirkey (2016) also reported high variability for the character in *A. paniculata*. A_{10} (Aruvipuram) was the earliest accession among the evaluated ones.

Considerable variation was noticed for number of primary branches which ranged from 14.33 to 32.33. A_{10} (Aruvipuram) was reported with highest number of primary branches. The results are in accordance with the findings of Kumar *et al.* (2014) in the same crop.

Number of secondary branches showed wide variability among the accessions studied and ranged from 34.29 to 155.67. This is in accordance with the earlier reports of Kumar *et al.* (2014) and Nagvanshi and Tirkey (2016) in kiriyat.

Wide variability was expressed for leaf length and leaf width with mean values ranging from 2.63 to 10.47 cms and 0.63 cm to 2.77 cm respectively. These results are in agreement with the reports of Pandey and Mandal (2010) and Kumar *et al.* (2014) in *A. paniculata*.

High magnitude of variability was observed for stem girth which ranged from 0.57 cm to 3.07 cm. Similar results have been obtained by Nagvanshi and Tirkey (2016) in kiriyat.

Considerable variation was noticed for leaf/stem ratio. It varied from 0.28 to 0.93 and A_{14} (Kottakkal) exhibited the highest leaf/stem ratio. Considerable diversity for the character leaf/stem ratio in kiriyat was also obtained by Misra *et al.* (2001).

Plant height showed high variability with mean values ranging from 38.33 cm to 106.97 cm. This is in accordance with the earlier reports of Misra *et al.* (2001), Pandey and Mandal (2010) and Kumar *et al.* (2014) in *A. paniculata*. The tallest accession was A_7 (Kottakkunnu).

Herbage yield exhibited remarkable variation with a wide range of 56.90 g to 137.25 g. Considerable deviation was reported in *A.paniculata* for the character by Misra *et al.* (2001), Prathanturarug *et al.* (2007), Kumar *et al.* (2014), Nagvanshi and Tirkey (2016) and Manjesh *et al.* (2016). Highest herbage yield was recorded for A_{10} (Aruvipuram).

Wide variability was exhibited for yield plant^{-1} with mean values ranging from 17.21 g to 37.79 g. In *A.paniculata,* Prathanturarug *et al.* (2007), Nagvanshi and Tirkey (2016) and Manjesh *et al.* (2016) also reported high variability of the character. A_{10} (Aruvipuram) had maximum yield plant^{-1}.

Average duration of plant exhibited a range between 182.67 and 213.00 days which indicated wide variability of the character. Nagvanshi and Tirkey (2016) had also reported high variability for the same in kiriyat. A_{13} (Mandya) was reported to have the longest duration.

Among thirty accessions, average total extractives (g) exhibited significant variation with a range from 13.59 g to 2.35 g. It is in agreement with the results of Padmesh *et al.* (1999), Misra *et al.* (2003), Prathanturarug *et al.* (2007), Sharma *et al.* (2009), Minz and Koche (2012), Kumar *et al.* (2014) and Manjesh *et al.* (2016) in *A. paniculata*. Total extractives was highest for A_{10} (Aruvipuram).

5.1.2 Coefficient of Variation

The amount of genetic variability present in the population for the desired characters is also expressed as the coefficient of variation. The genotypic coefficient

of variation (GCV) is the estimate of variability available in the crop which enables the breeder to compare and assessing the amount of variability present for different biometric characters. The phenotypic coefficient of variation is the estimate of total variability. For the characters exhibiting negligible difference between estimates of GCV and PCV, selection will be effective as the environmental influence is low for these characters.

In the present study phenotypic coefficient of variation (PCV) ranged from 5.07 (duration) to 60.03 (number of secondary branches). High PCV were observed for number of secondary branches (60.03) followed by total extractives (50.86), leaf length (48.72), leaf/stem ratio (44.30), leaf width (42.10), stem girth (41.36), plant height (38.68), herbage yield (31.77), yield plant^{-1} (31.76), seedling height (15 DAT) (20.58), number of leaves seedling^{-1} (15 DAT) (21.10) and number of primary branches (21.07).

Similar results were obtained by different scientists in *A. paniculata* . High PCV for plant height has been reported by (Paul, 2000, Misra *et al.*, 2001 and Devi, 2016). Kumar *et al.* (2014) and Nagvanshi and Tirkey (2016) earlier reported high PCV for herbage yield. Misra *et al.* (2001) also reported high PCV for yield plant^{-1}, leaf/stem ratio, seedling height (15 DAT) and number of leaves seedling^{-1} (15 DAT). High PCV for total extractives was reported by Paul (2000), and Kumar *et al.* (2014). Devi (2016) and Nagvanshi and Tirkey (2016) reported moderate PCV for number of secondary branches and stem girth. Moderate PCV was reported for number of primary branches and leaf length (Sharma and Singh, 2012) and leaf width (Devi, 2016).

Days to 50 per cent flowering (11.72) and duration exhibited moderate and low levels of PCV which is in agreement with the report of Devi (2016) in *A. paniculata*.

In the present study genotypic coefficient of variation (GCV) ranged from 4.73 (duration) to 59.09 (number of secondary branches). High GCV as well as PCV was observed for total extractives (46.479), leaf/stem ratio (39.34), plant height (38.59), herbage yield (24.03) and yield plant^{-1} (23.93) that indicated its high degree of genetic variation and so these characters can be improved through selection. These results are in agreement with the reports in *A.paniculata* by Misra *et al.* (2001), Kumar *et al.* (2014), Devi (2016) and Nagvanshi and Tirkey (2016).

In the current investigation genotypic coefficient of variation (GCV) of number of secondary branches (59.09), leaf length (43.01), stem girth (41.17), leaf width (41.13) and number of primary branches (20.05) were high; but moderate GCV was reported for number of secondary branches and stem girth (Devi, 2016 and Nagvanshi and Tirkey, 2016); number of primary branches and leaf length (Sharma and Singh, 2012) and leaf width (Devi, 2016) in *A.paniculata*.

Days to 50 per cent flowering (11.46) and duration (4.73) exhibited moderate and low levels of GCV respectively as that of the report of Devi (2016) in kiriyat.

The difference between PCV and GCV was significantly high for leaf length, herbage yield and total extractives, indicating the influence of environment on these characters. As the difference between PCV and GCV is less it is concluded that the character expression is largely decided by the genotype. Nagvanshi and Tirkey (2016) in *A.paniculata* also reported that PCV value was higher than the GCV for herbage yields and leaf length (Nagvanshi and Tirkey, 2016). Low PCV and GCV estimates were observed for duration which shows that there exists low variability for the character which in turn acts as a constraint for genetic improvement though selection.

5.1.3 Heritability and Genetic Advance

After assessing the degree of variability in a population, total variance should be partitioned into heritable and non heritable components in order to evaluate the true breeding nature of the particular trait under study. Heritability represents the relative degree at which a character is transmitted from parents to off-spring. High heritability of a character indicates low influence of environment in its expression and the phenotype of the trait strongly reflects the genotype. These traits with high heritability could be improved by adopting simple selection methods (Johnson *et al.*, 1955). Further, the information on genetic variation, heritability and genetic advance helps to predict the genetic gain that could be obtained in later generations.

Heritability (in broad sense) was high for all the characters except number of leaves seedling^{-1} (15 DAT), herbage yield and yield plant^{-1}. The highest heritability was obtained for stem girth (99.06 %) which is followed by number of secondary branches (96.87 %), seedling height (15 DAT) (96.33 %), days to 50 per cent flowering (95.55 %), leaf width (95.46 %), plant height (89.52 %), number of primary branches (88.55 %), duration (87.11 %), herbage yield (98.92 %), yield plant^{-1} (98.07 %), and duration (87.11 %), total extractives (83.51 %), leaf/stem ratio (78.85 %), leaf length (77.91 %), while moderate heritability was observed for herbage yield (57.22 %), yield plant^{-1} (56.73 %) and number of leaves seedling^{-1} (15 DAT) (56.39 %).

Similar findings were reported from the works of various scientists in *A. paniculata*. High heritability for stem girth is in accordance with the findings by Misra *et al.* (2003), Nagvanshi (2014) and Devi (2016). Reports by Nagvanshi (2014) and Devi (2016) support the findings of the present study namely high heritability estimates for number of primary and secondary branches Days to 50 per cent flowering, duration, seedling height (15 DAT) and leaf width exhibited high

heritability, which is in agreement with the findings of Paul (2000), Nagvanshi (2014) and Devi (2016). Studies by Misra *et al.* (2003), Nagvanshi (2014) and Devi (2016) supports the high heritability estimate for plant height obtained in the present study. Total extractives exhibited high heritability, which is in accordance with the reports of Paul (2000), Sharma and Singh (2012) and Devi (2016). Leaf length and leaf/stem ratio exhibited high heritability in the present investigation as supported by similar findings in the experiments conducted by Devi (2016).

Herbage yield and yield plant^{-1} and number of leaves seedling^{-1} (15 DAT) exhibited moderate heritability in the present investigation, but earlier reports in *A. paniculata* by Paul (2000), Sharma and Singh (2012), Nagvanshi (2014) and Devi (2016) showed high heritability for the characters.

All the characters exhibited high genetic advance (as per cent of mean) except duration (9.10 %) which exhibited low genetic advance. The highest estimate was obtained for number of secondary branches (119.80 %) followed by total extractives (87.50 %), stem girth (84.41 %), leaf width (82.79 %), plant height (79.30 %), leaf length (78.20 %), leaf/stem ratio (71.97 %), yield plant^{-1} (45.30 %), seedling height (15 DAT) (40.85 %), number of primary branches (38.44 %), herbage yield (37.44 %), number of leaves seedling^{-1} (15DAT) (32.64 %) and days to 50 per cent flowering (23.08 %).

Reports of high genetic advance for herbage yield by Sharma and Singh (2012) and yield plant^{-1} by Sharma and Singh (2012) and Devi (2016) in *A. paniculata* support the estimates from the present study. Total extractives was reported with high genetic advance which is in agreement with the reports of Paul (2000) and Sharma and Singh (2012) in kiriyat. Number of secondary branches, primary branches and number of leaves seedling^{-1} (15DAT) showed high genetic advance in the present investigation and this is in accordance with the report by Nagvanshi (2014). High genetic advance for stem girth was obtained. Nagvanshi

(2014) has also reported high genetic advance for stem girth. Studies conducted in *A.paniculata* by Devi (2016) support the present study for high genetic advance in the characters plant height and seedling height (15 DAT).

Genetic advance (per cent mean) was high for days to 50 per cent flowering and it was low for duration. Paul (2000) and Nagvanshi (2014) also reported the same result for days to 50 per cent flowering and Devi (2016) for duration. Genetic advance (per cent mean) was high for leaf width in the present study which is in accordance with the report in *A.paniculata* by Nagvanshi (2014). Genetic advance (per cent mean) was high for leaf length and leaf/stem ratio. This finding is in contrast to the reports of Devi (2016) in *A.paniculata* where the magnitudes of genetic advance (as percent mean) were low for leaf length and leaf/stem ratio.

High heritability along with high genetic advance indicates additive gene action which in turn provides an opportunity for genetic improvement through selection (Panse, 1957).

In the present study, high heritability coupled with high genetic advance was observed for seedling height, number of secondary branches, leaf length and width, stem girth, leaf/stem ratio, plant height and total extractives. These are in agreement with the reports by Misra *et al.* (2003), Nagvanshi (2014) and Devi (2016) for stem girth; Paul (2000), Sharma and Singh (2012) and Devi (2016) for total extractives; Nagvanshi (2014) for number of secondary branches and primary branches; Nagvanshi (2014) and Devi (2016) for days to 50 per cent flowering and duration, leaf width; Misra *et al.* (2003), Devi (2016) for leaf length and leaf/stem ratio and Nagvanshi (2014) and Devi (2016) for plant height.

Since, the characters number of secondary branches, leaf length and width, stem girth, leaf/stem ratio, plant height and total extractives exhibited high

heritability along with high genetic advance (as per cent of mean), there is a scope for improvement on these characters through selection.

5.1.3 CORRELATION COEFFICIENT ANALYSIS

Correlation coefficient analysis of plant characters with yield and among themselves will reveal the magnitude of the relationship between different traits along with the effect of one character on the other and on yield. Genotypic associations between characters is represented as genotypic correlations and are reliable estimates used for differentiating vital association from non vital ones for facilitating crop improvement (Falconer, 1964).

In the present investigation, relationship of yield plant^{-1} with twelve yield components and total extractives along with their relationship among themselves were examined using correlation analysis. Genotypic correlations in general were high as compared to their phenotypic correlations indicating strong inherent association between the characters which might be masked by modifying effects of environment.

High positive correlation was recorded for yield plant^{-1} with herbage yield, leaf/stem ratio, stem girth, seedling height (15 DAT), plant height, number of secondary branches, total extractives, number of leaves seedling^{-1} (15DAT) and number of primary branches. Earlier reports on positive genotypic correlation of yield with herbage yield (Valdiani *et al.*, 2012; Nagvanshi, 2014 and Devi, 2016), leaf/stem ratio (Valdiani *et al.*, 2012), stem girth (Devi, 2016), plant height (Nagvanshi, 2014 and Devi, 2016), number of secondary branches (Devi, 2016), number of leaves seedling^{-1}, seedling height and total extractives (Valdiani *et al.*, 2012) and number of primary branches (Devi, 2016) supports the findings of present study.

Total extractives exhibited high positive correlation with seedling height, number of leaves seedling^{-1}, leaf/stem ratio (Valdiani *et al.*, 2012), yield plant^{-1}, herbage yield (Nagvanshi, 2014), number of secondary branches, plant height, stem girth, and number of primary branches (Devi, 2016).

The association of yield plant^{-1} and total extractives with leaf length, leaf width, days to 50 percent flowering and duration was significantly negative in the present investigation (Devi, 2016). This suggests that selection of early flowering, early maturing accessions with short and thin leaves would result in better yielding types with high amount of total extractives.

High genotypic correlation and phenotypic correlation existing between yield plant^{-1} and herbage yield is in accordance with the report of Nagvanshi (2014) and Devi (2016). Earlier reports of high genotypic correlation and phenotypic correlation of yield plant^{-1} with leaf/stem ratio by Valdiani *et al.* (2012), stem girth and plant height by Nagvanshi (2014) and Devi (2016), number of secondary branches by Devi (2016), number of leaves seedling^{-1}, seedling height and total extractives by Valdiani *et al.* (2012) substantiate the present findings.

The above mentioned characters except herbage yield exhibited high heritability coupled with high genetic advance and it also exhibited low environmental correlation. Hence, it suggests that indirect selection based on these characters would simultaneously lead to the improvement of yield as their phenotypic values reflect the genotypic worth.

For efficient indirect selection for yield on the basis of yield attributes, estimates of interrelationships among yield components is essential as it provides more reliable information for efficient selection.

Seedling height (15 DAT) and seedling height (15 DAT) showed highly significant positive correlation with herbage yield, plant height, yield plant^{-1}, total extractives and among themselves which is similar to the report by Valdiani *et al.* (2012).

Days to 50 per cent flowering and duration had highly significant negative correlation with herbage yield, yield plant^{-1} and total extractives. Days to 50 per cent flowering and duration had highly significant positive correlation with leaf length and leaf width and among themselves which is similar to the report by Devi (2016). In accordance with the reports by Devi (2016) they exhibited highly significant negative correlation with stem girth and for leaf/stem ratio as that reported by Valdiani *et al.* (2012).

Days to 50 per cent flowering and duration had highly significant positive correlation with leaf length and leaf width and among themselves which is similar to the report by Devi (2016). Earlier report by Valdiani *et al.* (2012) supports its present negative correlation with total extractives, leaf/stem ratio, herbage yield and yield plant^{-1}. Reports by Devi (2016) agree with the negative correlation of days to 50 per cent flowering with number of secondary branches, plant height, stem girth, seedling height (15 DAT) and number of primary branches.

Earlier reports on positive correlation of number of primary branches and number of secondary branches with herbage yield, yield plant^{-1} and among themselves (Devi, 2016); leaf/stem ratio, number of leaves seedling^{-1}, seedling height, stem girth and total extractives (Valdiani *et al.*, 2012); plant height and number of secondary branches (Nagvanshi, 2014) and (Devi, 2016) supports the findings of present study. Number of primary branches exhibited negative association with days to 50 per cent flowering, duration, leaf width and leaf length which is in agreement with findings of Valdiani *et al.* (2012).

Highly significant positive association had been noticed for leaf length and leaf width with days to 50 per cent flowering and duration and also with themselves. This association is in confirmation with that reported by Devi (2016). Negative correlation was already estimated for leaf length and width with total extractives, herbage yield and yield plant^{-1} (Valdiani *et al.*, 2012; Nagvanshi, 2014 and Devi, 2016); leaf/stem ratio , number of leaves seedling^{-1} and seedling height (Valdiani *et al.*, 2012); number of secondary branches, plant height, stem girth and number of primary branches (Devi, 2016).

Stem girth showed positive correlation with leaf/stem ratio which was reported by both Devi (2016) and Valdiani *et al.* (2012). These two characters exhibited positive correlation with yield plant^{-1} and plant height (Valdiani *et al.*, 2012; Nagvanshi, 2014), number of secondary branches (Devi, 2016), seedling height, number of leaves seedling^{-1}, number of primary branches and total extractives (Valdiani *et al.*, 2012). Earlier reports supports their negative association with duration, days to 50per cent flowering (Devi, 2016), leaf width, leaf length and days to 50 per cent flowering (Nagvanshi, 2014).

Positive correlation was observed between plant height and herbage yield. This is in accordance with the report of Nagvanshi (2014) and Devi (2016). These two characters showed positive association with number of leaves seedling^{-1}, seedling height, total extractives, number of primary branches (Valdiani *et al.* (2012), leaf/stem ratio , stem girth (Devi, 2016 and Valdiani *et al.*, 2012), yield plant^{-1}, number of secondary branches, total extractives and number of primary branches. As observed by earlier researchers they possessed negative association with leaf width, leaf length Nagvanshi (2014), days to 50 per cent flowering and duration (Devi, 2016).

The above association suggests that indirect selection based on herbage yield, plant height, number of secondary branches, number of leaves seedling^{-1} (15DAT),

seedling height (15DAT) and number of primary branches would improve yield plant^{-1} and total extractives.

5.1.4 PATH ANALYSIS

The association of different component characters among themselves and with yield is quite important for making an efficient selection criterion for yield. The total correlation between yield and its component characters may sometimes be misleading, as it might be an over-estimate or under-estimate because of its association with other characters which are also associated with economic yield. Hence, indirect selection by correlated response may sometimes not be fruitful. When many characters are affecting a given character, splitting the total correlation into direct and indirect effects based on association between the dependent variable like yield and independent variables like yield components could be beneficial. This kind of information will help in making the basis of selection more meaningful for breeding programme.

In the present study, maximum positive direct effect on yield plant^{-1} was exhibited by plant height (0.861) followed by herbage yield (0.824), days to 50 per cent flowering (0.769), leaf/stem ratio (0.579), total extractives (0.411), number of primary branches (0.358), number of secondary branches (0.341) and seedling height (15 DAT) (0.336) (Fig. 4). Characters that have positive direct effect as well as exhibiting positive correlation were plant height, herbage yield and total extractives. Plant height exerted positive indirect effect via total extractives and leaf/stem ratio.

Earlier reports on positive direct effect of plant height, herbage yield, days to 50 per cent flowering, leaf width (Nagvanshi, 2014 and Devi, 2016), leaf/stem ratio, total extractives (Nagvanshi, 2014), seedling height (15 DAT) (Devi, 2016), number of primary branches (Nagvanshi, 2014) and number of secondary branches

(Nagvanshi, 2014 and Devi, 2016) on yield plant^{-1} is in concordance with the findings in the present study.

Herbage yield exhibited high positive genotypic correlation and direct effect on yield plant^{-1}. It exerted high positive indirect effect via total extractives and plant height. This is same as that reported by Devi (2016).

Total extractives was found to have high positive direct effect and genotypic correlation. It had high positive indirect effect via plant height which is in agreement with that reported by Nagvanshi (2014).

It is concluded that as maximum positive direct effect on yield plant^{-1} is exhibited by plant height, herbage yield, days to 50 per cent flowering, leaf/stem ratio, total extractives, number of primary branches, number of secondary branches and seedling height (15 DAT). Hence it suggests that these characters should be given due weightage in selection programmes for improving yield plant^{-1} and total extractives.

5.1.4 MAHANALOBIS D^2 ANALYSIS

Estimation of degree of variability for each of the characters reflects the scope for improving the character under consideration through selection. In a hybridization programme diverse parents are selected inorder to exploit heterosis. Hence the knowledge of genetic diversity among the genotypes is necessary for population improvement. Based on the genetic diversity analysis, diverse parents among the genotypes can be selected. Therefore, in the present study information on genetic diversity present in the thirty accessions of kiriyat was analyzed.

Thirty genotypes were grouped into seven clusters based on fourteen characters and the relative magnitude of D^2 values. The greater the distance between two clusters, greater the divergence between accessions included in these two clusters

and vice versa. Out of the seven clusters, cluster VII was the largest cluster with thirteen accessions followed by cluster VI with five accessions, cluster V which contained four accessions, clusters III and IV with two accessions each and cluster I was a solitary cluster with one accession, indicating high degree of heterogeneity among the genotypes. This was supported by the genetic diversity study report on kiriyat by Nagvanshi and Tirkey (2016), Devi (2016) and Lattoo *et al.* (2008).

Cluster VI had the maximum cluster mean for seedling height (13.29cm), number of leaves seedling^{-1} (15 DAT) (10.4 days), number of primary branches (28.19), stem girth (2.75 cm), leaf/stem ratio (0.88), plant height (101.6 cm) and herbage yield (119.58g). Hence, accessions in this cluster were found to be superior in terms of economic characters.

Cluster I was a solitary cluster with one accession (A9). The accession was noticed for its early maturing habit as it had minimum days to 50 percent flowering (193.00) and duration (182.66). It also had highest number of secondary branches (145.00) and total extractives (12.10 g).

The average inter and intra cluster distances are furnished in table 10.

Clusters that are separated by high inter cluster distance exhibit maximum divergence. Highest inter cluster distance was observed between cluster VI and cluster VII (9337.03) followed by that between cluster I and cluster VII (6726.74), cluster IV and VI (6076.40), cluster II and VII (6054.26); I and IV (5105.60), cluster II and IV (3789.44), V and VI (3736.23), III and VII (3361.29) and the least was between V and III (838.90). Intra cluster distance highest for cluster IV (510.76) and least for cluster VI (355.92).

The present findings are supported by the findings of Devi (2016) in which 136 genotypes of *A. paniculata* were classified into twelve clusters based on D^2 value. 47 genotypes were included in cluster III. Inter-cluster distance was highest

between cluster VII and X (1882.208) while intra-cluster distance was highest for cluster XI (531.957).

The study revealed that variability existed among the different ecotypes of kiriyat and the ecotype collected from Aruvipuram (A_{10}) was found to be superior in terms of herbage yield and quality (as % of total extractives) followed by ecotypes from Kottakkal (A_{14}) and Kottakkunnu (A_7). Since highest inter cluster distance was observed between cluster VI and cluster VII (9337.03), selection of accessions included in these clusters could be exploited for obtaining maximum heterosis. The difference between PCV and GCV was significantly high for leaf length, herbage yield and total extractives, indicating the influence of environment on these characters. As the difference between PCV and GCV is less it is concluded that the character expression is largely decided by the genotype. Since, the characters number of secondary branches, leaf length and width, stem girth, leaf/stem ratio, plant height and total extractives exhibited high heritability along with high genetic advance (as per cent of mean), there is a scope for improvement on these characters through selection. High genotypic correlation and phenotypic correlation existing for yield plant^{-1} with herbage yield, plant height, number of secondary branches, number of leaves seedling^{-1} (15DAT), seedling height (15DAT) and number of primary branches which suggests that indirect selection based on herbage yield, plant height, number of secondary branches, number of leaves seedling^{-1} (15DAT), seedling height (15DAT) and number of primary branches would improve yield plant^{-1} and total extractives.

SUMMARY

6. SUMMARY

The study entitled "Genetic divergence in kiriyat (*Andrographis paniculata* Nees)." was under taken at College of Agriculture, Vellayani during 2015-17 with an objective to assess the genetic variability present in the natural ecotypes of kiriyat from different regions and identifying the superior ecotypes in terms of herbage yield and quality.

Thirty accessions of kiriyat were collected from different parts of India and were evaluated for genetic variability with respect to herbage yield and quality in terms of total extractives. Observations were recorded for seedling height at 15 DAT (Days After Transplanting) (cm), number of leaves seedling-1, days to 50 percent flowering, number of primary branches, number of secondary branches, leaf length (cm), leaf width (cm), stem girth (cm), leaf/stem ratio, plant height, herbage yield (fresh yield) (g), yield plant^{-1} (dry weight) (g), duration and total extractives (%).

Analysis of variance revealed significant difference among the accessions for all the characters considered under study. The accession A_{10} from Aruvipuram showed highest mean values for herbage yield, yield plant^{-1} and total extractives. However, A_{14} (Kottakkal) and A_7 (Kottakkunnu) were on par with A_{10}. The accessions A_{14} (Kottakkal) and A_{15} (Nilambur) showed highest mean values for number of secondary branches and number of leaves seedlings^{-1} (15 DAT) respectively. Mean value for days to 50 percent flowering was least for accession A_{10}. The lowest yield was exhibited by A_3 (Coimbatore) accession.

Highest GCV was observed for number of secondary branches followed by total extractives, leaf length, stem girth, leaf width, leaf/stem ratio, plant height, herbage yield, yield plant^{-1}, number of leaves seedling^{-1} (15 DAT), number of primary branches and seedling height (15 DAT). Days to 50 percent flowering exhibited moderate level of GCV whereas, duration exhibited low GCV.

Heritability (in broad sense) was high for all the characters under study except number of leaves seedling^{-1} (15 DAT), herbage yield and yield plant^{-1}. The highest heritability was obtained for stem girth followed by number of secondary branches, seedling height (15 DAT), days to 50 percent flowering, leaf width, plant height, number of primary branches, duration, herbage yield, yield plant^{-1}, duration, total extractives, leaf/stem ratio, leaf length, while moderate heritability was observed for herbage yield, yield plant^{-1} and number of leaves seedling^{-1} (15 DAT).

All the characters exhibited high genetic advance (as % of mean) except duration which exhibited low genetic advance. The highest estimate was obtained for number of secondary branches followed by total extractives, stem girth, leaf width, plant height, leaf length, leaf/stem ratio, yield plant^{-1}, seedling height (15 DAT), number of primary branches, herbage yield, number of leaves seedling^{-1} (15DAT) and days to 50 percent flowering.

Highly significant positive correlation was recorded between yield plant^{-1} and herbage yield followed by leaf/stem ratio, stem girth, seedling height (15 DAT), plant height, number of secondary branches, total extractives, number of leaves seedling^{-1} (15DAT) and number of primary branches. The association was significantly negative with leaf length followed by leaf width, days to 50 percent flowering and duration.

Characters exhibiting positive direct effect on yield plant^{-1} were plant height followed by herbage yield, days to 50 percent flowering, leaf/stem ratio, total extractives, number of primary branches, number of secondary branches, seedling height (15 DAT) and leaf width; while characters such as number of leaves seedling^{-1} (15 DAT) followed by leaf length and stem girth had high negative direct effect on yield plant^{-1}.

Cluster VI had the maximum cluster mean for seedling height, number of leaves seedling^{-1} (15 DAT), number of primary branches, stem girth, leaf/stem ratio, plant height, herbage yield and total extractives. Hence, accessions in this cluster were found to be superior in terms of economic characters.

The genetic divergence was studied using Mahanalobis D^2 statistics and accessions were grouped into seven clusters. Cluster VII accommodated maximum number of accessions (13) followed by cluster VI (5), cluster V (4), cluster IV (3), clusters III and II (2) and cluster I (1). Highest inter cluster distance was between clusters VI and VII while intra cluster distance was highest for cluster IV.

The study revealed that variability existed among the different ecotypes of kiriyat and the ecotype collected from Aruvipuram (A_{10}) was found to be superior in terms of herbage yield and quality (as % of total extractives) followed by ecotypes from Kottakkal (A_{14}) and Kottakkunnu (A_7).

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GENETIC DIVERGENCE IN KIRIYAT

(*Andrographis paniculata* Nees).

by

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ABSTRACT

The study entitled "Genetic divergence in kiriyat (*Andrographis paniculata* Nees)." was under taken at the College of Agriculture, Vellayani during 2015-17 with the objective to assess the genetic variability present in the natural ecotypes of kiriyat from different regions and identifying the superior ecotypes in terms of herbage yield and quality.

Thirty accessions of kiriyat were collected from different parts of India and were evaluated for genetic variability with respect to herbage yield (fresh weight) and quality in terms of total extractives (%). Accession A_{10} from Aruvipuram showed highest mean values for seedling height (15 DAT), number of primary branches, herbage yield (137.25 g), yield plant^{-1} (dry herbage yield plant^{-1}) (37.79 g) and total extractives (13.6 %) followed by the A_{14} (Kottakkal) and A_7(Kottakkunnu). The accessions A_{14} (Kottakkal) and A_{15} (Nilambur) showed highest mean values for number of secondary branches and number of leaves seedlings^{-1} (15 DAT) respectively. Mean value for days to 50 percent flowering was least for accession A_{10}. The lowest yield was exhibited by A_3 (Coimbatore) accession. Average duration of the plants exhibited ranged between 182.67 and 213 days. The earliest accession was A_{10} (Aruvipuram) with an average duration of 182.67 days.

Seedling height, number of leaves seedling^{-1}, number of secondary branches, leaf length and width, stem girth, leaf/stem ratio, plant height, herbage yield, yield plant^{-1} and total extractives exhibited high coefficient of variations. Heritability was high for all the characters except number of leaves seedling^{-1} (15 DAT), herbage yield and yield plant^{-1} which possessed moderate heritability. GA (% mean) was high for all the characters except plant duration. The association analysis revealed a significant correlation among almost all characters and also with yield.

Path coefficient analysis revealed that plant height, herbage yield, number of primary and secondary branches had high positive direct effect on yield.

The genetic divergence was studied using Mahanalobis D^2 statistics and accessions were grouped into seven clusters. Cluster VII accommodated maximum number of accessions (13) followed by cluster VI (5), cluster V (4), cluster IV (3), clusters III and II (2) and cluster I (1). Highest inter cluster distance was between clusters VI and VII while intra cluster distance was highest for cluster IV.

The study revealed that variability existed among the different ecotypes of kiriyat and the ecotype collected from Aruvipuram (A_{10}) was found to be superior in terms of herbage yield and quality followed by ecotypes from Kottakkal (A_{14}) and Kottakkunnu (A_7).