Genetic Divergence in Ashwagandha [*Withania somnifera* (L.) Dunal]

अश्वगंधा [*विथानिया सोमनिफेरा* (एल.) डुनाल] में आनुवांशिक अपसरण

KAPIL KUMAR NAGAR

Thesis

Master of Science in Agriculture

(Plant Breeding and Genetics)

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DEPARTMENT OF PLANT BREEDING AND GENETICS
RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
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BY

KAPIL KUMAR NAGAR

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Maharana Pratap University of Agriculture and Technology
Rajasthan College of Agriculture, Udaipur

CERTIFICATE-I

Dated: / /2018

This is to certify that **Mr. Kapil Kumar Nagar** has successfully completed the Comprehensive Examination held on 28 / 05 / 2018 as required under the regulation for the degree of **Master of Science in Agriculture**.

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Dated: / /2018

This is to certify that the thesis entitled **"Genetic Divergence in Ashwagandha [*Withania somnifera* (L.) Dunal]"** submitted for the degree of **Master of Science in Agriculture** in the subject of **Plant Breeding and Genetics** embodies bonafide research work carried out by **Mr. Kapil Kumar Nagar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on / /2018.

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This is to certify that **Mr. Kapil Kumar Nagar,** student of **Master of Science in Agriculture**, Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur has made all the corrections / modifications in the thesis entitled **"Genetic Divergence in Ashwagandha [*Withania somnifera (L.)* Dunal]"** which were suggested by the external examiner and the advisory committee in the oral examination held on / /2018. The final copies of the thesis duly bound and corrected were submitted on / /2018, are enclosed herewith for approval.

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Enclose: One original and three copies of bound thesis forwarded to the Director, Resident Instructions, Maharana Pratap University of Agriculture and Technology, Udaipur through the Dean, Rajasthan College of Agriculture, Udaipur.

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Place: Udaipur **(KAPIL KUMAR NAGAR)**

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CONTENTS

* APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

^{o}C	Degree Celsius
µg	Microgram
µg /ml	Microgram per milliliter
%	Percentage
ANOVA	Analysis of variance
CD	Critical difference
Cm	Centimeter
CV	Coefficient of variance
d.f.	Degree of freedom
DPPH	2,2-diphenyl-1-picrylhydrazyl
et al.,	Coworkers
G	Gram
G.A	Genetic Advance
h^2	Heritability
g/l	Gram per litre
H_2SO_4	Sulphuric acid
L	Linneaus
M	Molar
M.S.	Mean sum of square
M.W.	Molecular weight
Mg	Milligram
mg/l	Milligram per Liter
Min	Minutes
ml	Milliliter
mm	Millimeter
N	Normal
NaOH	Sodium hydroxide
nm	Nanometer
r_g	Genotypic correlation coefficient
r_p	Phenotypic correlation coefficient
SEm	Standard error mean
S.S.	Sum of square

1. INTRODUCTION

Medicinal plants constitute a large segment of the flora, which provide raw materials for use by pharmaceutical cosmetic, fragrance on flavour industries. India has a rich heritage and long history a using medicinal and aromatic plant in improving the quality of life. The Indian system of medicines comprises of ayurveda, siddha and unani are having their long root in our society. Ayurveda is above 5000 years old and predominantly use medicinal plants for their preparation and formulations. Modern pharmacopeia also listed at least 25 percent of drigs derived from plants and vast majority although synthetic analogues built on prototype compounds isolated from plants. India is fortunate perhaps to have the richest reservoir of traditional medicinal plants and prescription.

As per the estimate of WHO about 80 percent of the world population depends on herbal medicinal for their primary health care. Not only that the care of some of the deadly and painful disease such as cancer AIDS, HIV, rheumatic orthgitis etc., look promising from herbal source. While the demand for herbal medicines is growing in developed countries, there are indication that consumers is developing countries are becoming disillusioned with modern health care system and seeking alternative to traditional medicines.

Ashwagandha [*Withania somnifera* (L.) Dunal] also known as Indian ginseng (poison) gooseberry or winter cherry is a plant of the solanaceaefamily (Mir *et al*., 2013) with chromosome 2n=48 is a native of north-western region and central India as well as Mediterranean region of north Africa.In India two species of genus *Withania viz*., *Withania somnifera* (L.) Dunal (Ashwagandha) are *Withania coagulans*(L.) Dunal (panir) are found. It is an interest to record that the cultivated plants have sizable differences from the wild plants not only in their morphological characters including low branching but also in their therapiutical action. *Withania sominifera* (L.) is an erect evergreen, 60-70 cm tall ,under domestication and it is grown for its roots, leaves are simple ovate and opposite. The flowers are inconspicuous greenish or dull yellow and bisexual. *Withaniacoagulans* isrigid grey under shrub of 60-120 cm height. The fruit is called berry and orange/red in colour when mature. The seeds are small flat yellow and uniform in shape and very light in weight (Atal *et al.*, 1961).

Ashwagandha is cultivated mainly in Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, Punjab and Uttar Pradesh whereas *Withania coagulans* (L.) found in wild. It is indigenous to India and is also found in Spain, Egypt, Israel, Jordan, Sudan, Iran, Afghanistan, Morocco, Baluchistan, Pakistan, Shrilanka, and Mediterranean region of east Africa. It is late *kharif* crop and grown under dry climate or required less irrigation for plant growth and rainfed cultivation. It is grown between 600-1200 meters altitudes. The semi tropical area receiving 60-75 cm annual rainfall with high temperature 20°c to 35°c is suitable for its cultivation. Ashwagandha is grown on marginal lands of Neemach and Mandsaur district of M.P. and Kota, Jhalawar, Pratapgarh, Chittorgarh and Baran districts of Rajasthan Ashwagandha is an important medicinal plant.Its roots leaves and seeds are used in ayurvedic and unani medicines.The medicinal utility of roots is due to present of number of alkaloids.The total alkaloids content in the roots varied from 0.16 to 0.66 percent (Biennial Progress Report of AICRP on Medicinal & Aromatic Plant, 2006-08).The main alkaloids are *withanolids, sominiferine, sominiferinine, somnine, withananine, pseudo withananinine,* and *asomnine* (Covello and Ciampa,1960).The roots are prescribed in medicines for hiccup, several female disorders, bronchitis, rheumatism, dropsy, stomach and lung inflammation and skin disease. Its roots and paste of green leaves are used to relieve joint pain and inflammation.It is also an in gradient of medicaments prescribed for curing disability and sexual weakness in males.Seeds are diuretic, warm leaves are used for providing comfort during eye disease (Nigam and Kandalkar,2006).

Limited breeding work has been done in this important medicinal crop for developing high yielding varieties. There are strong possibilities todevelop genotypes having high dry root yield and *Withanoids* content.Hence identification of desirable genotypes for particular trait is necessary. There is wide variability in the dry root yield and size of roots in ashwagandha (Das *et al*., 2011).This suggests that there is a good scope for increasing productivity and production by developing high dry root yielding varieties.Therefore, it is necessary to study the available variability in genotypes of ashwagandha considering the status and low dry root yield productivity of the crop, there is need to develop and identify superior genotypes by exploiting the available variation.

Keeping the above points in view the present investigation has been proposed to be under taken with the following objectives:

1. To assess the genetic variability parameters for morphological traits with dry root yield and quality traits.
2. To study genotypic and phenotypic correlation and path coefficient analysis.
3. To find out genetics divergences among the genotypes.

2. REVIEW OF LITERATURE

An improvement of a crop can be done by breeding high yielding varieties with improved quality which depends upon the extent, nature and magnitude of genetic variability present in the material and the extent to which it is heritable. Genetic variability and divergence is of greatest interest to plant breeder as it plays a vital role in farming successful breeding programmeyield is the most important economic factor, polygenic in nature and depend on various contribution factors. Thus an understanding of the association among component traits and their direct and indirect contributions towards yield is essential. Correlation merely describes the mutual association between variables while, path analysis provides effective means for examining the specific forces acting to produce a given correlation and it reveal direct and indirect contribution of individual characters towards yield. In any crop breeding programme, genetic diversity is essential pre-requistic in selecting desirable parents for hybridization and evolving high yielding genotypes. The study a D^2 statistics assesses the genetic divergence among population along with relative contribution of different yield components to total divergence.

Thus present investigation was conducted to estimation variability parameters, correlation, path coefficient analysis and genetics divergence for dry root yield and its contributing and quality traits in Ashwagandha [*Withania somnifera*(L.) dunal]. In

thelight of above facts the important work done in ashwagandha has been reviewed under following heads:

1. Genetic variability parameters
2. Correlation and path analysis
3. Genetic divergence

2.1 Genetic Variability Parameters:

Presence of genetic variability is a pre-requisite for any crop improvement. An insight into the magnitude of variability present in a crop species is of outmost importance as it provides basis for effective selection. Phenotypic variability is the observable variation present in character in a population and it includes both genotypic and environmental component of variation. Genotypic variation is due to genotypic difference among individual within a population and is the main concern for plant breeders.

Fisher(1918) first time total genetic variance partitioned into three component *viz.*, (a)additive genetic component (b)dominant component (c) epistasis component. Additive genetic variance could be exploited for genetic advance through selection.

Panse (1957) stated that if heritability was due to dominance and epistasis effects, the genetic gain would be low, while in other cases where heritability was due to additive gene effects, a high genetic advance could be expected.

Detailed reviews on these aspects are presented in tabular form (Table 1.)

2.2 Correlation and Path analysis:

The concept of correlation coefficient was given by Galton (1889) and later on it was elaborated by fisher (1918 and 1936). The statistics which measures the relationship between two or more variables is known as correlation coefficient. In plant breeding correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Further path coefficient analysis is simply standardized partial regression coefficient which splits the correlation coefficient into the measure of direct and indirect effects of a set of independent variables on a dependent. Path analysis initially suggested by wright (1921) but was

applied for first time in plant breeding by Deway and lu (1959). A detailed review on these aspects are presented in tabular form (Table 2).

Table-1 Reference on variability parameters in Ashwagandha

S.No.	Character	High to moderate GCV	High to moderate Heritability	High to moderate G.A.
1.	**Day to flowering**	-	Sahu *et al*. (2015).	-
2.	**Days to 75 percent Maturity**	-	-	-
3.	**Plant height (cm)**	Laxminarayan and Mukund (2003).	Srivastava *et al.* (2017).	Mishra *et al.* (1998) and Srivastava *et al*. (2017).
4.	**Number of primary branches per plant**	Laxminarayan and Mukund (2003), Arun kumar *et al.* (2007), Sundesh and Tank (2013), Singh *et al*. (2014), Sukh Dev *et al.* (2015) and Joshi *et al*. (2014).	Laxminarayan and Mukund (2003).	Laxminarayan and Mukund (2003).
5.	**Number of secondary branches per plant**	kumar *et al.* (2007), Sundesh and Tank (2013) and Joshi *et al*.(2014).	Singh *et al*. (2014).	Singh *et al*. (2014).
6.	**Leaf area index**	-	-	-
7.	**Root length (cm)**	kumar *et al.* (2007) Singh *et al*. (2014) and Joshi *et al*. (2014).	Joshi *et al*. (2014), Singh *et al*.(2014) and Sahu *et al.* (2015).	Singh *et al.* (2014) and Joshi *et al.* (2014).
8.	**Root diameter in collar**	kumar *et al.* (2007), Yadav *et al*. (2008) and Singh *et al.* (2014).	Singh *et al*. (2014), Joshi *et al*. (2014) and Sahu *et al*. (2015).	Yadav *et al*. (2008), Singh *et al.* (2014) and Joshi *et al*. (2014).

S. No.	Character	High to moderate GCV	High to moderate Heritability	High to moderate G.A.
9.	**Fresh root yield (g/plant)**	Mishra *et al.* (1998), Arun kumar *et al.* (2007) and Yadav *et al*. (2008).	Srivastava *et al.* (2017).	Yadav *et al.* (2008) and Srivastava *et al*. (2017).
10.	**Dry root yield (g/plant)**	Laxminarayan and Mukund (2003), Mishra *et al*. (1998), Arun kumar *et al.* (2007), Sundesh and Tank 2013, Dubey (2010), Sahu *et al.* (2015) and Joshi *et al*. (2015).	Laxminarayan and Mukund(2003), Dubey (2010), Sangwan *et al.* (2013), Sahu *et al*. (2015) and Joshi *et al.* (2015).	Laxminarayan and Mukund (2003), Yadav *et al.* (2008), Dubey (2010), Sangwan *et al*. (2013) and Joshi *et al*. (2014).
11.	**Fresh plant weight(g/plant)**	Sangwan *et al.* (2013).	Mohsina and Datta (2007) and Sangwan *et al.* (2013).	Mohsina and Datta (2007) and Sangwan *et al.* (2013).
12.	**Dry plant weight (g/plant)**	-	-	-
13.	**100-Seed weight (g)**	Yadav et al. (2008).	-	Mohsina and Datta (2007).
14.	**Harvest index(%)**	-	-	-
15.	**Total alkaloid content**	Sundesh and Tank (2013) and Joshi *et al*. (2015).	Joshi *et al*. (2014) and Sukh Dev *et al*. (2015).	Joshi *et al*. (2014) and Sukh Dev *et al*. (2015).

Table-2 Reference on correlation with dry root yield for different traits in Ashwagandha

S.No.	Characters	Positive Correlation	Negative Correlation
1.	**Day to flowering**	Sundesh and Tank (2013) and Gami *et al.* (2016).	-
2.	**Days to 75 per cent maturity**	Sundesh and Tank (2013), Punetha and Gaur (2014), Sukhdev *et al.* (2015) andGami *et al.* (2016).	Sukhdev *et al.* (2015).
3.	**Plant height (cm)**	Mohsina and Datta (2007), Kubsad *et al.* (2009), Sundesh and Tank (2013),Gami *et al.* (2016), Chaudhary *et al*. (2016) and Patel A.I. and Desai B.S. (2017).	Kubsad *et al.*(2009).
4.	**Number of primary branches per plant**	Pol *et al.* (2003), Mohsina and Datta (2007), Sukhdev *et al.* (2015), Gami *et al.* (2016) and Chaudhary *et al*. (2016).	Sundesh and Tank (2013).
5.	**Number of secondary branches per plant**	Pol *et al.* (2003), Gami *et al.* (2016) and Chaudhary *et al*. (2016).	Sundesh and Tank (2013).
6.	**Leaf area index**	Kubsad *et al.* (2009) and Kubsad *et al.* (2011).	-
7.	**Root length (cm)**	Mishra *et al*. (1998), Pol *et al.* (2003), Kumar *et al.* (2008), Yadav *et al.* (2008), Kubsad *et al.* (2011), Kumar *et al.* (2011), Das *et al.* (2011), Sundesh and Tank (2013), Punetha and Gaur (2014), Sukhdev *et al.* (2015)and Patel A.I. and Desai B.S. (2017).	Kubsad *et al.* (2009).

S. No.	Characters	Positive correlation	Negative correlation
8.	**Root diameter in collar**	Mishra *et al.* (1998), Laxminarayan and Mukund (2003), Pol *et al.* (2003), Kumar *et al.* (2008), Yadav *et al.*(2008), Kubsad *et al.* (2009), Kubsad *et al.* (2011), Kumar *et al.* (2011), Sangwan *et al.* (2013), Sundesh and Tank (2013), Punetha and Gaur (2014), Sukhdev *et al.* (2015), Gami *et al.* (2016) andPatel A.I. and Desai B.S. (2017).	-
9.	**Fresh root yield (g/plant)**	Yadav *et al.* (2008), Kumar *et al.* (2008), Sangwan *et al.* (2013) and Punetha and Gaur (2014).	-
10.	**Dry root yield (g/plant)**	Mishra *et al.* (1998), Pol *et al.* (2003), Laxminarayan and Mukund (2003), Kumar *et al.* (2008), Yadav *et al.* (2008), Kubsad *et al.*(2009), Dubey (2010), Kubsad *et al.* (2011), Sundesh and Tank (2013), Sangwan *et al.* (2013),Punetha and Gaur (2014), Sukhdev *et al.* (2015), Gami *et al.* (2016) and Patel A.I. and Desai B.S. (2017).	-
11.	**Fresh plant weight(g/plant)**	--	-
12.	**Dry plant weight (g/plant)**	Pol *et al.* (2003), Kubsad *et al.* (2009) and Kubsad *et al.* (2011).	-
13.	**100-seed weight (g)**	Chaudhary *et al.* (2016).	-
14.	**Harvest index(%)**	Kubsad *et al.* (2009) and Kubsad *et al.* (2011).	-
15.	**Total alkaloid content**	Kumar *et al.* (2011), Sundesh and Tank (2013), Sangwan *et al.* (2013), Sukhdev *et al.* (2015) and Gami *et al.* (2016).	Pol *et al.* (2003).

2.3 Genetics Divergence

The variability present among different genotypes of a species is known as genetic diversity. Genetic variability arises due to geographical separation or due to genetic barriers to cross ability.D^2 statistic found to be a powerful tool to measures genetic divergence among set of genotype (Mahalanobis,1936). This technique measures the force of differentiation at two levels namely intracluster and intercluster levels and thus helps in selection of hybridization programme. The genetic are likely to producers high heterotic effect and desirable segregates.

Several statistical procedure using multiple measurements Mahalanobis (1928), Fisher (1938), Rao (1952) and Anderson (1960) were developed to measure the divergence among population. However, Mahalanobis's (1936) D^2 statistics, based on means and various of populations remain of considerable significance in several biological population.

Kumar *et al.* (2007) assessed six phenotypic characters and three *withanolide* markers in 25 accessions of *Withania somnifera* collected from different states of India for studying genetic variability. The variability ranges observed at phenotypic and genotypic levels were polymorphic. Based on D^2 values and PCA (Principal Component Analysis) of phenotypic traits like plant height, number of branches per plant, number of seeds per berry, root length, root diameter and root yield, these 25 accessions were grouped in five clusters. The relative contribution of each character towards genetic divergence was worked out. Five accessions–AGB002 (Rajasthan), AGB003 (J&K), AGB004 (Madhya Pradesh), AGB006 (J&K) and AGB009 (Punjab) representing clusters 2 and 4 exhibited maximum intra and inter-cluster divergence. The cluster 5 representing accession AGB053 (Andhra Pradesh) was having mixed traits.

Jain *et al.* (2007) studied genetic divergence among 55 ashwagandha genotypes ofdifferent geographic origin which was assessed using Mahalanobis D^2statistics observation revealed significant genotypic differences and accordingly genotypes were classified into tenclusters. Cluster I was the largest with fifteen genotypes followed by II and III clusters whichhave nine genotypes. Cluster IV, V, VI, VII and VIII were also large and consisting more thanone genotype whereas cluster IX and X contained only one most divergent genotype. The

interclusterdistance was minimum (33.02) between cluster I and II and maximum (222.00) betweencluster II and IX. The genotype of cluster IX was unique as it was tallest with higher dry rootyield per plant and root diameter. The genotype of cluster II possessed highest alkaloid contentand root length, whereas the maximum primary and secondary branches per plant observed in thegenotypes of cluster X. Thus, hybridization among these genotypes can generate desirabletransgressivesegregants.

Yadav *et al.* (2007) assessed 32 genotypes of ashwagandha was assessed for ninequantitative characters using Mahalanobis D^2 analysis. Based on D^2 values, the genotypes weregrouped into five clusters with cluster II having the highest genotypes and cluster V with thelowest number. The distribution pattern of genotypes in different clusters was random and therewas little association of genetic divergence with agroecological distributions of genotypes.However, the genotypes of same agro-ecological origin had shown some tendency to cometogether in same cluster. The genotypes of clusters II, IV and V were identified as diverse as wellas having higher mean values for all of the important yield component characters. Thus,hybridization involving genotypes of these clusters is advocated in order to achieve high yieldingsergeants.

Gupta *et al.* (2011**)** estimated genetic divergence of 75 collections of ashwagandha (*Withania somnifera*) for 10 characters. The collections were classified into 14 discrete clusters. The clustering pattern revealed that there was no parallelism between genetic and geographic distribution as the collections from the same geographical regions were found scattered in different clusters. There was sustained variation in clusters distance. Maximum genetic diversity was observed between collections belonging to clusters XII and XIII. On the basis of relative character contribution towards genetic divergence, the highest contributing character was 12-deoxywithastramonalide content in roots (rank 1st with 28.48% contribution) followed by 12-deoxywithastramonalide content in leaves (rank 2nd with 18.63% contribution) and *Withaferin*-A in roots (rank 3rd with 17.82% contribution).

Kumar *et al.* (2011) assessed genetic diversity for morphometric traits and root textural quality parameters among two morphologically distinct groups: Poshita and Nagore of ashwagandha. The PCA separated the morphometric and root texture variables distinctly into two different principal components: PC-1 and PC-2, respectively, indicating that both are negatively associated. All the morphtypes in

Poshita group showed high positive loadings in PC-1 indicating that component genotypes are high root yielding. Nagore morphtypes were low yielding but the root texture was good.

Reddy *et al.* (2012) designed the study to assess genetic diversity for morphometriccharacters and root textural quality parameters among two morphologically distinct groups:Poshita and Nagore. The PCA separated the morphometric and root texture variables distinctly into two different principal components: PC-1 and PC-2, respectively, indicating that both are negatively associated. All the morphotypes in Poshita group showed high positive loadings in PC-1 indicating that component genotypes were high root yielding. Nagore morphotypes were low yielding but the root texture was good. Clustering of morphotypes grouped Poshita and Nagore separately with high inter-cluster distances indicating that both groups were highly divergent from each other, suggesting that there is sufficient scope for varietal improvement through hybridization.

Singh *et al*. (2014) evaluatednineteen ashwagandha germplasm and 2 check varieties to study the diversity pattern among the collected accession. The genotypes were grouped into five clusters. The distribution pattern indicated that the maximum number of genotypes (5) were grouped into cluster II, followed by five in cluster IV. The inter-cluster distance was higher than intra cluster distance indicating wide genetic diversity among the genotypes.

Sahu *et al*. (2015)studied twenty ashwagandha genotypes for genetic diversity using morphological and RAPD markers and found high GCV and PCV for number of berries per plant and dry root yield per plant. While days to 75 per cent flowering, days to 75 per cent maturity, plant height, root length and alkaloid content had low GCV and PCV. High heritability was recorded for days to 75 per cent flowering, no. of berries per plant, dry root yield per plant, root diameter and root length.

Joshi *et al.* (2015) studied genetic divergence among 40 ashwagandha [*Withania somnifera* (L.) Dunal] accessions of different geographic origin wereassessed using Mahalanobis D^2 statistics. Observations revealed significant genotypic differences and accordingly genotypes were classified into six clusters. Cluster I was the largest with thirty genotypes followed by II and III clusters, which a four and three genotypes, respectively. Cluster IV, V and VI contained only one most

divergent genotype. The maximum inter-cluster distance (1538.09) was found between cluster II and VI, followed by that between II and III (983.03). The minimum inter-cluster distance was observed between cluster I and II (285.09). The genotype of cluster VI was unique as it was having highest values for diameter of root at collar region with high dry root yield. The cluster II was desirable in respect of days to flower initiation and days to maturity and also had highest value for number of primary branches per plant, *withanoloide* content (%). The cluster III exhibited highest value for plant height. The cluster IV had highest mean values for number of secondary branches per plant and root length.

Manivel *et at*. (2017) evaluated genetic divergence with 48 pure lines and two checks JA134 (parent) and JA20 by Mahalanobis D^2 statistics for the genetic divergence estimation. The accessions were grouped in to ten clusters, where cluster I was the largest containing 12 accessions, followed by cluster III consisting of ten accessions. Root yield per plant (15.1%) contributed maximum towards genetic diversity. Based on the inter cluster distance and *per se* performance, the pure lines DWS84 and DWS85 were selected which could be intercrossed to obtain high heterosis and also to recover transgressive segregants for the improvement of root yield and its quality. Pure lines developed in the present study form important genetic resources for the improvement of yield and quality of ashwagandha.

3. MATERIALS AND METHODS

The experiment was carried out to explore the information on "**Genetic Divergences in Ashwagandha [***Withaniasomnifera*(L.) Dunal**]**". The Experiment was laid out late *kharif*-2017 in the Botany field at Rajasthan college of Agriculture, MaharanaPratap University of Agriculture and Technology, Udaipur.

3.1 Experimental Site and Conditions

Geographically, Udaipur is situated at 24^0-35' N latitude and 73^0-42' E longitude and at an elevation of 582.17 meters above mean sea level. The climatic conditions of the area represent subtropical condition with humid climate. The meteorological data on temperature, rainfall, and relative humidity during crop growth period *Kharif*-2017, recorded at Agro-meteorological Observatory, Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur (Table 3.1). The soil of experimental field was clay loam, deep, well drained and alluvial in origin and has fairly good moisture holding capacity.

3.2 Experimental materials

The study was comprised of 60 diverse genotypes along with three standard checks *viz.*, JA-20 (Jawahar Ashwagandha-20), JA-134 (Jawahar Ashwagandha-134) and RVA-100 (Raj Vijay Ashwagandha). The diverse genotypeswere collected from different agro climatic zone of Rajasthan. The detail list of genotypes is given in Table 3.2.

3.3 Experimental Design

Field experiment was conducted to assess genetic variability, correlation and geneticdivergence among sixty three genotypes with three standard check (JA-20,JA-134 and RVA-100) by growing them in a Randomized Block Design (RBD) with three replications a single row plot of 4.0meter length maintaining a crop geometry of 30 X 5 cm at Instructional Farm Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, MPUAT, Udaipur during late *kharif*-2017. The recommended package of practices organic cultivation was followed to raise the healthy crop. To eliminate border effect to non-experimental rows were putted on both sides of experimental rows.

3.4 Characters Studied:

Observation were recorded on following fifteen traits for present study on ten randomly selected competitive plants from each genotype in each replication except for days to flowering and day to 75 per cent maturity, where observation were recorded on plot bases. To avoid border effect observation were not recorded on the first and last plant in the each row. Detailed description of procedure following for recording the data given below.

3.4.1 Days of flowering

Number of days from the date of sowing to date, on which flowers appear in plants each plot, was recorded.

3.4.2 Days to 75 percent maturity

The total number of days from the date of sowing to date, on which maturity occurs in 75 percent plants in each plot, was recorded.

3.4.3 Plant height (cm)

The plant height of the each ten plants selected randomly from each replication of each genotype were measured from the base of the plant to the terminal tip at the time of maturity and averaged.

3.4.4 Number of primary branches per plant

The branches arising on main axis were counted from each randomly selected ten plants from each replication of each genotype, at the time of maturity and averaged.

3.4.5 Number of secondary branches per plant

The numbers of secondary shoot branches arising from primary shoot branches were calculated from each ten randomly selected plants from each replication of each genotype, at the time of maturity of the crop and averaged.

3.4.6 Leaf area index

Leaf area indexis a dimensionless quantity that characterizes plant canopies. It is defined as the one sides green leaf area per unit ground surface area in broadleaf canopies.

3.4.7 Root length (cm)

The length of the root of the each randomly selected ten plants from each replication of each genotype were measured and averaged, at the time of harvesting.

3.4.8 Root diameter at collar region (mm)

The diameter of the root collar of the each ten randomly selected plants from each replication of each genotype were measured by Vernier calliper and averaged at the time of harvesting.

3.4.9 Fresh root yield per plant (g)

The weight of the fresh roots of selected plants of each genotype was measured in gram and averaged.

3.4.10 Dry root yield per plant (g)

The sun dried plant weight of the dry roots of selected plants of eachgenotype were measured in gram and averaged.

3.4.11 Dry plant weight per plant (g/plant)

The sun dried plant weight, of each randomly selected ten plants from each replication of each genotype were measured and averaged.

3.4.12 Fresh plant weight (g/plant)

The weight of the fresh plants of selected plants of eachgenotype was measured in gram and averaged.

3.4.13 100 seed weight (g)

One hundred seeds from randomly selected individual plant of each treatment are weighedon an electronic balance and expressed in grams.

3.4.14 Harvest index (%)

It was calculated as ratio of the total economic yield to the total biological yieldfor each ten randomly selected plants from each replication of each genotype.

$$\text{Harvest Index (\%)} = \frac{\text{Total dry root weight}}{\text{Total dry plant weight}} \times 100$$

3.4.15. Total alkaloid content (%)

Total alkaloid content from roots and leaves of each ten randomly selected plants from each replication of each genotype, extracted after harvesting using the method of Mishra (1996) with suitable modifications.

3.5 Statistical Analysis:

The data was analysed statistically in order to find out the parameters of genetic variability, correlations and path analysis as per the methods suggested by Panse and Sukhatme (1995). The data was subjected to D^2 analysis (Mahalanobis, 1936) as elaborated by Murthy and Arunachalam (1966). The grouping of genotypes into different clusters was done by following Tocher's method as described by Rao (1952). The genotypic and phenotypic variances and coefficients of variation were worked out asper the method of Burton (1952) and heritability and genetic advance by following the method as suggested by Lush (1948), Robinson *et al*. (1958) and Burton and De Vane (1953) and thecorrelations among various variables and the path coefficient were estimated as per the procedure of Dewy and Lu (1959). The following methods were followed for the analysis of data:

3.5.1 Analysis of variance for experimental design

Analysis of variance of the data recorded on different characteristics was carried out as per the standard procedure suggested by Panse and Sukhatme (1995). The following model was adopted for the analysis of variance of various characters:

$$Y\ ij = \mu + \alpha i + \beta j + eij$$

Where,

Yij = observation of ith treatment and jth block

μ = General mean

αi = ith treatment effect

βj = jth block effect

eij = random error associated with the ith treatment and jth block

Table 3.3 Analysis of variance with expected mean squares

Sources of	Degrees of	Sum of	Mean	Expected mean	F- cal

Variation	freedom	squares	squaressquaresculated	
Replication	r-1	SSrMSRσ2g + gσ2 r	MSR/MSE	
Genotypes	g-1	SSgMSGr2σ g + σ e	MSG/MSE	
Error	(r-1) (g-1)	SSe	MSE	σ2g
Total	rg-1			

Where,

r = Number of replications

g = Number of genotypes

(MSR) = Mean sum square due to replications

(MSG) = Mean sum square due to genotypes

(MSE) = Mean sum square due to error

$\sigma^2 g$ = variance due to genotype

$\sigma^2 r$ = variance due to replication

$\sigma^2 e$ = variance due to error

Standard error of mean (S.Em): It was calculated as

$$S.Em = \sqrt{\frac{EMS}{r}}$$

Standard error of differences (S.Ed): It was calculated as

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

Critical differences (C.D.): It was calculated as

$$C.D. = \sqrt{\frac{2EMS}{r}} \times t\,(r-1)\,(t-1) \quad \text{(at 5\% or 1\% level of significance)}$$

Coefficient of variation (C.V.) : It was calculated as

$$C.V.\ (\%) = \frac{\sqrt{EMS}}{\bar{x}} \times 100$$

Where

EMS = Error mean sum of square

r = Number of replication

$\bar{X}$ = General mean for the character under study

Range

The lowest and highest values of each character were recorded

3.5.2 Estimation of variability parameters

The genotypic($\sigma^2 g$) and phenotypic ($\sigma^2 p$) variances were calculated according to the following formula:

(i) Genotypic variance

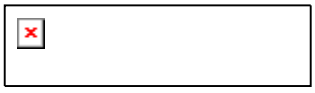
Genotypic variance Vg = $\frac{MSG-MSE}{R}$

(ii) Phenotypic variance

Phenotypic variance (Vp)= Vg + Ve (MSE)

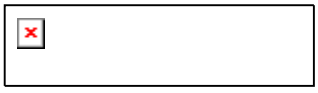
(iii) Genotypic coefficient of variance (GCV):

The magnitude of genetic variance existing in a character was estimated as per the formula suggested by Burton (1952).



(iv) Phenotypiccoefficient of variance (PCV):

The magnitude of phenotypic variance existing in a character was estimated as per the formula given by Burton (1952).



The genotypic and phenotypic coefficients of variation were categorized as per the method suggested by Sivasubramanian and Menon (1973):

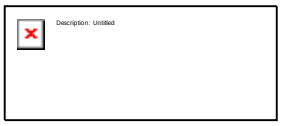
0-10% = Low

10-20% = Moderate

>20% = High

(v) Heritability broad sense (h^2):

It is the proportion of genotypic variance to the phenotypic variance. It was estimated by the formula as suggested by Burton and Devane(1953) and Hanson *et al.*, (1956).



The calculated heritability was classified into three groups as suggested by Johnson *et al.*(1955):

0-30% = Low

30-60% = Moderate

>60% = High

Expected genetic advance (GA)

Genetic advance as percent mean of each character was worked out by adopting the Following formula given by Johnson *et al.* (1955).

$$GA = k \times h^2 \times \sigma^2 p$$

Where,

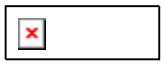
h2 = Heritability in broad sense

k = Selection differential, which is equal to 2.06 at 5% intensity of selection (Lush, 1948)

σ2p = Phenotypic standard deviation

Genetic advance as per cent of mean (GAM)

Genetic advance as percentage over mean was worked as suggested by Johnson *et al.*(1955).

GAM 

Where,

GA = Genetic advance

X = General mean

Genetic advance as percent of mean was categorized as per the formula suggested byJohanson*et al.* (1955).

0-10 % = Low

10-20 % = Moderate

>20 % = High

3.5.3 Correlation Studies

The correlation coefficients among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated by employing the formulae given by Al-Jibourie*et al.* (1958).

$$\text{Genotypic correlation } r_{xy}(G) = \frac{CoV_{xy}(G)}{\sqrt{V_x(G) \times V_y(G)}}$$

$$\text{Phenotypic correlation } r_{xy}(P) = \frac{CoV_{xy}(P)}{\sqrt{V_x(P) \times V_y(P)}}$$

Where,

Covxy (G) = Genotypic covariance between ‘x’ and ‘y’

Covxy (P) = Phenotypic covariance between ‘x’ and ‘y’

Vx (G) = Genotypic variance of character ‘x’

Vx (P) = Phenotypic variance of character ‘x’

Vy (G) = Genotypic variance of character ‘y’

Vy (P) = Phenotypic variance of character ‘y’

Significance of phenotypic correlations was tested at 5 per cent and 1 per cent levels ofsignificance against the expected value from Fisher’s table at (n-2) degree of freedom.

3.5.5 Path coefficient analysis:

Path coefficient is a standardized partial regression coefficient and measures the direct and indirect influence of one variable upon another thereby permitting the separation of the correlation coefficient into the component of direct and indirect effects.

Path coefficient is the ratio of the standard deviation of the effect due to a given cause of the total standard deviation of the effects. The path coefficient analysis was carried out as per the method suggested by Dewey and Lu (1959).

Path coefficients were analysed at genotypic level only for dry root yield per plant.

Path coefficient analysis for dryroot yield per plant: Path coefficients were worked out using 15 characters *viz*.

1. Day to flowering
2. Days to 75 percent maturity
3. Plant height (cm)
4. Number of primary branches per plant
5. Number of secondary branches per plant
6. Leaf area index
7. Root length (cm)
8. Root diameter in collar region (mm)
9. Fresh root yield (g/plant)
10. Dry root yield (g/plant)
11. Fresh plant weight(g/plant)
12. Dry plant weight (g/plant)
13. 100 seed weight (g)
14. Harvest index (%)
15. Total alkaloid content(%)

The direct and indirect effects of 14 characters on dry root yield /plant (Y) were obtained as per procedure given below:

$r_1Yr_{11}\ r_{12}\ldots\ldots\ldots\ r_{1\,14}P_1Y$

r_2Y $\qquad\qquad$ $r_{21}\ r_{22}\ldots\ldots\ldots\ r_{2\,15}\,P_2Y$

,, $\qquad\qquad$,, $\qquad\qquad$,,

,, $\qquad\qquad$,, $\qquad\qquad$,,

,, $\qquad\qquad$,, $\qquad\qquad$,,

,, $\qquad\qquad$,, $\qquad\qquad$,,

$r_{14}Yr_{14\,1}\ r_{14\,2}\ldots\ldots\ldots\ r_{14\,14}P_{14}Y$

A $\qquad\qquad$ B $\qquad\qquad$ C

Where,

r_1Y, r_2Y, r_3Y,…., $r_{14}Y$ are the genotypic correlations of day to flowering,days to 75 percent maturity, plant height,number of primary branches per plant,number of secondary branches per plant,leaf area index,root length,root diameter in collar region,fresh root yield,dry root yield, fresh plant weight,dry plant weight,100 seed weight,harvest index andtotal alkaloid content.

P_1Y, P_2Y, P_3Y,…….., $P_{14}Y$ are the direct effects of day to flowering,days to 75 percent maturity,plant height,number of primary branches per plant,number of secondary branches per plant,leaf area index,root length,Root diameter in collar region,fresh root yield per plant,dry root yield per plant,fresh plant weight(g/plant),dry plant weight (g/plant),100 seed weight,harvest index and total alkaloid content (Y).

Or A = BC

Values of 'C' vector were obtained as:

$$C = B^{-1}A$$

Where,

A is the vector of direct correlations of eleven characters with dry root yield Y.

B^{-1} is the inverse of mutual correlation matrix of characters.

C is the vector of direct effects.

The inverse of this matrix was carried out by Pivotal condensation method (Singh and Chaudhary, 1979).

To obtain indirect effect, B matrix was multiplied with vector C as follows:

$$D = C \times B$$

Where,

D is the matrix of direct and indirect effect

B is the matrix of correlation among seven characters.

The residual effect was computed as follows:

$$R = \sqrt{1-(r_1YP_1Y+r_2YP_2Y+r_3YP_3Y+----------+r_{15}YP_{15}Y}$$

Where, R is the residual effect.

3.5.6 Genetic divergence

a) Mahalanobis D^2 analysis

Mahalanobis (1936) D^2 analysis was used for assessing the genetic divergence among thetest genotypes involving quantitative characters. The generalized distance between any two populations is given by the formula.

$$D^2 = \Sigma^{\lambda}_{ij}\sigma_{ai}\sigma_{aj}$$

Where,

D2 = Square of generalized distance

$^{\lambda}_{ij}$ = Reciprocal of the common dispersal matrix

$\sigma_{ai} = (\mu_{i1}-\mu_{i2})$

$\sigma_{aj} = (\mu_{j1}-\mu_{j2})$

μ = General mean

Since, the formula for computation requires inversion of higher order determinant,transformation of the original correlated unstandardized character mean (Xs) to standardized

Uncorrelated variable (Ys) was done to simplify the computational procedure. The D^2 values wereobtained as the sum of squares of the differences between pairs of corresponding uncorrelated (s)values of any two uncorrelated genotypes (Rao, 1952).

b) Cluster of D^2 values

All n (n-1)/2 D^2 values were clustered using Tocher's method described by Rao (1952).

c) Intra cluster distance

The intra cluster distances were calculated by the formula given by Singh and Choudhary(1977).

$$\text{Square of the intra cluster distance} = \frac{\Sigma D^2_i}{n}$$

Where,

ΣD^2_i is the sum of distance between all possible combinations of the genotypes includedin a cluster.

n = Number of all possible combinations

d) Inter cluster distance

The intercluster distances were calculated by the formula described by Singh andChoudhary(1977).

$$\text{Square of the intra cluster distance} = \frac{\Sigma D^2_i}{n_i n_j}$$

Where,

ΣD^2_i is the sum of distances between all possible combinations ($n_i n_j$) of the genotypes included in the clusters study.

n_i = Number of genotypes in cluster i

n_j=Number of genotypes in cluster j

Table 3.1 Mean weekly meteorological parameters during the crop growth period

Standard week	Temp. (max) (^{0}C)	Tem. (min) (^{0}C)	RH (max) (%)	RH(min) (%)	Sunshine (h)	Rainfall (mm)
10 Sept-16 Sept	31.8	21.6	89	78	4.5	36.8
17 Sept-23 Sept	31.7	20.9	80	50	4.6	1.8
24 Sept-30 Sept	33.7	20.0	75	39	8.4	0.0
1 Oct-7 Oct	34.8	18.5	63	25	7.7	0.0
8 Oct-14 Oct	34.7	18.7	68	25	6.5	0.0
15 Oct-21 Oct	35.6	18.7	61	19	8.9	0.0
22 Oct-28 Oct	33.6	14.4	74	47	9.0	0.0
29 Oct-4 Nov	32.4	13.5	79	59	8.4	0.0
5 Nov-11 Nov	30.0	13.0	83	64	7.7	0.0
12 Nov-18 Nov	28.6	12.0	84	51	6.6	0.0
19 Nov-25 Nov	26.2	9.3	80	60	5.7	0.0
26 Nov-2 Dec	28.6	8.8	80	58	8.2	0.0
3 Dec-9 Dec	23.5	12.2	94	80	2.4	4.2
10 Dec-16 Dec	24.9	14.2	89	68	6.0	0.0
17 Dec- 23 Dec	25.4	7.8	84	55	5.5	0.0
24 Dec-30 Dec	26.2	6.3	92	52	8.6	0.0
31 Dec-6 Jan	24.2	5.2	90	45	8.1	0.0
7 Jan-13 Jan	25.2	7.4	87	41	7.2	0.0
14 Jan-20 Jan	27.8	7.3	90	35	8.8	0.0
21 Jan-27 Jan	25.4	6.1	84	32	8.7	0.0
28 Jan-3Feb	28.6	7.7	80	30	8.9	0.0
4 Feb-10 Feb	25.7	8.5	81	36	5.7	0.0
11 Feb-17 Feb	26.9	9.1	78	40	8.4	0.0
18 Feb-24 Feb	31.7	12.0	77	23	8.6	0.0
25 Feb-3Mar	32.5	12.8	69	20	7.3	0.0
4 Mar-10 Mar	32.3	12.0	56	23	7.5	0.0
11 Mar-17 Mar	33.5	13.5	52	18	7.7	0.0
18 Mar-24 Mar	32.6	14.2	58	21	7.2	0.0
25 Mar-31 Mar	37.5	15.7	47	13	8.6	0.0
1 Apr-7 Apr	37.8	17.6	46	18	7.5	2.2
8 Apr-14 Apr	36.7	19.8	49	23	5.2	0.0
15 Apr-21 Apr	37.3	19.3	29	15	8.3	0.0
22 Apr-28 Apr	38.8	20.3	36	14	9.3	0.0

Table 3.2 Details of Ashwagandha[*Withaniasomnifera*(L.) Dunal] genotype used for the present investigation.

S.No.	Name of Genotype	Collection
1	MPAS-1	Sanlikhera (Jhalawar)
2	MPAS-2	Sanlikhera (Jhalawar)
3	MPAS-3	Sanlikhera (Jhalawar)
4	MPAS-4	Sanlikhera (Jhalawar)
5	MPAS-5	Bavrikhera (Jhalawar)
6	MPAS-6	Bavrikhera (Jhalawar)
7	MPAS-7	Bavrikhera (Jhalawar)
8	MPAS-8	Nandiyakheri (Jhalawar)
9	MPAS-9	Nandiyakheri (Jhalawar)
10	MPAS-10	Nandiyakheri (Jhalawar)
11	MPAS-11	Nandiyakheri (Jhalawar)
12	MPAS-12	Nandiyakheri (Jhalawar)
13	MPAS-13	Pipliya(Jhalawar)
14	MPAS-14	Pipliya (Jhalawar)
15	MPAS-15	Pipliya (Jhalawar)
16	MPAS-16	Pipliya (Jhalawar)
17	MPAS-17	Pipliya (Jhalawar)
18	MPAS-18	Rajpura (Jhalawar)
19	MPAS-19	Rajpura (Jhalawar)
20	MPAS-20	Rajpura (Jhalawar)
21	MPAS-21	Pachpahar (Jhalawar)
22	MPAS-22	Pachpahar (Jhalawar)
23	MPAS-23	Pachpahar (Jhalawar)
24	MPAS-24	Chatarpura (Jhalawar)
25	MPAS-25	Chatarpura (Jhalawar)
26	MPAS-26	Chatarpura (Jhalawar)
27	MPAS-27	Chatarpura (Jhalawar)
28	MPAS-28	Haripura (Jhalawar)
29	MPAS-29	Haripura (Jhalawar)
30	MPAS-30	Haripura (Jhalawar)
31	MPAS-31	Haripura (Jhalawar)
32	MPAS-32	Nakariya (Kota)
33	MPAS-33	Nakariya (Kota)
34	MPAS-34	Nakariya (Kota)
35	MPAS-35	Nakariya (Kota)
36	MPAS-36	Nakariya (Kota)
37	MPAS-37	Hanotiya (Kota)
38	MPAS-38	Hanotiya (Kota)
39	MPAS-39	Hanotiya (Kota)
40	MPAS-40	Hanotiya (Kota)
41	MPAS-41	Hanotiya (Kota)

S.No.	Name of Genotype	Collection
42	MPAS-42	Sohankheda (Kota)
43	MPAS-43	Sohankheda (Kota)
44	MPAS-44	Sohankheda (Kota)
45	MPAS-45	Sohankheda (Kota)
46	MPAS-46	Ramganjmandi (Kota)
47	MPAS-47	Ramganjmandi (Kota)
48	MPAS-48	Ramganjmandi (Kota)
49	MPAS-49	Modak (Kota)
50	MPAS-50	Modak (Kota)
51	MPAS-51	Modak (Kota)
52	MPAS-52	Modak (Kota)
53	MPAS-53	Modak (Kota)
54	MPAS-54	Devali (Kota)
55	MPAS-55	Devali (Kota)
56	MPAS-56	Devali (Kota)
57	MPAS-57	Devali (Kota)
58	MPAS-58	Devali (Kota)
59	MPAS-59	Devali (Kota)
60	MPAS-60	Kherabad (Kota)
61	JA-20	Check
62	JA-134	Check
63	RVA-100	Check

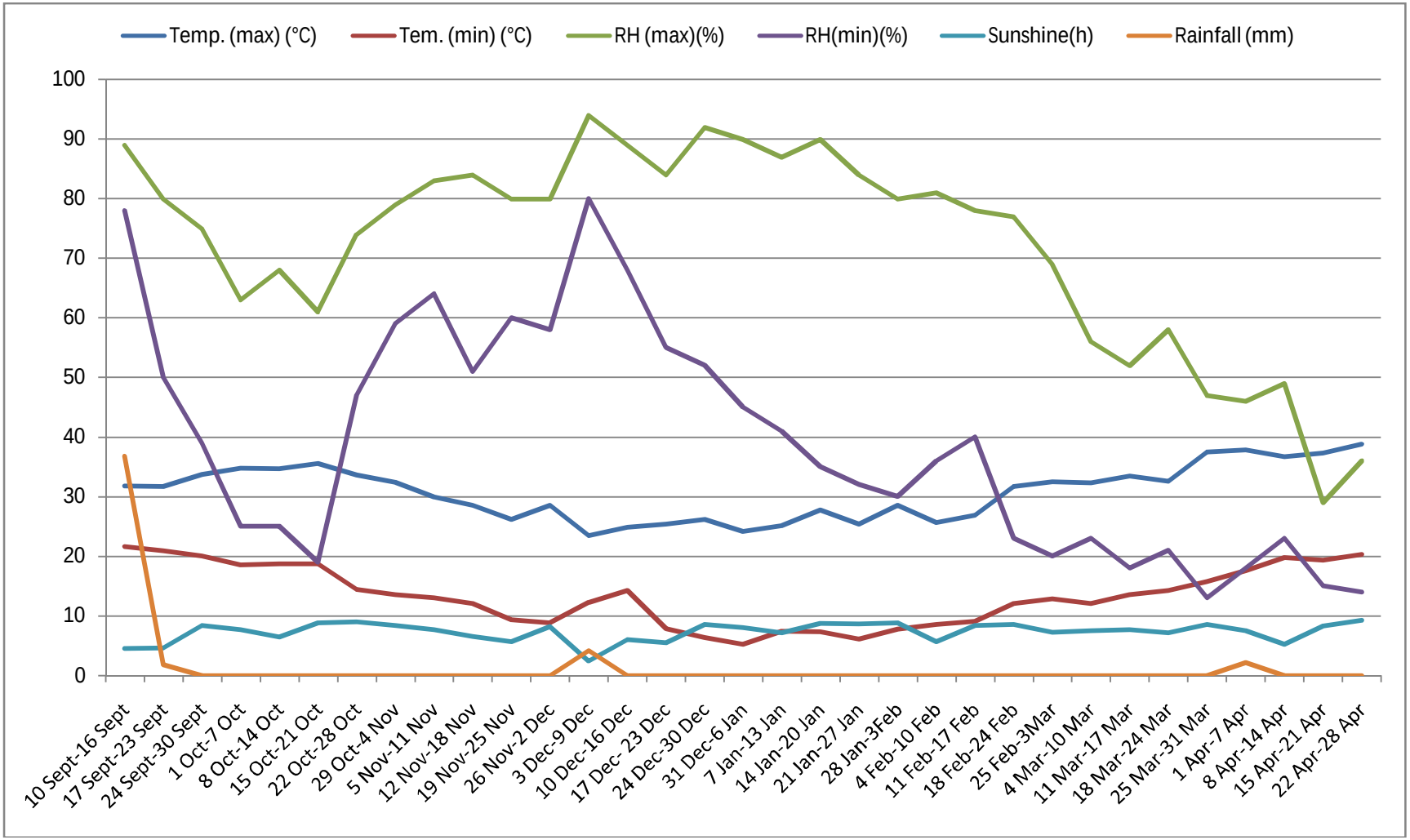


Fig.1: Mean weekly meteorological parameters during the crop growth period

4. RESULTS AND DISCUSSION

The present study entitled “Genetic Divergences in ashwagandha[*Withaniasomnifera*(L.) Dunal]” was conducted with sixty diverse genotypes along with threestandard checks *viz*.The Experiment was laid out due late *kharif*-2017 in the Botany field at Rajasthan College of Agriculture, MaharanaPratap University of Agriculture and Technology, Udaipur and results of the investigation are presented under the fallowing sub heads;

4.1. Analysis of variance

4.2. Mean values and range performance

4.3. Genetic variability parameters

4.4. Correlation coefficient analysis

4.5. Path coefficient analysis

4.6 Genetic divergence

4.1 Analysis of variance:

The resultsanalysis of variance revealed that the genotypes differs significantly for the characters such as days of flowering, days to 75 per cent maturity, plant height, number of primary branches per plant, number of secondary branches per plant, leaf area index, root length (cm), root diameter at collar region (mm), fresh root yield per plant (g), dry root yield per plant (g), dry plant weight per plant (g/plant), fresh plant weight (g/plant), 100 seed weight (g), harvest index (%) and total alkaloid content (%).

4.2 Mean values and range performance:

The observations recorded for fifteen characters from all sixty three genotypes and their mean performance are presented in appendix I.

The data reveals that range and mean for all characters *viz.*, days to flowering (95.66 to 106.00), plant height(27.76 to 46.76 cm), number of primary branches per plant(2.96 to 6.16), number of secondary branches per plant(6.96 to 11.26), leaf area index(0.85 to 1.033), root length (15.9 to 23.7 cm), root diameter at collar region (5.7 to 11.96 mm), fresh root yieldper plant (8.6 to 19.30 mm), dry root yield per plant (0.81 to 4.91 g), dryplant weight perplant (18.98 to 60.77 g),fresh plant weight (64.98 to 218.25 g), 100-seedweight(0.176 to 0.241 g), harvest index (1.4 to 24.16 %)and total alkaloid content (0.27 to 0.48 %). Ranges of all characters tell that there is a variation among genotypes, which can be used for selection during crop improvement program.

4.2.1 Day to flowering

In all 63 genotypes, mean days to flowering ranged from 95.66(MPAS-2) to 106 days (MPAS-31 and MPAS-46), with over all mean 101 days. Genotype MPAS-2 (95.66 days) was earliest to flower followed by MPAS-11 (96 days) and MPAS-5(96.33) whereas genotype MPAS-31 and MPAS-46 (106 days) were found for late flowering.

4.2.2 Day to 75 per cent maturity

The mean for days to75 per cent maturity commemorated was170.18. It ranged from 165(MPAS-22) to 174.33(JA-134) days. The minimum days to 75 per cent maturity depicted by MPAS-22 (165) followed by MPAS-11(165.67) and MPAS-37 (165.33) days.

4.2.3 Plant height

The mean plant height commemorated was 38.91 cm. It ranged from 27.76 (MPAS-17) to 46.77 (MPAS-42) cm and closely followed by MPAS-46 (46.06), MPAS-38 (45.7).

4.2.4 Number of primary branches per plant

The range of average value for number of primary branches per plant ranged between 2.97 (MPAS-7) to 6.17 (MPAS-43). The highest number of primary branches per plant was exhibited by MPAS-43 (6.17) followed by MPAS-50 (6.06), MPAS-30 (6.06) and MPAS-53 (5.96).

4.2.5 Number of secondary branches per plant

The range of average value for number of secondary branches per plant rangedfrom 6.97 (MPAS-38) to 11.27(MPAS-20)with over all mean value 9.53. The highest number of secondary branches per plant was exhibited by MPAS-20 (11.27) followed by MPAS-27, (11.27), MPAS-45, MPAS-2 (11.10) and MPAS-33(11.06).

4.2.6 Leaf area index

The leaf area index of ashwagandha measured varied significantly among genotypes. It ranged from 0.85 to 1.03 with over all mean value0.93. The minimum leaf area index was recorded by the genotype MPAS-54 (0.85) and maximum by MPAS-25 (1.03).

4.2.7 Root length

The sixty three genotypes studied in the present investigation showed a significantrange of variation, *i.e.* from 15.9 (MPAS-26) to 23.7 cm (MPAS-45) for root length, with a mean of 20.38. The maximum root length exhibited by MPAS-45 (23.7) was followed by MPAS-24 (23.3), MPAS-5 (23.4) and MPAS-21 (22.9).

4.2.8 Root diameter in collar region

There were significant differences among genotypes for root diameter. It was ranged from 5.76 (MPAS-17) to 11.96 mm (MPAS-34)with over all mean value8.72 mm. The 27 genotypes showed higher root diameter over themean.

4.2.9 Fresh root yield per plant

There were significant differences among genotypes for fresh root yield per plant. It ranged from 8.67 (MPAS-32) to 19.30 g (MPAS-37)with over all mean value 13.57 g. The maximum fresh root yield per plant was recorded by genotype MPAS-37 followed by MPAS-46 (18.20), MPAS-60 (17.80), MPAS-54 (17.50) and JA-134 (17.44).

4.2.10 Dry root yield per plant

The dry root yield per plant ranged from 0.81 (MPAS-59) to 4.92 g (MPAS-37)with over all mean value 2.67 g. The maximum dry root yield exhibited by the genotype MPAS-37 followed by MPAS-46 (3.81), MPAS-24 (3.72) and MPAS-4 (3.65).

4.2.11 Fresh plant weight per plant

The fresh plant weight per plant varied significantly among the genotypes investigated. The Fresh plant weight per plant ranged from 64.98 (MPAS-6) to 218.25 g (MPAS-9)with over all mean value108.38 g. The maximum fresh plant weight per plant was depicted by the genotype MPAS-15(206.57 g), MPAS-8 (166.28 g) and MPAS-5 (141.57 g).

4.2.12 Dry plant weight per plant

The dry plant weight per plant varied significantly among the genotypes investigated. The dry plant weight per plant ranged from 18.98(MPAS-32) to 60.77 g (MPAS-9) with over all mean value 33.38 g. The maximum dry plant weight per plant exhibited by genotype MPAS-9 (60.77)followed byMPAS-8 (59.08 g), MPAS-15 (57.29 g) and MPAS-24 (52.09 g).

4.2.13 100-seed weight

The 100 seed weight of ashwagandha evaluated varied significantly among genotypes. It ranged from 0.176(MPAS-53) to 0.241 g (MPAS-48) with over all mean value 0.20 g. The maximum 100 seed weight recorded by genotype MPAS-48 (0.2419) followed by MPAS-26 (0.237 g), MPAS-10 (0.236 g) and MPAS-35 (0.235 g).

4.2.14 Harvest Index

The mean value of harvest index in all 63 genotypes ranged from 4.43 (MPAS-43) to 24.16 % (MPAS-37), with over all mean value 8.89 %. Genotype MPAS-37 (24.16 %) had highest harvest index followed by MPAS-46 (18.23%) and MPAS-36 (18.92 %).

4.2.15 Total alkaloid content

Significant differences among genotypes for total alkaloids content of ashwagandha root were noticed. Total alkaloids content of root ranged from 0.27 (MPAS-21) to 0.48 % (MPAS-42) with over all mean valueof genotypes was 0.37%. The maximum total alkaloid content exhibited by genotype MPAS-42 (0.48 %) followed by genotypeMPAS-48 (0.48 %), JA-20 (0.48 %) and MPAS-18 (0.48).

4.3 Genetic variability parameters:

Knowledge of genetic control of yield components is useful to plant breeder. Success of breeding programme is largely depends on the extend of genetic variability present in the material, greater the diversity in the material better the chances for evolving promising and desired types. Since environment has a great influences on many quantitative and qualitative traits,the observation variability can be grouped under heritable and non-heritable components and this can be estimated by the parameters like genotypic coefficient of variation (GCV), phenotypiccoefficient of variation (PCV), heritability (broad sense) and genetic gain. This would help the breeder in developing and formulating selection programme for genetic improvement of crop plant.

Johanson*et al.* (1955)suggested that both heritability and genetic gain would be more useful in predicting the effect of selection. Hence in the present study, genetic variability parameters *viz.*, Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), heritability (broad sense), genetic advance were estimated for all characters and furnished in the table 4.2 and discussed in following headings.

4.3.1 Genotypic coefficient of variation:

The existence of high magnitude of genetic variability was evident through high values of genotypic coefficient of variation for majority of the traits *viz.*,harvest index (47.97 %), followed by dry plant weight (31.48 %),dry root yield (31.07 %)and fresh plant weight per plant (g/plant) (24.83 %) The present findings are in accordance with the findings ofSundeshaandTank (2013), Joshi *et al*. (2013), Singh *et al*.(2014),

Sukhdev*et al.* (2015),Manival*et al*.(2017),Patel A.I. and Desai B.S. (2017) whereas it was moderate for fresh root yield g/plant (18.65 %), total alkaloid content (15.31 %), root diameter in collar region (15.24 %),number of primary branches per plant (14.45 %)and number of secondary branches per plant (10.02 %) indicating the presence of genetic variability for the traits. While rest of the traits exhibited low genotypic coefficient of variation root length (8.17 %) followed by plant height (8.12 %), 100 seed weight (7.14 %), leaf area index (5.28 %), days to flowering (2.30 %) and days to 75 per cent maturity (0.67 %). The present findings are in accordance with the findings of Patel and Desai(2017).

4.3.2 Phenotypic coefficient of variation:

The highest phenotypic coefficient of variation was observed for harvest index (50.97 %)followed by dry root yield per plant (34.67 %), dry plant weight per plant(32.48 %), fresh plant weight per plant(27.54 %) and fresh root yield g/plant (22.67 %). The similar results were also reported byJoshi *et al.*(2013), Singh *et al.*(2014), Sukhdev*et al.* (2015),Manival*et al*.(2017),Patel and Desai (2017). The moderate values of phenotypic coefficient of variation exhibited in root diameter in collar region (18.85 %), number of primary branch per plant (18.15 %), total alkaloid content (15.44 %), number of secondary branch (12.85 %), root length (10.46 %) and plant height (10.15 %) whereas low ofvalues phenotypic coefficient of variation exhibited in 100 seed weight (9.21 %) followed by leaf area index (5.62 %), days to flowering (3.22 %) and days to 75 per cent maturity (1.91 %).

The phenotypic coefficient of variation was higher in magnitude than the respective genotypic coefficient of variation for all the characters. The phenotypic coefficients of variation estimate were generally higher than genotypic coefficient of variation estimates indicating positive effect of environment on character expression.

4.3.3 Heritability:

The high estimates of heritability values noticed in characters like total alkaloid content (98.37 %), dry plant weight per plant (93.90 %), harvest index (88.58 %), leaf area index (88.16 %), fresh plant weight (81.28 %),dry root yield per plant (80.29 %) and fresh root yield per plant (67.69 %),root diameter at collar region (65.41 %), plant height (63.93 %), number of primary branches per plant(63.41 %), root length (61.02

%), number of secondary branches per plant (60.84 %) and 100 seed weight (60.18), The similar results were also reported byO.Sangwa*et al.* (2013),Sundeshaand Tank (2013), Joshi *et al.*(2013), Singh *et al*. (2014), Sukhdev*et al.* (2015) and Patel and Desai (2017).Moderate estimates of heritability value were observed in characters like days of flowering(50.90 %). High to moderate estimates of heritability was observed for almost all the characters studied but it was comparatively low in days to 75 per cent maturity (12.37 %).The similar results were also reported bySundesha and Tank (2013) and Sangwan*et al.*(2013),except days to flowering and days to 75 per cent maturity, all the characters had shown broad sense heritability above 60%.

4.3.4 Genetic advance

The highest genetic advance was observed for fresh plant weight per plant (49.99 %) followed by dry plant weight per plant (20.98 %). The magnitude of genetic advance was medium for harvest index (8.29 %), plant height (5.2 %), fresh root yield per plant (4.29 %) days to flowering (3.41 %), root length (2.68 %) and root diameter at collar region (2.22 %) and the lowest genetic advance was recorded for number of secondary branches per plant (1.54 %), dry root yield per plant (1.53 %), number of primary branches per plant (1.18 %), days to 75 % maturity (0.83 %), leaf area index (0.13 %), total alkaloid content (0.12 %) and 100 seed weight (0.02 %).

4.3.5 Genetic gain:

The highest genetic gain was observed for days to 75 per cent maturity (171.01 %) followed by fresh plant weight (158.37 %), days of flowering (104.41 %), dry plant weight per plant (54.36 %) and plant height (44.12 %). The magnitude of genetic gain was medium for root length (23.07 %), fresh root yield per plant (17.86 %) and harvest index (17.17 %) and the lowest genetic gain was recorded for number of secondary branches per plant (11.07 %), root diameter at collar region (10.95 %), number of primary branches per plant (6.14 %),dry root yield per plant (4.21 %), leaf area index (1.03 %), total alkaloid content (0.50 %) and 100 seed weight (0.23 %).

High heritability along with high genetic advance was observed for fresh plant weight. On the other hand high heritability with low genetic advance was observed for total alkaloid content, leaf area index, 100 seed weight and days to 75 per cent maturity. Selection for these

characters will be more effective in later generation only. Most of the characters under study exhibited high estimates of heritability. On the other hand high heritability with high genetic advance these characterswould be effective in selection of suitable genotype for ashwagandha improvement.

4.4 Correlation coefficient analysis

The knowledge of genetic correlation for yield, its components and various quality characters become very important when the breeder is confronted with problem a combing high yield potential with desirable agronomical and quality parameters. Association studies would provide reliable information on nature, extent and direction of selection.

Knowledge about interrelationship between yield and yield contributing characters facilitates the choice of efficient breeding method to be adopted and selection of parents for crop improvement. Phenotypic correlation coefficient helps in determining selection index whereas genotypic correlation coefficient provides a close measure of association between characters which may be useful for overall improvement of crops.

In the present investigation, correlation coefficients were estimated among 15 characters to find out association of dry root yield per plant with its components at genotypic (r_g) as well as phenotypic (r_p) levels in table 4.3.

The perusal of data given in table 4.3 revealed that in general, the genotypic correlation coefficients were relatively higher than their corresponding phenotypic correlation coefficients for all the characters that indicated inherent association between various characters. The degree of association was quantified on the basis phenotypic and genotypic correlation coefficient.

4.4.1 Correlation between dry root yield per plant and other characters:

A perusal of table 4.3revealed that dry root yield per plant was positively and significantly correlated at both phenotypic as well as genotypic level with fresh root yield per plant (rp = 0.3343**, rg = 0.378**) and harvest index (rp = 0.732**, rg = 0.739**).The similar results were also reported byKubsad*et al*., (2009), Kumar *et al.,* (2011), Joshi *et al* (2013),Sukhdev*et al*., (2015) andSundesh*et al.*, (2016),

Dry root yield per plant was negatively and significantly correlated at both phenotypic as well as genotypic level with days to flowering (rp = -0.203**, rg = -0.265**) and number of primary branch per plant (rp = -0.160*, rg = -0.252*). Negative correlation of dry root yield both at genotypic and phenotypic level was seen with total alkaloid content in root (r_g= -0.095,r_p = -0.086).The similar results were also reported bySukhdev*et al*. (2015) andSundesh*et al*. (2016).

4.4.2 Correlation among different characters:

Days to flowering showed significant correlation in positive direction at both phenotypically and genotypicallylevel with number of primary branch per plant (rp = 0.164*, rg = 0.212*). However, days to flowering also showed significant and negative correlation at both phenotypically and genotypically level with root length (rp = -0.162*, rg = -0.258*), dry plant weight per plant (rp = -0.238**, rg = -0.310**) and fresh plant weight per plant (rp = -0.188**, rg = -0.231**).The similar results were also reported byPatel and Desai*et al*. (2017).

Days to 75 per cent maturity exhibited significant and positive correlation at both phenotypically and genotypically level with fresh plant weight per plant (rp =0.182*, rg = 0.448 *).The similar results were also reported by Gami*et al*. (2016).

The plant height exhibited significant and positive correlation at both phenotypically and genotypically level with root diameter in collar region (rp = 0.162*, rg = 0.225*), total alkaloid content (rp = 0.151*, rg = 0.202*). The similar results were also reported byKubsad*et al*. (2009), Sukhdev*et al*. (2015) andSundesh*et al*. (2016), However, number of secondary branches per plant also exhibited significant and negative correlation at both phenotypically and genotypically level with number of pods per cluster (rp = -0.164*, rg = -0.231*) and dry plant weight per plant (rp = -0.183*, rg = -0.220*). The similar results were also reported byKumar *et al*. (2012).

The number of primary branch per plant showed significant and negative correlation at both phenotypically and genotypicallylevel with 100 seed weight (rp = -0.146*, rg = -0.238*).The similar results were also reported bySundesh*et al*. (2016)

The number of secondary branch per plant showed significant and negative correlation at both phenotypically and genotypically levelwith fresh root yield per plant (rp = -0.219**, rg = -0.311**).The similar results were also reported bySundesh*et al*. (2016)

The root lengthshowed significant and negative correlation at both phenotypically and genotypicallylevel with root diameter in collar region (rp = -0.151*, rg = -0.192*) and leaf area index (rp = -0.159*, rg = -0.205*).The similar results were also reported byKumar *et al.*(2011) andSundesh*et al*. (2016).

The fresh root yield per plant showed significant and positive correlation at both phenotypically and genotypicallylevel with harvest index (rp = 0.279**, rg = 0.303**) and also showed significant and negative correlation with leaf area index (rp = -0.181*, rg = -0.218*).The similar results were also reported by Kumar *et al*. (2012).

The dry plant weight per plant showed significant and positive correlation at both phenotypically and genotypically levelwith fresh plant weight per plant (rp = 0.666**, rg = 0.751**) and also showed significant and negative correlation with harvest index (rp = -0.608**, rg = -0.628**).

The fresh plant weight per plant showed significant and negative correlation at both phenotypically and genotypically level with (rp = -0.340**, rg = -0.411**).

Leaf area index showed significant and positive correlation at both phenotypically and genotypically levelwith 100 seed weight (rp = 0.181*, rg = 0.263*).

4.5 Path coefficient analysis

In order to achieve a clear cut picture of cause and effect relationship of yield and attributes and their extent of association, simple correlation studies is not sufficient. Path analysis derived by Wright (1921) provides splitting the correlation coefficient into direct and indirect effects of traits on yield, thereby making the cause and effect relation very tacit.

Path analysis provides information about how close the other traits to the yield. Direct and indirect attribution of component characters towards the yield was analyzed using only the genotypic correlation. In the present study path coefficient analysis was carried out for dry root yield per plant and its component traits at genotypic level.

4.5.1 Path coefficient analysis for dry rootyield per plant:

The direct and indirect effects of 14 dependent characters on dry root yield per plant as independent character was obtained on path coefficient analysis using genotypic path coefficient are presented in table 4.4.

4.5.2 Direct effects

Out of fourteen characters, nine characters showed positive and direct effect on fresh root yield perplant at genotypic level. The highest positive direct effect on dry root yield per plant was exhibited by harvest index (1.235) followed by dry plant weight per plant (0.647), days to 75 per cent maturity (0.134), number of secondary branches per plant (0.109), fresh plant weight per plant (0.102) leaf area index (0.038), plant height (0.016) root length (0.014) and total alkaloid content (0.006). The characters which had negative and direct effect on fresh root yield days to flowering (-0.145) followed by fresh root yield per plant (-0.057), 100 seed weight (-0.051), root diameter in collar region (-0.051), number of primary branch per plant (-0.026),respectively.The similar results were also reported byKubsad*et al*. (2009).

4.5.3 Indirect effects

Dry plant weight per plant (0.486) and days to flowering (0.033) exhibited considerable positive indirect effect on dry root yield per plant through fresh plant weight but harvest index (-0.508) and number of secondary branch per plant (-0.015) showed considerable negative indirect effect on it through fresh plant weight per plant.

Harvest index (0.375) followed by days to 75 per cent maturity (0.060), dry plant weight per plant (0.0127) and fresh plant weight per plant (0.0121) exhibited considerable positive indirect effect on dry root yield per plant through fresh plant weight per plant but (-0.033) and leaf area index(-0.008) showed considerable negative indirect effect on it via fresh plant weight per plant.The similar results were also reported byKubsad*et al*., (2009).

Harvest index (0.244) and days to flowering (0.037) and days to 75 % maturity (0.017) exhibited considerable positive indirect effect on dry root yield per plant through root length but dry plant weight per plant (-0.09) and fresh root yield per plant (-0.010) showed considerable negative indirect effect on it through root length.The similar results were also reported byKubsad*et al*., (2009).

Harvest index (0.146)followed by days to 75 per cent maturity (0.005) and root length (0.0019) exhibited considerable positive indirect effect on dry root yield per plant throughplant height but dry plant weight per plant (0.142) and number of secondary branch (-0.025) showed considerable negative indirect effect on it via plant height.

Harvest index (0.086) anddays to 75 per cent maturity (0.031) exhibited considerable positive indirect effect on dry root yield per plant throughdays to flowering but dry plant weight per plant (-0.201) and fresh plant weight per plant (-0.023) showed considerable negative indirect effect on it throughdays to flowering.

Residual effect

The residual effect on dry root yield per plant was 0.30 indicated that 99.70 per cent of variability was governed by above said character and 0.30 per cent variability was due to environment effect.

4.6 Genetic divergence:

Genetic diversity present in available genotypes plays an important role in crop improvement for characters of interest. For the selection of parents in hybridization, diversity among parents for the character of interest, estimation of genetic distance is most important. The concept of D^2 technique was originally developed by P. C. Mahalanobis in 1928 but the application of this technique for the assessment of genetic diversity in plant breeding was suggested by Rao (1952). Higher the genetic diversity between the parents, greater are the chance of achieving transgressivesegregants. D^2 statistics is a potential tool for obtaining quantitative estimates of divergence between biological populations and has extensively been applied to assess diversity. D^2 gives clear idea about diverse nature of the population.

4.6.1 Multivariate analysis of variance

D^2 analysis was carried out using fifteen characters *viz.*, days of flowering, days to 75 per cent maturity, plant height, number of primary branches per plant, number of secondary branches per plant, leaf area index, root length, root diameter at collar region, fresh root yield per plant, dry root yield per plant, dry plant weight per plant, fresh plant weight per plant, 100 seed weight, harvest index and total alkaloid content having significant difference between genotype and independency for observation. A multivariate analysis of variance indicates that there was significant difference between genotypes over the characters.

4.6.2 Grouping of genotypes into various clusters

The sixty three genotypes were grouped in 8 clusters. The number of genotypes in each cluster ranged from 2 to 18. Clustering of genotypes under study is presented in Table 4.5and all the genotypes were grouped into eight clusters, indicating the presence of diversity for different characters. The cluster VII had highest number of genotypes (18) followed by (10) in cluster III,(9) in cluster IV,(8) in cluster V,(7) in cluster VI,(5) in cluster I,(4) in cluster IIand (2) in cluster VIII.The similar results were also reported by Joshi *et al.,* (2015).The clustering pattern revealed that, in general, genotypes from same origin showed no tendency to be in same cluster.

Looking to the pattern of genotypes distribution into different clusters in the present study, it appeared that geographical distance between the genotypes had no relation with the genetic divergence as the genotypes from same source had fallen into different clusters as well as the same cluster contained genotypes from different sources.

4.6.2 Intra and inter clusters distance:

The average intra and inter cluster distance are given in table 4.6. Maximum intra cluster distance was in cluster-III (42.22) followed by IV (40.76), II (35.50), I (35.48). There were no intra-cluster distance in some clusters like V, VI, VII and VIII. The high intra-cluster distance in cluster III indicated the presence of wide genetic diversity among the genotypes in this cluster.

The average inter cluster values were maximum between cluster II and VII (273.18) followed by cluster VII and VIII (188.62) and cluster I and cluster VII (136.670 and cluster VI and cluster VII (133.77). On the rest of pairs, average divergence ranged from 119.93 (III and VII) and 111.46 (V and VII). The similar results were also reported by Joshi *et al.*, (2015).

4.6.3 Relative contribution of different characters:

Relative contribution of each of the 15 characters towards the total divergence was worked out using per cent I rank and some D^2 for each character over the pairs of genotype (table 4.7). Trend of contribution of different characters was same in both the methods. Maximum contribution towards the total D^2 using square of $D^2$was found to be from total alkaloid content (61.60 %)followed by dry plant weight per plant (16.44 %), leaf area index (8.76 %), harvest index (6.50 %), dry root yield (1.18 %), fresh plant weight (1.08 %), fresh root yield and number of primary branch (0.87 %), 100 seed weight (0.82 %), root diameter in collar region (0.61 %), number of secondary branch/plant (0.51 %), plant height (0.36 %), root length (0.31 %), days to flowering (0.10 %) and the at least or zero contribution was from days to 75 per cent maturity.

4.6.4 Cluster means

The cluster means (Table 4.8) indicated that cluster VIII was having maximum dry root yield per plant (4.91), harvest index (24.16), fresh root yield per plant (19.03), root length (21.33) and plant height (44.16), cluster VII having maximum fresh plant weight (166.25), dry

plant weight (59.08), number of secondary branch per plant (10.66) and root diameter in collar region (9.30), cluster V shows earliest days to flowering (99), earliest day to 75 per cent maturity (165) and number of primary branch per plant (5.83), cluster VI shows maximum leaf area index (1.023) and cluster II having maximum total alkaloid content (0.47) and 100-seed weight (0.212) therefore selection of genotypes for these characters may be made from these clusters.

Table 4.1: Mean sum of squares for different characters studied in ashwagandha

Source of variance	df	Days to flowering	Days to 75 % maturity	Plant height (cm)	Number of primary branch per plant	Number of secondary branch per plant	Root length (cm)	Fresh root yield per plant	Root diameter in collar region	Dry plant weight per plant	Fresh plant weight per plant	Harvest index	Lea are ind
Replication	2	3.3492	9.1481	1.5293	0.5182	0.4813	2.8233	0.2406	2.379	21.2453	10.9642	0.9437	0.00
Genotypes	62	21.322**	13.148**	35.586**	1.838**	3.325**	10.090**	22.289**	6.246**	338.485**	2339.909**	56.988**	0.007
Error	124	5.1879	9.2342	5.6319	0.2965	0.5874	1.7689	3.0595	0.9357	7.1629	166.7452	2.3479	0.00

*, ** Significant at 5 % and 1 % level of significance, respectively

Df = degree of freedom

	P							1.0000	0.0171	0.0234	0.0793	0.2793**	-0.1818*	-0.1188	-0.1016	0.3436**
Root Diameter In Collar Region	G								1.0000	0.0478	0.0079	-0.0446	-0.0330	-0.0435	0.0247	-0.0387
	P								1.0000	0.0528	-0.0152	-0.0224	-0.0542	-0.0261	0.0180	-0.0065
Dry Plant Weight/plant	G									1.0000	0.7519**	-0.6288**	-0.0526	-0.0267	0.0646	-0.0147
	P									1.0000	0.6661**	-0.6083**	-0.0421	-0.0219	0.0359	0.0035
Fresh Plant Weight/plant	G										1.0000	-0.4118**	-0.0816	-0.0543	-0.0579	0.0733
	P										1.0000	-0.3403**	-0.0836	-0.0485	0.0079	0.0872
Harvest Index	G											1.0000	-0.0277	-0.0302	-0.0144	0.7394**
	P											1.0000	-0.0396	-0.0315	0.0234	0.7328**
Leaf Area Index	G												1.0000	0.0288	0.2633*	-0.0648
	P												1.0000	0.0244	0.1817*	-0.0732
Total Alkaloid content	G													1.0000	0.0986	-0.0957
	P													1.0000	0.0711	-0.0868
100 Seed Weight	G														1.0000	0.0755
	P														1.0000	0.0931
Dry Root Yield/plant	G															1.0000
	P															1.0000

Harvest Index	0.0865	-0.146	0.1465	-0.2462	-0.1731	0.2447	0.375	-0.0551	-0.7769	-0.5089	**1.2356**	-0.0342	-0.0373	-0.0178	**0.7394**
Leaf Area Index	-0.0021	-0.0133	-0.0073	-0.001	0.0056	-0.008	-0.0085	-0.0013	-0.002	-0.0032	-0.0011	**0.0387**	0.0011	0.0102	**-0.0648**
Total Alkaloid content	0	-0.002	0.0013	0.0006	-0.0002	-0.0008	-0.0008	-0.0003	-0.0002	-0.0003	-0.0002	0.0002	**0.0064**	0.0006	**-0.0957**
100 Seed Weight	0.0045	-0.0262	0.0012	0.0122	-0.0022	-0.0059	0.0047	-0.0013	-0.0033	0.003	0.0007	-0.0135	-0.0051	**-0.0513**	**0.0755**

Residual effect = 0.3059 ** Significant at level 1 % level, Bold value indicate direct effect

Table 4.2.: Estimates of variability parameters of different characters in ashwagandha

S.N.	Character	Mean	GCV	PCV	h^2 (Broad Sense)	GA	GG
1	Day to flowering	101	2.3	3.22	50.9	3.41	104.41
2	Day to 75 % maturity	170.19	0.67	1.91	12.37	0.83	171.01
3	Plant height (cm)	38.92	8.12	10.15	63.93	5.2	44.12
4	Number of primary branches/ Plant	4.96	14.45	18.15	63.41	1.18	6.14
5	Number of secondary branches/ Plant	9.53	10.02	12.85	60.84	1.54	11.07
6	Root length (cm)	20.39	8.17	10.46	61.02	2.68	23.07
7	Fresh root yield g/Plant	13.57	18.65	22.67	67.69	4.29	17.86
8	Root diameter in collar region (mm)	8.73	15.24	18.85	65.41	2.22	10.95
9	Dry plant weight g/plant	33.38	31.48	32.48	93.9	20.98	54.36
10	Fresh plant weight g/plant	108.38	24.83	27.54	81.28	49.99	158.37
11	Harvest index (%)	8.9	47.97	50.97	88.58	8.27	17.17
12	Leaf area index	0.94	5.28	5.62	88.16	0.1	1.03
13	Total alkaloid content (%)	0.38	15.31	15.44	98.37	0.12	0.50
14	100 seed weight	0.21	7.14	9.21	60.18	0.02	0.23
15	Dry root yield per plant	2.68	31.07	34.67	80.29	1.53	4.21

Table 4.3 genotypic and phenotypic correlation between dry root yield per plant and other characters studied in Ashwagandha

Character		Days to flowering	Days to 75% maturity	Plant height	No. of primary branches/ plant	No. of secondary branches/ plant	Root length	Fresh root yield/plant	Root diameter in collar region	Dry plant weight/ plant	Fresh plant weight/ plant	Harvest index	Leaf area index	Total alkaloid content	100-seed weight	Dry root yield/ plant
Days to Flowering	G	1.0000	0.2322	0.1551	0.2125*	-0.0456	-0.2587*	-0.0208	0.0930	-0.3106**	-0.2314**	0.0700	-0.0553	0.0078	-0.0870	-0.2650**
	P	1.0000	0.0358	0.1082	0.1643*	-0.0245	-0.1622*	-0.0885	0.0808	-0.2380**	-0.1884**	0.0455	-0.0516	0.0172	-0.0820	-0.2034**
Day to 75% Maturity	G		1.0000	0.0377	-0.1596	-0.2471	0.1286	0.4484*	0.2081	0.0568	-0.1120	-0.1181	-0.3430	-0.3156	0.5108	-0.1175
	P		1.0000	0.0421	-0.0391	-0.0822	0.0766	0.1829*	0.0884	0.0102	-0.0570	-0.0945	-0.1232	-0.1230	0.1021	-0.0980
Plant Height	G			1.0000	0.0611	-0.2318*	0.1307	0.0067	0.2257*	-0.2201*	-0.1250	0.1186	-0.1878	0.2025*	-0.0230	-0.0512
	P			1.0000	0.0947	-0.1649*	0.0687	0.0477	0.1627*	-0.1835*	-0.1230	0.1116	-0.1255	0.1515*	-0.0813	-0.0172
Number of Primary Branches/ Plant	G				1.0000	-0.0276	0.0878	-0.2237	-0.0418	0.0685	0.0197	-0.1993	-0.0258	0.1007	-0.2387*	-0.2525*
	P				1.0000	0.0352	0.0209	-0.1317	-0.0660	0.0604	0.0415	-0.1312	-0.0179	0.0764	-0.1465*	-0.1602*
Number of Secondary Branches/ Plant	G					1.0000	-0.1638	-0.3113**	0.1823	0.0153	-0.1424	-0.1401	0.1459	-0.0262	0.0436	-0.0893
	P					1.0000	-0.1121	-0.2195**	0.0948	0.0238	-0.0639	-0.1095	0.0771	-0.0156	0.0618	-0.0602
Root Length	G						1.0000	0.1856	-0.1924*	-0.1403	0.0122	0.1981	-0.2058*	-0.1316	0.1157	0.1911
	P						1.0000	0.0566	-0.1518*	-0.1221	0.0130	0.1283	-0.1596*	-0.0977	0.0535	0.1146
Fresh Root Yield /Plant	G							1.0000	-0.0375	0.0196	0.1181	0.3035	-	-	-	0.3782*

											**	0.2188*	0.1325	0.0913	*

Table 4.4: Direct and indirect effects of different correlated characters towards dry root yield per plant in Ashwagandha

Character	Day to flowering	Day to 75% maturity	Plant height cm	Number primary branches/ Plant	Number secondary branches/ Plant	Root length (cm)	Fresh root yield g/plant	Root diameter in collar region	Dry plant weight /plant	Fresh plant weight /plant	Harvest index	Leaf area index	Total alkaloid content	100 Seed weight	Dry root yield
Day to Flowering	**-0.1451**	-0.0337	-0.0225	-0.0308	0.0066	0.0375	0.003	-0.0135	0.045	0.0336	-0.0102	0.008	-0.0011	0.0126	**-0.265**
Day to 75% Maturity	0.0313	**0.1349**	0.0051	-0.0215	-0.0333	0.0174	0.0605	0.0281	0.0077	-0.0151	-0.0159	-0.0463	-0.0426	0.0689	**-0.1175**
Plant Height cm	0.0026	0.0006	**0.0166**	0.001	-0.0039	0.0022	0.0001	0.0038	-0.0037	-0.0021	0.002	-0.0031	0.0034	-0.0004	**-0.0512**
Number of Primary Branches/ Plant	-0.0056	0.0042	-0.0016	**-0.0264**	0.0007	-0.0023	0.0059	0.0011	-0.0018	-0.0005	0.0053	0.0007	-0.0027	0.0063	**-0.2525**
Number of Secondary Branches/ Plant	-0.005	-0.0269	-0.0253	-0.003	**0.109**	-0.0178	-0.0339	0.0199	0.0017	-0.0155	-0.0153	0.0159	-0.0029	0.0048	**-0.0893**
Root Length (cm)	-0.0038	0.0019	0.0019	0.0013	-0.0024	**0.0145**	0.0027	-0.0028	-0.002	0.0002	0.0029	-0.003	-0.0019	0.0017	**0.1911**
Fresh Root Yield g/Plant	0.0012	-0.0257	-0.0004	0.0128	0.0178	-0.0106	**-0.0573**	0.0021	-0.0011	-0.0068	-0.0174	0.0125	0.0076	0.0052	**0.3782**
Root Diameter In Collar Region	-0.0048	-0.0107	-0.0116	0.0021	-0.0093	0.0099	0.0019	**-0.0512**	-0.0024	-0.0004	0.0023	0.0017	0.0022	-0.0013	**-0.0387**
Dry Plant Weight/plant	-0.201	0.0368	-0.1425	0.0444	0.0099	-0.0908	0.0127	0.031	**0.6472**	0.4866	-0.407	-0.034	-0.0173	0.0418	**-0.0147**
Fresh Plant Weight/plant	-0.0238	-0.0115	-0.0128	0.002	-0.0146	0.0012	0.0121	0.0008	0.0772	**0.1027**	-0.0423	-0.0084	-0.0056	-0.0059	**0.0733**

Table 4.5: Cluster composition

Cluster	Number of genotypes	Genotype
I	5	MPAS-5, MPAS-8, MPAS-10, MPAS-24, MPAS-56
II	4	MPAS-2, MPAS-26, MPAS-55, MPAS-58
III	10	MPAS-7, MPAS-17, MPAS-21, MPAS-23, MPAS-37, MPAS-53, MPAS-54, MPAS-59, JA-34, RVA-100
IV	9	MPAS-1, MPAS-22, MPAS-28, MPAS-30, MPAS-40, MPAS-41, MPAS-43 MPAS-47, MPAS-51
V	8	MPAS-6, MPAS-19, MPAS-25, MPAS-34, MPAS-36, MPAS-38, MPAS-45, MPAS-46
VI	7	MPAS-11, MPAS-14, MPAS-18, MPAS-20, MPAS-42, MPAS-48, MPAS-57
VII	18	MPAS-3, MPAS-4, MPAS-12, MPAS-13, MPAS-16, MPAS-27, MPAS-29, MPAS-31, MPAS-32, MPAS-33, MPAS-35, MPAS-39, MPAS-44, MPAS-49, MPAS-50, MPAS-52, MPAS-60, JA-134
VIII	2	MPAS-9, MPAS-15

Table 4.6: Average intra and inter cluster D^2 values in 63 genotypes of ashwagandha

	Cluster-I	**Cluster-II**	**Cluster-III**	**Cluster-IV**	**Cluster-V**	**Cluster-VI**	**Cluster-VII**	**Cluster-VIII**
Cluster-I	**35.486**	74.119	95.393	83.373	47.912	52.597	172.155	68.065
Cluster-II		**35.506**	89.750	200.674	105.282	127.938	308.681	129.736
Cluster-III			**42.224**	145.514	77.427	131.481	162.187	133.273
Cluster-IV				**40.768**	56.910	71.239	75.206	96.493
Cluster-V					**0.000**	72.136	111.466	62.329
Cluster-VI						**0.000**	133.778	39.893
Cluster-VII							**0.000**	188.625
Cluster-VIII								**0.000**

Table 4.7 Relative contribution of different characters

Source	Times Ranked 1st	Contribution %
1 Days to Flowering	2.000	0.10
2 Day to 75% Maturity	0.000	0.01
3 Plant Height (cm)	7.000	0.36
4 Number Of Primary Branches/ Plant	17.000	0.87
5 Number Of Secondary Branches/ Plant	10.000	0.51
6 Root Length (cm)	6.000	0.31
7 Fresh Root Yield g/Plant	17.000	0.87
8 Root Diameter In Collar Region	12.000	0.61
9 Dry Plant Weight per plant	321.000	16.44
10 Fresh Plant Weight	21.000	1.08
11 Harvest Index (%)	127.000	6.50
12 Leaf Area Index	171.000	8.76
13 Total Alkaloid content	1203.000	61.60

14 100 Seed Weight	16.000	0.82
15 Dry Root Yield	23.000	1.18

Table 4.8: Cluster mean for fifteen characters in ashwagandha

Character	Day to Flowering	Day to 75% Maturity	Plant Height (cm)	Number of Primary Branches/ Plant	Number of Secondary Branches/ Plant	Root Length (cm)	Fresh Root Yield g/Plant	Root Diameter In Collar Region	Dry plant weight / plant	Fresh plant weight/plant	Harvest index	Leaf area index	Total alkaloid content	100 seed Weight	Dry root yield/plant
Cluster-I	101.765	170.358	39.389	4.969	9.645	20.563	13.507	8.841	28.824	93.312	9.504	0.940	0.393	0.211	2.614
Cluster II	99.926	169.481	40.354	5.041	9.426	20.048	12.621	8.319	34.167	110.363	7.901	0.940	0.470	0.212	2.529
Cluster III	100.583	169.583	36.235	5.125	9.450	19.492	14.114	9.242	55.292	165.402	4.048	0.927	0.428	0.199	2.238
Cluster IV	100.526	170.930	38.059	4.806	9.435	20.716	13.699	8.791	34.482	114.609	8.335	0.931	0.314	0.206	2.645
Cluster V	99.000	165.000	36.733	5.833	10.533	18.400	12.667	7.300	41.987	126.877	8.863	0.857	0.372	0.181	3.713
Cluster VI	101.000	170.000	39.667	5.067	9.170	19.000	16.500	7.567	19.640	109.070	18.923	1.023	0.356	0.194	3.720
Cluster VII	103.667	170.333	36.567	5.193	10.667	18.367	11.633	9.300	59.080	166.253	6.253	1.010	0.291	0.202	3.677
Cluster VIII	100.000	165.333	44.167	5.100	7.867	21.333	19.303	8.167	20.417	74.113	24.167	0.873	0.370	0.185	4.917

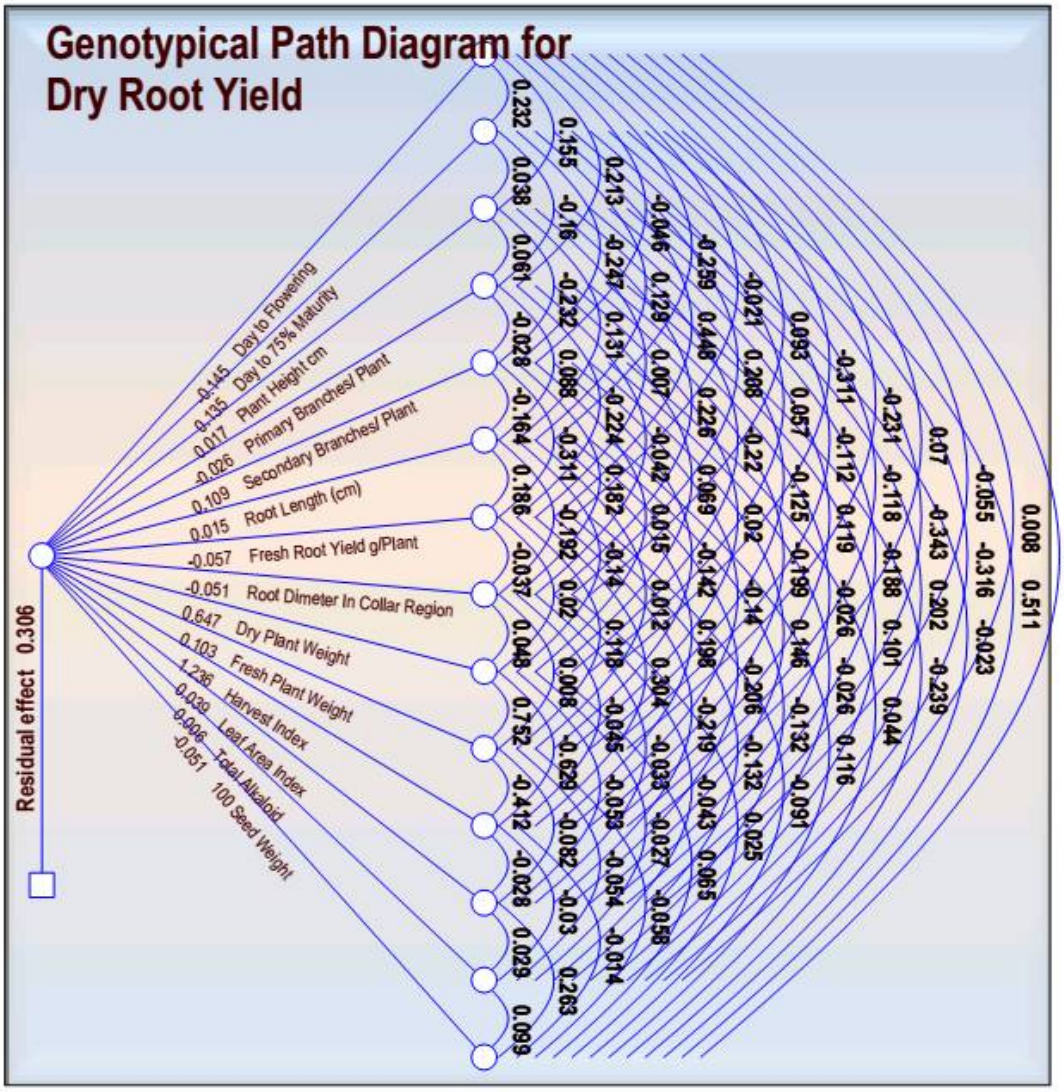


Fig.2: Genotypic path diagram for seed yield per plant

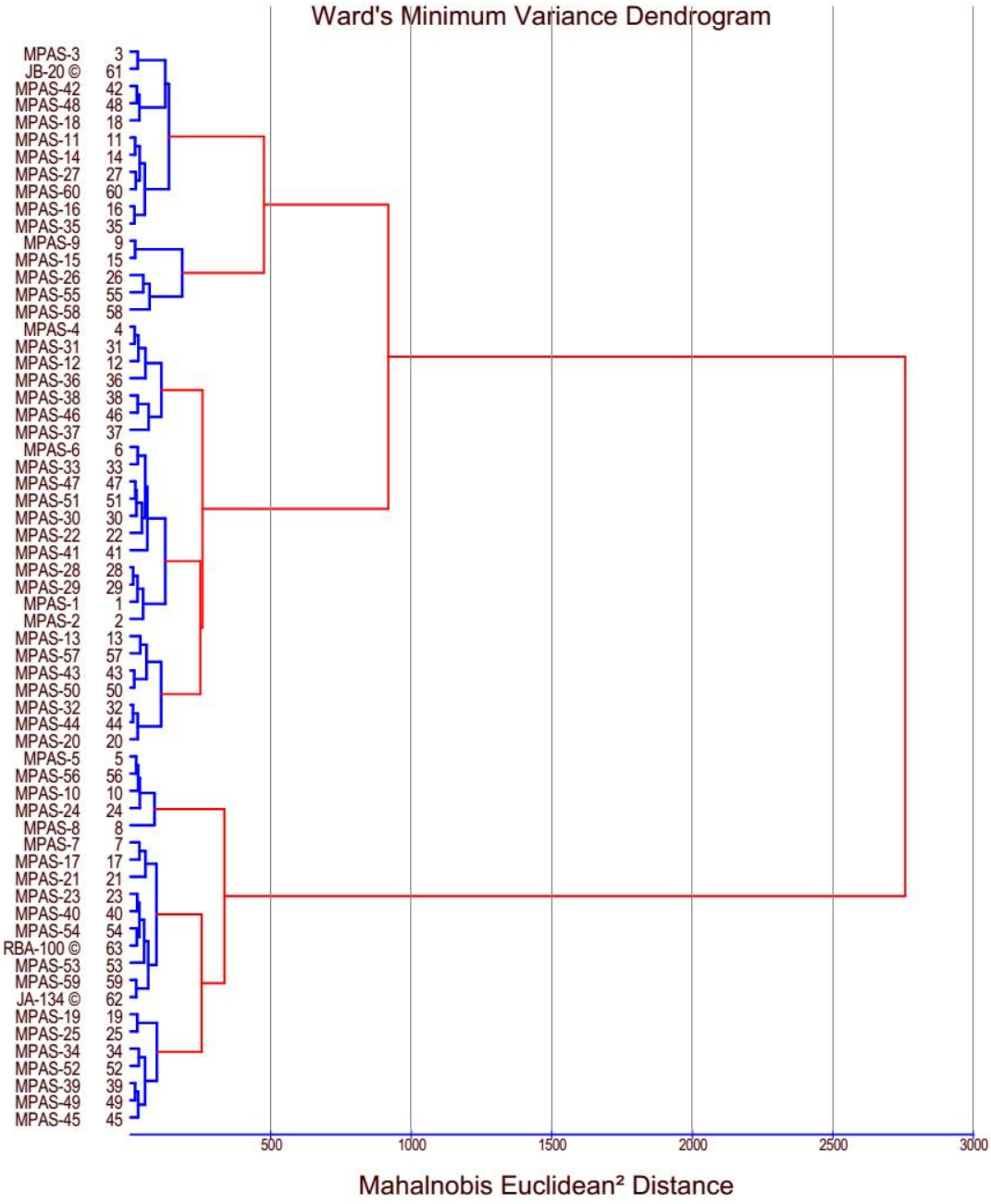


Fig.3: Wards minimum dendrogram

5. SUMMARY AND CONCLUSION

The experiment was carried out to explore the information on "**Genetic divergence in ashwagandha**[*Withaniasomnifera*(L). Dunal]". The study was comprised of 60 promising genotypes of ashwagandha along with three standard checks namely JA-20 (Jawahar Ashwagandha-20), JA-134 (Jawahar Ashwagandha-134) and RVA-100 (Raj Vijay Ashwagandha) to elicit information on the genetic variability, correlation coefficients, path coefficients and genetic divergence for root yield and its contributing characters.

The Experiment was laid out in randomized block designwith three replications during late *kharif*-2017 in the Botany field at Rajasthan College of Agriculture, MaharanaPratap University of Agriculture and Technology, Udaipur. Theobservations were recorded on ten random selected competitive plants for fifteen characters, *viz.*,days to flowering,days to 75 percent maturity, plant height (cm),number of primary branches per plant,number of secondary branches per plant,leaf area index,root length (cm),root diameter in collar region (mm),fresh root yield (g/plant),dry root yield (g/plant),fresh plant weight(g/plant),dry plant weight (g/plant),100 seed weight (g),harvest index(%), total alkaloid content (%), whereas observation for days to flowering and days to 75 per cent maturity were recorded on plot basis.

Mean squares due to genotypes for all the characters were significantas revealed from ANOVA indicating substantial amount of genetic variability among the genotypes under study. Genotypes exhibited wide range of variation for different characters *viz.*, days to flowering (95.66 to 106.00), plant height(27.76 to 46.76 cm), number of primary branches per plant(2.96 to 6.16), number of secondary branches per plant(6.96 to 11.26), leaf area index(0.85 to 1.033), root length (15.9 to 23.7 cm), root diameter at collar region (5.7 to 11.96 mm), fresh root yieldper plant (8.6 to 19.30 g), dry root yield per plant (0.81 to 4.91 g), dry plant weight perplant (18.98 to 60.77 g),fresh plant weight per plant (64.98 to 218.25 g), 100-seedweight(0.176 to 0.241 g), harvest index(1.4 to 24.16 %)and total alkaloid content (0.27 to 0.48 %)indicating an adequate variability for exercising selection and use in the breeding programs.

1 Maximum dry root yield per plantwas exhibited by genotype MPAS-37 (4.92 g) followed by MPAS-3 (4.45 g), MPAS-59 (4.05 g) and MPAS-46 (3.81 g).

2 Highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV)was depicted by harvest index (47.97, 50.97) followed by dry root yield per plant (31.07, 34.67), dry plant weight per plant (31.48, 32.48) whereas, the

lowest estimates of PCV and GCV was observed for days to 75 per cent maturity (0.67, 1.91).

3 A wide range of expected genetic advance was observed for different character. High estimates of genetic advance were recorded for the character *viz*., fresh plant weight per plant (49.99) and dry plant weight per plant (20.98).

4 High heritability was found for total alkaloid content (98.37), dry plant weight per plant (93.90), harvest index (88.58) and leaf area index (88.16). On the other hand high heritability with high genetic advance was observed for fresh plant weight per plant and dry plant weight per plant.

5 The dry root yield per plant was positively and significantly correlated at both phenotypic as well as genotypic level with fresh root yield per plant and harvest index with dry root yield per plant yield per plant was negatively and significantly correlated at both phenotypic as well as genotypic level with days to flowering and number of primary branch per plant. Negative correlation of dry root yield both at genotypic and phenotypic level was observed with total alkaloid content in root.

6 Days to flowering showed significant correlation in positive direction at both phenotypically and genotypically level with number of primary branch per plant. Days to 75 per cent maturity exhibited significant and positive correlation at both phenotypically and genotypically level with fresh plant weight per plant. Plant height exhibited significant and positive correlation at both phenotypically and genotypically level with root diameter in collar region and total alkaloid content. Dry plant weight per plant showed significant and positive correlation at both phenotypically and genotypically level with fresh plant weight per plant. Leaf area index showed significant and positive correlation at both phenotypically and genotypically level with 100 seed weight.

7 Path coefficient analysis revealed thatOut of fourteen characters, nine characters showed positive and direct effect on fresh root yield perplant at genotypic level. The highest positive direct effect on dry root yield per plant was exhibited by harvest index followed by dry plant weight per plant, days to 75 per cent maturity, number of secondary branches per plant, fresh plant weight per plant, leaf area index, plant height, root length and total alkaloid content.The characters which had negative and direct effect on fresh root yield Days to flowering followed by fresh root yield per plant, 100 seed weight, root diameter in collar region, number of primary branch per plant.

8 Harvest index followed by days to 75 per cent maturity, dry plant weight per plant and fresh plant weight per plant exhibited considerable positive indirect effect on dry root yield per plant through fresh plant weight per plant and leaf area index.

9 On the basis of D^2 analysis, 63 genotype of ashwagandha were grouped into 8 clusters. The cluster VII had maximum number of genotypes (18) followed by cluster III (10), cluster IV (9), cluster V (8), cluster VI (7), cluster I (5), cluster II (4) and cluster VIII (2).

10 The average inter cluster values were maximum between cluster VII and VIII followed by cluster II and VII. Cluster VII showed maximum genetic divergence with cluster II.

11 Maximum intra cluster distance was in cluster-III followed by cluster-IV, cluster-II, and cluster-I, There were no intra-cluster distance in some clusters like V, VI, VII and VIII.

12 Concluded draw from, the present investigation that genotypes MPAS-3, MPAS-37, MPAS-46, MPAS-59,MPAS-24, are appeared promising with respect to dry root yield per plant as well as other yield contributing trait. Least difference between GCV and PCV for different characters indicated the least effect of environment and total genetic potential was reflected in genotypes. Thus, selection of genotypes would be effective. Positive and significant correlation among dry root yield per plant and contributing characters would help in indirect selection for dry root yield per plant in the crop like ashwagandha. Existence of diversity among genotypes in different clusters provided scope of getting transgressive segregants on making crosses among them.

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ABSTRACT

Genetic Divergence in ashwagandha [*Withaniasomnifera*(L.)Dunal]

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The present investigation entitled"Genetic Divergence inashwagandha [*Withania somnifera* (L.)Dunal]" was carried outwith63 diverse genotypes of ashwagandha includingthree standard checks *viz.*, JA-20 (Jawahar Ashwagandha-20), JA-134 (Jawahar Ashwagandha-134) and RVA-100 (Raj Vijay Ashwagandha). The diverse genotypeswere collected from different agro climatic zone of Rajasthan.The experiment was laid out in randomized block design with three replicationsduring*kharif*-2017at Botany field, Rajasthan College of Agriculture, in Udaipur.

Observations were recorded for fifteen characters on ten randomly selected competitive plants for each genotype in each replication except some of the characters which were recorded on whole plot basis *viz.*,of day to flowering,days to 75 percent maturity, plant height,number of primary branches per plant,number of secondary branches per plant,leaf area index,root length (cm),root diameter in collar region (mm),fresh root yield (g/plant),dry root yield (g/plant),fresh plant weight(g/plant),dry plant weight (g/plant),100 seed weight (g),harvest index(%), total alkaloid content (%). Sixty three genotypes (includes 3 checks) were evaluated for fifteen characters and analysis of variance, correlation, path analysis and genetic divergence were performed for the mean data.

The results revealed that a highest GCV and PCV were found for harvest index (47.97, 50.97), dry root yield per plant (31.07, 34.67), dry plant weight per plant (31.48, 32.48). High h^2 was found for total alkaloid content (98.37), dry plant weight per plant (93.90), harvest index (88.58) and leaf area index (88.16). On the other hand high heritability with high genetic advance was observed for fresh plant weight per plant and dry plant weight per plant.High estimates of genetic advance were recorded for the character *viz.*, fresh plant weight per plant (49.99) and dry plant weight per plant (20.98).The dry root yield per plant

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was positively and significantly correlated at both phenotypic as well as genotypic level with fresh root yield per plant and harvest index with dry root yield per plant yield per plant was negatively and significantly correlated at both phenotypic as well as genotypic level with days to flowering and number of primary branch per plant.

The highest positive direct effect on dry root yield per plant was exhibited by harvest index followed by dry plant weight per plant, days to 75 per cent maturity, number of secondary branches per plant, fresh plant weight per plant, leaf area index, plant height, root length and total alkaloid content.On the basis of D^2 analysis, 63 genotype of ashwagandha were grouped into 8 clusters. The cluster VII had highest number of genotypes (18) followed by 10 in cluster III,9 in cluster IV,8 in cluster V, 7 in cluster VI,5 in cluster I,4 in cluster IIand 2 in cluster VIII.The average inter cluster values were maximum between cluster VII and VIII followed by cluster II and VII. While maximum intra cluster distance was in cluster-IIIfollowed by cluster-IV, cluster-II, cluster-I.

अनुक्षेपण

अश्वगंधा[*विथानियासोमनिफेरा*(एल.)डुनाल] मेंआनुवांशिकअपसरण

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वर्तमानअन्वेषण

"अश्वगंधा[*विथानियासोमनिफेरा*(एल.)डुनाल]मेंआनुवांशिकअपसरण"अश्वगंधाके 63विविधसमपैत्रकोंकेसाथकियागयाथा.जिसमेंतीनमानकजांचशामिलहैं; जेए-20 (जवाहरअश्वगंधा-20), जेए-134 (जवाहरअश्वगंधा-134) औरआरवीए-100 (राजविजयअश्वगंधा)।समपैत्रकोंकोराजस्थानकेविभिन्नकृषिजलवायुक्षेत्रसेएकत्रकिएगएथे।पादपप्रजनन औरआनुवंशिकीविभाग, राजस्थानकृषिमहाविद्यालयउदयपुर,केनिर्देशात्मकप्रक्षेत्रमेंखरीफ 2017 केदौरानतीनप्रतिकृतियोंकेसाथयादृच्छिकखंडकअभिकल्पनामेंप्रयोगकियागयाथा।

प्रत्येकप्रतिलिपिमेंप्रत्येकसमपैत्रकोंकेलिएयादृच्छिकरूपसेचुनेगएदसप्रतिस्पर्धीपौधोंपर 15 लक्षणकेलिएअवलोकनोंकोअभिलिखितकियागयाथा, जिनमेंसेकुछपात्रजोपूरेक्षेत्रकेआधारपरदर्जकिएगएथे, फूलोंकेदिन, 75 प्रतिशतपरिपक्वताकेदिन, पौधोंकीऊंचाई, प्रतिपौधाप्राथमिकशाखाओंकीसंख्या, प्रतिपौधाद्वितीयशाखाओंकीसंख्या, पत्तीक्षेत्रसूचकांक, जड़लंबाई (सेमी), मूल-संधिक्षेत्र (जड़) मेंजड़व्यास, ताजाजड़उपज (ग्रा./पौधा), सूखीजड़उपज (ग्रा./पौधा), ताजापौधेकावजन (ग्रा./पौधा), सूखेपौधेकावजन (ग्रा./पौधा), 100 बीजोवजन (ग्रा.), फसलसूचकांक(%), कुलक्षाराभसामग्री।63समपैत्रकों(3 मानकशामिलहैं) कामूल्यांकन 15 लक्षणकेलिएकियागयाथाऔरऔसतविवरणकेलिएभिन्नता, सहसंबंध, पथविश्लेषणऔरअनुवांशिकविचलनकाविश्लेषणकियागया।

नतीजेबतातेहैंकिफसलसूचकांक(47.97, 50.97), प्रतिपौधेसूखीजड़पैदावार (31.07, 34.67),सूखेपौधेकेवजन (31.48, 32.48) केलिएएकउच्चजीसीवीऔरपीसीवीपाएगएथे, जबकिपीसीवीऔरजीसीवीकेसबसेकमअनुमानदिनोंकेलिए 75% परिपक्वता(0.67, 1.91) केलिएमापागया।उच्चएच^{2}कुलक्षाराभसामग्री (98.37), प्रतिपौधेसूखेपौधेवजन(93.90), फसलसूचकांक (88.58) औरपत्तीक्षेत्रसूचकांक (88.16)

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केलिएपायागयाथा।दूसरीओरउच्चआनुवांशिकअग्रिमकेसाथउच्चविरासतप्रतिपौधाताजापौधेकेवजनऔर पौधेकेसूखेपौधेकेवजनकेलिएमापागया।आनुवांशिकअग्रिमकेउच्चअनुमानचरित्र, जैसेताजापौधाकेलिएदर्जकिएगएथेवजनप्रतिपौधे (49.99) औरप्रतिपौधावजन (20.98)।प्रतिपौधाकीसूखीजड़पैदावारसकारात्मकरूपसेऔरमहत्वपूर्णरूपसेप्रतिबिंबितहोतीहैऔरसाथ हीसाथजीनोटाइपिकस्तरपरताजाजड़पैदावारकेसाथमहत्वपूर्णरूपसेसहसंबंधितहोताहैऔरप्रतिपौधोंकी उपजकेसाथसूखीजड़पैदावारकेसाथफसलसूचकांकनकारात्मकरूपसेऔरमहत्वपूर्णरूपसेफेनोटाइपि ककेसाथ-
साथजीनोटाइपिकस्तरपरभीसहसंबंधितहोताहैफूलोंकेप्रतिदिनऔरप्रतिपौधेप्राथमिकशाखाकीसंख्याकेसा थप्रतिपौधेशुष्कजड़उपजपरउच्चतमसकारात्मकप्रत्यक्षप्रभावफसलसूचकांकद्वाराप्रदर्शितकियागयाथा, इसकेबादप्रतिपौधेसूखेपौधेकेवजन, 75 प्रतिशतपरिपक्वताकेलिएदिन, प्रतिपौधाद्वितीयशाखाओंकीसंख्या, प्रतिपौधाताजापौधेवजन, पत्तीक्षेत्रसूचकांक, पौधोंकीऊंचाई, जड़कीलंबाईऔरकुलक्षाराभसामग्री।

डी^{2}विश्लेषणकेआधारपर, अश्वगंधाके 63 समपैत्रकोंको 8 समूहोंमेंबांटागयाथा।समूहोंVII मेंअधिकतमसंख्यामेंसमपैत्रकों(18),समूहोंIII (10), समूहोंIV (9), समूहों V (8), समूहोंVI (7), समूहोंI (5), समूहोंII (4) औरVIII (2)।समूहोंVII औरVIII केबादसमूहोंII औरVII केबादऔसतअंतरसमूहोंमानअधिकतमथे।जबकिअधिकतमअंतरासमूहोंदूरीसमूहों-3 मेंसमूहों-4, समूहों-2, समूहों-1 केबादथी, समूहोंVII मेंउच्चअंतराल-समूहोंदूरीनेइससमूहोंमेंसमपैत्रकोंकेबीचव्यापकआनुवांशिकविविधताकीउपस्थितिकासंकेतदिया।

APPENDIX-I Mean values performance of fifteen traits in ashwagandha

Character	Days to Flowering	Days to 75% Maturity	Plant Height (cm)	Number of Primary Branches/ Plant	Number of Secondary Branches/ Plant	Root Length (cm)	Fresh Root Yield/ Plant (g)	Root Diameter In Collar Region (mm)	Dry Plant Weight /plant (g)	Fresh Plant Weight (g)	Harvest Index (%)	Leaf Area Index	Dry Root Yield/ Plant (g)	100 Seed Weight (g)	Total Alkaloid content (%)
MPAS-1	98.33	171.33	35.57	4.07	9.90	20.23	17.32	6.83	37.67	124.13	9.49	0.92	3.55	0.22	0.41
MPAS-2	95.67	170.00	32.57	4.00	11.10	20.27	11.57	8.40	48.44	137.14	5.20	0.96	2.53	0.20	0.42
MPAS-3	97.67	171.00	40.05	4.80	9.97	22.27	18.31	7.97	27.02	99.46	16.86	0.86	4.45	0.22	0.48
MPAS-4	102.00	167.33	37.97	5.20	10.43	21.73	12.03	8.70	33.85	96.43	10.86	0.99	3.66	0.22	0.39
MPAS-5	96.33	168.00	39.40	5.73	9.23	23.40	12.58	7.20	46.27	141.57	5.92	0.92	2.75	0.22	0.33
MPAS-6	106.00	169.33	40.10	4.53	8.47	19.60	10.78	9.33	22.18	64.99	13.40	0.87	2.90	0.21	0.38
MPAS-7	101.33	170.00	34.73	2.97	9.30	19.50	18.55	8.27	40.35	127.56	6.55	0.92	2.64	0.21	0.30
MPAS-8	103.67	170.33	36.57	5.19	10.67	18.37	11.63	9.30	59.08	166.25	6.25	1.01	3.68	0.20	0.29
MPAS-9	99.33	169.33	41.50	5.73	7.53	21.37	14.40	8.70	60.78	218.25	4.91	0.92	2.99	0.20	0.41
MPAS-10	96.00	170.67	40.27	4.13	10.00	21.13	10.03	11.23	49.26	147.59	7.93	0.92	3.88	0.24	0.34
MPAS-11	96.00	165.67	39.63	5.27	10.57	21.80	11.95	8.27	38.60	127.50	7.69	0.95	2.95	0.20	0.46
MPAS-12	99.33	169.00	35.83	4.30	8.78	18.43	10.56	8.53	21.40	79.35	12.81	1.02	2.70	0.24	0.37
MPAS-13	98.67	169.00	33.87	5.13	9.47	20.73	9.20	6.47	26.45	88.90	5.43	0.96	1.45	0.19	0.40
MPAS-14	100.67	166.67	38.87	4.03	10.27	19.43	11.08	11.37	34.34	118.52	9.07	0.98	3.11	0.19	0.46
MPAS-15	103.33	167.00	35.83	4.87	9.57	19.70	16.95	8.53	57.29	206.57	4.58	0.89	2.62	0.20	0.42
MPAS-16	100.33	170.33	34.37	3.53	8.43	17.60	15.63	9.20	25.98	115.76	13.61	0.96	3.49	0.22	0.43
MPAS-17	101.67	169.33	27.77	5.43	10.17	19.50	15.27	5.77	37.01	127.13	7.35	0.98	2.72	0.21	0.29
MPAS-18	99.33	169.33	33.97	4.90	10.27	18.43	12.30	6.60	36.95	94.52	5.70	1.02	2.11	0.22	0.48
MPAS-19	101.67	168.00	34.63	5.77	11.03	19.63	10.03	7.10	20.19	86.16	14.88	0.99	2.98	0.22	0.31
MPAS-20	100.33	169.00	40.13	5.40	11.27	20.90	11.36	11.47	22.62	92.16	9.64	0.88	2.17	0.20	0.45
MPAS-21	97.33	171.00	37.46	4.39	11.03	22.90	15.52	8.53	41.39	89.46	5.49	0.88	2.27	0.21	0.27
MPAS-22	99.00	165.00	36.73	5.83	10.53	18.40	12.67	7.30	41.99	126.88	8.86	0.86	3.71	0.18	0.37
MPAS-23	98.67	172.67	39.40	5.57	9.53	22.43	8.77	7.43	31.01	113.70	9.47	0.91	2.91	0.19	0.31
MPAS-24	99.33	171.00	38.43	5.29	7.97	23.30	16.43	11.03	52.09	133.24	7.15	0.94	3.72	0.22	0.31
MPAS-25	98.00	167.67	37.37	3.30	9.40	19.63	12.92	11.00	23.52	73.45	13.99	1.03	3.24	0.20	0.31

Character	Days to Flowering	Days to 75% Maturity	Plant Height (cm)	Number of Primary Branches/ Plant	Number of Secondary Branches/ Plant	Root Length (cm)	Fresh Root Yield/ Plant (g)	Root Diameter In Collar Region (mm)	Dry Plant Weight /plant (g)	Fresh Plant Weight (g)	Harvest Index (%)	Leaf Area Index	Dry Root Yield/ Plant (g)	100 Seed Weight (g)	Total Alkaloid content (%)
MPAS-26	98.67	171.67	41.97	5.30	10.23	15.90	9.65	9.90	44.77	119.88	5.87	0.86	2.62	0.24	0.45
MPAS-27	99.00	170.33	42.87	5.10	11.27	19.60	15.72	8.47	33.72	84.14	8.97	0.99	3.00	0.19	0.42
MPAS-28	98.67	170.33	37.23	5.83	9.33	21.40	12.51	7.60	40.81	95.78	6.55	0.93	2.68	0.21	0.40
MPAS-29	102.33	170.33	39.07	5.53	9.30	17.93	13.72	8.90	36.78	86.26	7.90	0.94	2.91	0.22	0.39
MPAS-30	103.00	173.00	39.07	6.07	9.07	20.43	14.10	7.70	38.74	86.33	6.71	0.93	2.59	0.22	0.35
MPAS-31	106.00	170.33	38.53	4.20	10.33	22.03	12.34	6.93	24.47	69.85	10.95	0.98	2.66	0.23	0.39
MPAS-32	105.67	170.00	39.27	5.60	10.47	21.83	8.67	7.80	18.98	68.90	10.38	0.88	1.96	0.19	0.41
MPAS-33	105.33	170.33	41.40	4.32	11.07	16.50	14.50	10.80	31.30	97.72	9.36	0.87	2.93	0.19	0.37
MPAS-34	105.00	172.33	37.27	5.77	10.33	21.37	12.50	11.97	27.46	112.48	7.15	0.93	1.97	0.22	0.32
MPAS-35	101.67	170.33	36.03	4.73	9.77	20.40	10.52	8.60	25.24	92.99	14.66	0.95	3.68	0.24	0.43
MPAS-36	101.00	170.00	39.67	5.07	9.17	19.00	16.50	7.57	19.64	109.07	18.92	1.02	3.72	0.19	0.36
MPAS-37	100.00	165.33	44.17	5.10	7.87	21.33	19.30	8.17	20.42	74.11	24.17	0.87	4.92	0.19	0.37
MPAS-38	101.67	169.67	45.70	4.20	6.97	22.70	14.93	7.67	20.56	88.28	14.97	0.97	3.06	0.22	0.39
MPAS-39	98.33	170.33	41.97	5.37	10.13	22.93	12.58	10.33	29.18	105.39	8.35	0.99	2.43	0.23	0.37
MPAS-40	99.00	173.00	42.93	5.27	10.37	20.47	14.47	8.03	34.39	118.58	5.09	0.96	1.74	0.20	0.30
MPAS-41	102.00	171.33	45.20	3.03	9.63	18.13	9.31	8.90	30.56	114.80	3.15	0.91	0.96	0.22	0.35
MPAS-42	102.67	168.67	46.77	5.70	9.23	16.67	12.43	8.67	29.05	96.41	5.01	1.00	1.45	0.19	0.48
MPAS-43	103.00	169.33	40.97	6.17	8.63	21.13	16.13	8.60	30.78	106.81	4.32	0.87	1.32	0.18	0.38
MPAS-44	104.00	170.00	39.30	5.67	9.73	22.73	10.40	9.50	23.66	83.20	9.68	0.90	2.29	0.19	0.43
MPAS-45	99.67	169.67	37.13	4.47	11.10	23.70	14.66	9.33	24.00	88.16	11.41	0.95	2.73	0.21	0.34
MPAS-46	106.00	174.00	46.07	5.23	10.37	20.87	18.20	10.37	20.92	84.32	18.24	0.91	3.81	0.23	0.41
MPAS-47	98.00	174.00	40.20	4.27	8.40	20.90	17.67	10.73	37.75	102.32	8.30	0.90	3.13	0.22	0.37
MPAS-48	102.00	169.33	43.97	5.80	9.23	21.67	10.93	7.37	32.31	109.43	4.03	0.98	1.29	0.24	0.48
MPAS-49	101.67	168.33	43.30	4.33	10.50	20.60	12.60	9.60	30.90	114.90	5.05	0.99	1.56	0.21	0.35
MPAS-50	105.00	171.33	38.60	6.07	10.03	21.17	13.40	8.60	26.96	116.26	5.42	0.92	1.46	0.21	0.39
MPAS-	102.	170.	41.	4.23	9.13	19.	13.8	7.63	37.97	80.	6.5	0.9	2.4	0.1	0.3

Character	Days to Flowering	Days to 75% Maturity	Plant Height (cm)	Number of Primary Branches/ Plant	Number of Secondary Branches/ Plant	Root Length (cm)	Fresh Root Yield/ Plant (g)	Root Diameter In Collar Region (mm)	Dry Plant Weight /plant (g)	Fresh Plant Weight (g)	Harvest Index (%)	Leaf Area Index	Dry Root Yield/ Plant (g)	100 Seed Weight (g)	Total Alkaloid content (%)
51	00	33	60			17	3			46	4	0	8	9	7
MPAS-52	104.33	168.00	38.47	5.97	8.80	17.30	12.08	9.37	31.12	101.57	7.82	1.02	2.43	0.18	0.33
MPAS-53	101.67	172.67	39.13	5.97	8.17	20.37	15.20	10.60	21.47	110.50	14.84	0.88	3.16	0.18	0.29
MPAS-54	98.67	173.67	36.57	4.43	9.03	20.47	17.50	9.53	33.16	98.01	4.86	0.85	1.61	0.19	0.30
MPAS-55	99.00	173.00	38.60	5.23	7.07	21.40	12.60	7.30	43.34	110.54	5.47	0.95	2.37	0.21	0.47
MPAS-56	103.67	172.33	37.13	4.63	9.70	19.83	12.53	8.87	49.65	128.08	4.35	0.95	2.16	0.21	0.35
MPAS-57	101.33	169.33	37.73	5.71	9.77	18.43	13.50	10.70	21.99	92.50	4.85	1.02	1.06	0.21	0.39
MPAS-58	104.00	172.00	35.03	5.90	9.60	16.63	13.53	11.33	54.66	99.64	1.49	0.94	0.82	0.19	0.46
MPAS-59	100.67	173.00	39.70	3.93	8.80	21.70	17.00	7.90	30.65	129.43	13.18	0.93	4.05	0.19	0.34
MPAS-60	100.33	173.00	39.63	4.90	8.30	21.50	17.80	8.30	33.40	113.17	8.76	0.99	2.91	0.20	0.44
JB-20 ©	103.33	170.00	39.37	4.33	8.00	22.87	14.33	7.43	21.13	117.00	11.41	0.86	2.40	0.19	0.48
JA-134 ©	102.00	174.33	35.53	4.33	9.23	21.10	17.44	7.40	24.45	98.72	13.34	0.89	3.26	0.22	0.31
RBA-100 ©	102.67	168.67	41.73	5.40	7.53	21.43	12.13	6.90	31.16	125.54	5.85	0.89	1.82	0.19	0.31
Mean	**101.00**	**170.19**	**38.92**	**4.96**	**9.53**	**20.39**	**13.57**	**8.73**	**33.38**	**108.38**	**8.90**	**0.94**	**2.68**	**0.21**	**0.38**
C.V.	2.26	1.79	6.10	10.98	8.04	6.52	12.89	11.08	8.02	11.91	17.22	1.93	15.39	5.81	1.97
F ratio	4.11	1.42	6.32	6.20	5.66	5.70	7.29	6.68	47.26	14.03	24.27	23.34	13.22	5.54	182.40
F Prob.	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.E.	1.32	1.75	1.37	0.31	0.44	0.77	1.01	0.56	1.55	7.46	0.88	0.01	0.24	0.01	0.00
C.D. 5%	3.68	4.91	3.84	0.88	1.24	2.15	2.83	1.56	4.33	20.87	2.48	0.03	0.67	0.02	0.01
C.D. 1%	4.87	6.49	5.07	1.16	1.64	2.84	3.74	2.07	5.72	27.58	3.27	0.04	0.88	0.03	0.02
Range Lowest	95.67	165.00	27.77	2.97	6.97	15.90	8.67	5.77	18.98	64.99	1.49	0.85	0.82	0.18	0.27
Range Highest	106.00	174.33	46.77	6.17	11.27	23.70	19.30	11.97	60.78	218.25	24.17	1.03	4.92	0.24	0.48

APPENDIX - II

Estimation of total alkaloid content (Harbourne's, 1984, method with suitable modifications).

1. Take 500 mg of root powder in stopper conical flask.
2. Add 5 ml of chloroform and 2-7 drops of liquid nitrogen. Shake well and keep overnight.
3. Next day filter the content of conical flask and 5-10 ml of chloroform to set the residue and wash the residues on the filter paper with chloroform.
4. Ensure complete extraction of alkaloid. Add 10 ml of ethanol to extract and mix the content with a glass rod.
5. Evaporate the solvent completely so as to remove ammonia.
6. Now add 10 ml of 0.01 N sulphuric acids to the conical flask.
7. Warm slightly to dissolve alkaloid.
8. Cool it and titrate against 0.01 N sodium hydroxide adding phenolphthalein as indicator.
9. Find the volume of acid consumers.

Percentage of alkaloid = 0.83 X Volume of sulphuric acid consumed