

**“GENETIC VARIABILITY AND PATH ANALYSIS
STUDIES IN GARLIC (*Allium sativum* L.)”.**

by

Gidmare Punam Pundlik

(Reg. No. 09/258)

A Thesis Submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, (INDIA)**

in Partial Fulfilment of the Requirements for the Degree

of

MASTER OF SCIENCE (HORTICULTURE)

in

VEGETABLE SCIENCE

**DEPARTMENT OF HORTICULTURE ,
POST GRADUATE INSTITUTE,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA , (INDIA)**

2011

**“GENETIC VARIABILITY AND PATH ANALYSIS
STUDIES IN GARLIC (*Allium sativum* L.)”.**

by

Gidmare Punam Pundlik

(Reg. No. 09/258)

A Thesis Submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, (INDIA)**

in Partial Fulfilment of the Requirements for the Degree

of

MASTER OF SCIENCE (HORTICULTURE)

in

VEGETABLE SCIENCE

Approved by

Dr. B. T. Patil

Chairman, Advisory Committee

Dr. M. N. Bhalekar
Committee Member

Dr. S. D. Warade
Committee Member

Dr. K. G. Shinde
Committee Member

Dr. N. S. Kute
Committee Member

**DEPARTMENT OF HORTICULTURE
POST GRADUATE INSTITUTE,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA , INDIA**

2011

CANDIDATE'S DECLARATION

*I hereby declare that this thesis or part
there of has not been submitted by
me or any other person to anyother
University or Institute
for a degree or
diploma.*

Place : MPKV, Rahuri

Date : / / 2011

(P. P. Gidmare)

Dr. B. T. Patil

Jr. Vegetable Breeder,
All India Co-ordinated
Vegetable Improvement Project (AICVIP),
Department of Horticulture
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413 722
Dist. Ahmednagar
Maharashtra state (India)

CERTIFICATE

This is to certify that the thesis entitled, “**GENETIC VARIABILITY AND PATH ANALYSIS STUDIES IN GARLIC (*Allium sativum* L.)**” submitted to the faculty of agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722, Dist. Ahmednagar, Maharashtra in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **Vegetable Science**, embodies the result of a bonafide research work carried out by **Mr. P. P. Gidmare**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree, diploma or publication.

The assistance and help received during the course of the investigations have been duly acknowledged.

Place : MPKV, Rahuri

Date : / / 2011

(B. T. Patil)
Research Guide

Dr. R. S. Patil
Associate Dean,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413 722, Dist. Ahmednagar,
Maharashtra, (India).

CERTIFICATE

This is to certify that, the thesis entitled, “**GENETIC VARIABILITY AND PATH ANALYSIS STUDIES IN GARLIC (*Allium sativum* L.)**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722, Dist. Ahmednagar, Maharashtra, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE) in Vegetable Science**, embodies the results of a bonafide research work carried out by **Mr. P. P. Gidmare** under the guidance and supervision of **Dr. B. T. Patil, Jr.** Vegetable Breeder, AICVIP, Department of Horticulture. It is of sufficiently high standard to warrant its submission to the University for the award of the said degree and that no part of the thesis has been submitted for any other degree or diploma.

Place : MPKV, Rahuri
Date : / / 2011

(R. S. Patil)
Associate Dean
(PGI)

ACKNOWLEDGEMENTS

It's my great pleasure to pen my deep sense of gratitude and hearty feelings of indebtedness to the most respected Dr. B. T. Patil, Junior Vegetable Breeder, All India Co-ordinated Vegetable Improvement Project, AICVIP, Department of Horticulture, M.P.K.V., Rahuri and Research Guide, for his generous treatment and constant encouragement during the course of investigation. His constructive and positive suggestions enlivened me to carry on the research. I greatly acknowledge his patience throughout and critical reading of the manuscript.

It is my proud privilege to record my sincere gratitude to Dr. S. D. Warade, Ex. Head, Department of Horticulture, M.P.K.V., Rahuri for providing necessary facilities and valuable suggestions and the members of advisory committee Dr. M. N. Bhalekar, Senior Vegetable Breeder, All India Co-ordinated Vegetable Improvement Project, AICVIP, Department of Horticulture, MPKV., Rahuri, Dr. K. G. Shinde, Vegetable Research Officer, Department of Horticulture and Dr. N. S. Kute, Associate Professor of Cytogenetics and Plant Breeding, Dept. of Botany, MPKV., Rahuri and Department of Statistics, M.P.K.V., Rahuri, for their valuable suggestions and guidance.

Words are too meager to express indebtedness and heartfelt gratitude towards Dr. S. A. Ranpise, Head, Department of Horticulture, Dr. A. M. Musmade, Prof. of Horticulture, Dr. A. R. Karale, Prof. of Horticulture, Dr. P V. Patil, Associate Prof. of Horticulture and Academic Incharge, Shri. S. N. Shelake, Agril. Assistant, Dr.G.C. Shinde, Shri. Ingle sir, Shri. Bharat Borude, Computer Typist, for their valuable co-operation during entire period of investigation.

I am very much thankful to Dr. H. G. More, Dean, Faculty of Agriculture, M.P.K.V., Rahuri, Dr. A. S. Jadhav, Ex. Dean, Faculty of Agriculture, M.P.K.V., Rahuri and Dr. R. S. Patil, Associate Dean, Post Graduate Institute, M.P.K.V.,

Rahuri. for their endless encouragement and providing all the facilities during the course of investigation.

I would like to express my thanks to Shri. Bachkar Mama, Sau, M. D. Autade, Agril. Asstt., Shri. P. G. Waghmare Mama and labour staff of vegetable project, Department of Horticulture, M.P.K.V., Rahuri for their opened handed help rendered during the course of this investigation.

It is really beyond my capacity to express my feelings for the overwhelming affection and co-operation that I received from all my department colleagues and friends Raju, Bandu kadam, Madhav, Nitin, Ashish, Raju, Nitin Kharche, Anand, Vinod, Umesh, Lakshman, Pranav, Attar sir, Ashish kulkarni, and specially to Jagesh Sonewane and seniors Rahul wankhede sir, Rohit sir, Asish sir, Rahul sir, Yashwant sir, Sandip sir, Nilu sir, Kapil sir, Parag sir, Arvind sir and Nanekar sir for their help during the course. I am also thankful to my sister khushali and bhauji S.K. Shende, Shomeshbhau, Khumesh, Bapubhau and my beloved brother Vijay. Words are not enough to quote the greatness of the most respected and beloved parents Vandana and Pundlik Gidmare, my all relatives specially Narayan mama who engrained the logical principles of life in me and covered the path to follow me on, with the flower of courage to reach the goal. I take this opportunity to express my profound regard to all my family members.

Finally, I express my grateful thanks to all those who directly or indirectly influenced my success.

Place : MPKV, Rahuri

Date : / / 2011

(P. P. Gidmare)

CONTENTS

CANDIDATE'S DECLARATION	iii
CERTIFICATES : 1. Research Guide	iv
2. Associate Dean (PGI)	v
ACKNOWLEDGEMENTS	vi
CONTENTS	viii
LIST OF TABLES	ix
LIST OF PLATES AND FIGURES	ix
ABBREVIATIONS	x
ABSTRACT	xi
1. INTRODUCTION	1
2. REVIEW OF LITERATURE	4
3. MATERIALS AND METHODS	30
4. EXPERIMENTAL RESULTS	48
5. DISCUSSION	84
6. SUMMARY AND CONCLUSIONS	97
7. LITERATURE CITED	100
8. VITA	112

LIST OF TABLES

Table	Title	Page No.
1	Different garlic genotypes with their sources	32
2	Qualitative characters of the garlic genotypes	49
3	Analysis of variance (M.S.S.) for 11 characters in garlic	51
4	Mean performance of different characters of 45 genotypes of garlic	52
5	Genetic variability parameters of 45 genotypes in garlic	54
6	Estimates of Phenotypic and Genotypic correlations of 11 different characters in garlic	60
7	Direct (diagonal) and indirect effects for yield and yield components in garlic	64
8	Value of D square	69
9	Distribution of 45 genotypes of garlic in 7 clusters	80
10	Average inter and intra-cluster D^2 and D values	81
11	Mean performances of seven clusters for various characters of garlic	83

LIST OF FIGURES

Figure No.	Title	Between Page No.
1	Plate 1	49-50
2	Genetic divergence among group of 45 genotypes of garlic	81-82

3	Path diagram	92-93
---	--------------	-------

LIST OF ABBREVIATIONS

@	:	At the rate of
b. s.	:	Broad science
C. D.	:	Critical difference
C. V.	:	Coefficient of variation
Cm	:	Centimeter
°C	:	Degree Celsius
DF	:	Degree of Freedom
<i>et al.</i>	:	<i>et alibi</i> (and associates)
etc	:	Etcetera
GCV	:	Genotypic coefficient of variation
g	:	Gram (s)
i.e.	:	That is
K cal	:	Kilo calories
Kg	:	Kilogram (s)
mss	:	mean sum of square
NS	:	Non significant
No.	:	Number
%	:	Per cent
PCV	:	Phenotypic coefficient of variation
RH	:	Relative Humidity
S. E.	:	Standard error
TSS	:	Total Soluble Solids
<i>Viz.,</i>	:	<i>Videlict</i> (namely)

ABSTRACT

“GENETIC VARIABILITY AND PATH ANALYSIS STUDIES IN GARLIC (*Allium sativum* L.)”.

by

Gidmare Punam Pundlik

A Candidate for the degree
of

Master of Science (Horticulture)

in

Vegetable Science

Research Guide	: Dr. B. T. Patil
Department	: Horticulture

The present investigation entitled, “Genetic variability and path analysis studies in garlic (*Allium sativum* L.)”, was undertaken to study the extent of variability, heritability (b. s.), genetic advance, correlation, path analysis and genetic divergence among forty-five diverse genotypes of garlic during *Rabi*, 2009 at All India Co-ordinated Vegetable Improvement Project, Department of Horticulture, MPKV., Rahuri, Dist. Ahmednagar.

The observations were recorded on qualitative i.e. colour of leaves, colour of bulb and size of leaves and quantitative characters *viz.*, number of leaves per plant,

*Abstract contd...**P.P. Gidmare*

plant height (cm), neck thickness (cm), average bulb weight (g), average bulb length (cm), average bulb diameter (cm), average weight of 10 cloves (g), number of cloves per bulb, yield per plot (kg), yield per hectare (q) and days required to harvest. Considerable amount of variability was observed for all the studied characters. The high GCV and PCV were observed for average weight of 10 cloves (37.91 and 38.08 respectively), yield per plot, yield per hectare and average bulb weight indicating the presence of good amount of variability for these characters. Comparatively, high heritability (b. s.) percentage was observed for days required for harvest (100.00) followed by average weight of 10 cloves (99.09), and number of cloves per bulb (97.07). It indicate that these characters are least influenced by environmental effects. Selection for improvement of such character may not be useful because broad sense heritability is based on genetic variance which includes both fixable and non fixable variances. The genetic advance was maximum for trait, like yield per hectare (56.82) followed by average bulb weight (11.49), The highest expected genetic advance as percent of mean was observed for average weight of 10 cloves (77.75) followed by average bulb weight (48.94), indicating that these characters are governed by additive gene action and should be improved by practicing selection procedure.

The magnitude of genotypic correlation coefficient in general was higher than the phenotypic correlation coefficient. In path coefficient analysis average bulb diameter (0.7693) exhibited maximum positive direct effect on yield per hectare followed by average bulb length (0.6467) while, neck thickness (-0.6421) had negative direct effects on yield per hectare.

D² analysis revealed the presence of genetic diversity among all the 45 genotypes, D² values ranged between 5.52 and 6609.44. The 45 genotypes were grouped into seven clusters. Cluster B comprises maximum number of genotypes (19) followed by cluster A (13) while, cluster D, F and G were solitary. The maximum intra-cluster distance was found in cluster C (D² = 155.75) followed by cluster A and cluster B. However, the maximum inter-cluster distance was observed between cluster G and B (5487.84). The genotypes viz., G-24, G-29, G-38, G-31, G-27, G-30 and G-22 should be improved by selection procedure for developing high yielding variety in garlic.

1. INTRODUCTION

Garlic (*Allium sativum* L.) belongs to family Alliaceae is the second most important cultivated Allium after onion and propagated vegetatively. It is used as a spice, flavoring agent and in pharmaceutical preparations due to its high medicinal properties like antimicrobial, anticarcinogenic and antidiabetic actions. According to Nadkarni (1927), garlic oil contains allylpropyl disulphide and another sulphur compounds. The oil is externally used in paralytic and rheumatic affections. It is also a good foreign exchange earner and large quantity of garlic is exported every year. The nutritive value of garlic per 100g of edible portion (dry garlic) is given as below;

Moisture (g)	: 62.0	Protein (g)	: 6.3
Fat (g)	: 0.1	Minerals (g)	: 1.0
Fibre (%)	: 0.8	Carbohydrates	: 29.8
		(g)	
Energy (k cal)	: 145.0	Calcium (mg)	: 160.0
Phosphorus	: 370.0	Iron (mg)	: 6.5
		(mg)	
Thiamine (mg)	: 0.06	Riboflavin (mg)	: 0.23
Vitamin C (mg)	: 13	Nicotinic acid	: 0.4
		(mg)	

India ranks second in world in the total area under garlic and third in production. In India area under garlic is 168 thousand hectares and production is 810 thousand tones

with average productivity of 4.8 tons/ha. Madhya Pradesh is a leading state in India with around 30% of both area and production. The main garlic growing states are Madhya Pradesh, Gujarat, Orissa, Maharashtra, Uttar Pradesh, Bihar, Rajasthan and Andhra Pradesh. In Maharashtra the major garlic growing districts are Nashik, Pune, Satara, Sangli. It is grown on an area of 7,500 hectares and the production is 57,000 MT with average productivity 7.6 tones per hectare (Anonymous 2009).

The information on magnitude of variability and extent to which desirable characters are heritable is essential to enhance the efficiency of selection. Since the quantitative characters are greatly influenced by the environment. Study under different locations and years is bring out genotype environment interaction for precise estimation of genetic parameters and predicting the advance under selection. Due to its vegetative propagation nature, clonal selection is the important breeding method and very scanty research work have been done on the association between different characters which is a prerequisite for executing a selection programme.

Yield being a complex quantitative character is dependent on a number of attributing traits. Therefore knowledge of association of different components together with their relative contributions have immense value in selection. Since estimates of correlation coefficient indicate only the interrelationships of the characters, but do not furnish information on cause and effect. The separation of correlation of coefficient into components of direct and

indirect effect through path analysis become important (Dewey and Lu, 1959). To bring about genetic improvement, the knowledge of magnitude and nature of variability in the available germplasm is essential which ultimately help in formulating of the effective breeding programme.

Heritability is really a measure of the efficiency of a selection system in separating genotypes. Burton and Devane (1953) described heritability as useful measure for considering ratio of genetic variance to the total variance. Genetic advance from selection has been one of the most important application is concerned with the comparison of different selection methods. It is therefore necessary to utilize heritability estimates in conjugation with selection differential which would indicate the expected genetic gain resulting through selection.

In view of this the present study was undertaken with the following objectives.

1. To study the variability in different garlic genotypes.
2. To study the correlation of different characters with yield.
3. To study the degree of divergence in different genetic stock of garlic.
4. To study the heritability, genetic advance and path analysis in garlic genotypes.

2. REVIEW OF LITERATURE

Garlic is one of the most important and popular spice and condiment crop grown both in India and abroad. However, the published literature on evaluation of varieties for variability, genetic diversity and correlation studies are essential for development of high yielding promising genotypes.

The relevant literature on the different aspects studied during the course of this investigation was reviewed here under suitable headings.

2.1 Variability studies

On going through the literature it was found that other spices and condiment crops have been widely studied with regard to variability, however garlic has been paid a little attention.

Contis et al. (1974) have studied the phenotypic coefficient of variance in their 3 years experiment on garlic

and reported that, the considerable variation for phenotypic variance for bulb weight and diameter.

Korla et al. (1981) conducted a two-year experiment with 11 clones and observed a considerable range of variation in number of cloves per bulb and weight of 20 cloves in both the years and for bulb yield per plot in one year. They found the highest genotypic variation for number of cloves per bulb and weight of 20 cloves.

Patil (1984) studied forty-five onion cultivars collected from different geographic regions of India for their variability in morphological, biochemical and storage characters of onion bulbs. He found significant differences among the onion cultivars in respect of morphological, biochemical and storage characters of onion bulbs indicating a high magnitude of variability in the cultivars under study.

Mehta and Patel (1985) conducted the experiment on 40 genotypes of garlic and concluded that, the highest variability was recorded for clove weight followed by yield of bulb per plot. However, estimates of the genotypic and phenotypic variance revealed that bulb yield per plot exhibited the highest phenotypic variance (30.99) and genotypic variance (30.60).

Shaha et al. (1990) studied the genetic variability in 32 diverse genotypes of garlic and indicated high phenotypic coefficient of variation (PCV) and genotypic

coefficient of variation (GVC) for weight of 50 cloves, plant height and bulb weight.

Vijay (1990) studied genetic variability of 7 genotypes of garlic and reported that, the maximum range of variation was recorded for size index of cloves followed by yield per plot. The genotypic co-efficient of variation was the highest in size index of cloves followed by weight of bulb.

Thakur et al. (1997) studied the genetic variability of 53 clones of garlic and the results indicated that, the significant variation in all the characters studied i.e. bulb yield per hectare, weight of bulb, number of cloves per bulb, plant height, number of leaves per plant, leaf length and leaf breadth.

Ghetia and Singh (2000) studied 26 genotypes of onion and showed that, the genotypic components of variation was higher than the environmental components indicating the phenotypic variability as a reliable measure of genotypic variability.

Godhani and Singh (2000) studied 25 genotypes of garlic and showed that, the genotypic and phenotypic coefficient of variation were high for yield of bulb per plot, weight of bulb, breadth and length of clove. However, GCV and PCV were moderate for dry matter of cloves, height of plant and number of leaves.

Killadi et al. (2000) studied thirty genotypes of garlic and reported the closeness of phenotypic coefficient of variation (PCV) and genotypic co-efficient of variation (GCV) for all characters viz; plant height, number of leaves per plant, clove length, yield per plot and yield per hectare.

Kohli and Prabal (2000) studied the variability in twenty six divergent clones of garlic and reported that, the significant variability was found for leaf size, plant height, weight of bulb, number of cloves per bulb, yield per plot, clove length, clove diameter and bulb diameter.

Mohanty and Das (2000) conducted the experiment on 12 varieties of onion and revealed that, high phenotypic coefficient of variation (PCV) was marked for number of leaves per plant (23.05%) and neck thickness (22.4%), while it was moderate for weight of bulb, plant height and yield and low for diameter of bulb. However, the magnitude of genotypic coefficient of variation (GCV) was high for number of leaves per plant (20.93%) whereas, moderate for neck thickness (19.61%) and weight of bulb (17.22%).

Shridhar (2000) studied 17 diverse genotypes of garlic and high magnitude of phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) were recorded for bulb yield, weight of 50 clove's and number of cloves per bulb.

Mohanty (2002) studied 12 genotypes of onion and showed that, the phenotypic co-efficient of variation (PCV) was high for neck thickness and number of leaves per plant, while it was moderate for plant height and weight of bulb. However, genotypic co-efficient of variation (GCV) was high for neck thickness and moderate for number of leaves per plant.

Khar et al. (2005) conducted the experiment on 47 elite lines of garlic and concluded that, the wide range of variability present in the elite lines of garlic under study. The PCV and GCV were high for neck thickness, number of leaves per plant, weight of bulb, clove weight and bulb yield.

Trivedi et al. (2006) studied variability of 20 onion genotypes and revealed that, the PCV value was higher than GCV for characters like bulb weight (23.83% and 15.88% respectively) and bulb yield (35.68% and 30.22% respectively).

Haydar et al. (2007) studied variability of 10 genotypes of onion and observed that, the highest genotypic and phenotypic coefficient of variation was recorded in fresh weight of bulb and days to harvest followed by bulb yield which also indicated that there was scope for selection.

Dubey et al. (2010) studied variability of 19 diverse genotypes of garlic and revealed that, the GCV and PCV were high for weight of 50 cloves, number of cloves/bulb, marketable yield, clove size index, clove diameter and total yield.

Singh et al. (2010) studied variability of 16 diverse genotypes of red onion and revealed that, the phenotypic and genotypic coefficients of variations were high for marketable yield (14.57 – 12.19%) and total yield (11.42 – 9.78%). However, moderate to low range of PCV and GCV were observed for remaining traits like plant height, bulb size index, neck thickness, bulb diameter, weight of 20 bulbs and days for harvesting.

2.2 Heritability

Heritability in a broad sense is the ratio of total genotypic variance to the phenotypic variance and heritability in narrow sense is the ratio of additive variance to phenotypic variance. Genotypic coefficient of variation gives little idea of the total variation that is heritable. The relative amount of heritable portion of variation can be accessed through heritability estimates and genetic advance.

Burton (1951) suggested the use of heritability estimates along with genotypic coefficient of variation to give precise estimates of genetic advance. According to Hanson et al. (1956), heritability and genetic advance are the two complementary concepts and thus heritability values may be used to estimate the expected genetic advance through selection.

The character with high heritability coupled with high genetic gain may be attributed to the additive effect

(Panse, 1957) which can easily be improved by selection. On the other hand, high heritability and low genetic advance may be attributed to the non-additive gene action. These characters may be improved through hybridization.

Korla et al. (1981) reported the high heritability and genetic advance for number of cloves per bulb and weight of 20 cloves. However, it was minimum for the bulb girth.

Singh (1981) studied nine garlic cultivars for six characters and observed high heritability values for plant height, leaf length, number of leaves per plant, number of cloves per bulb, clove weight and bulb weight per plant.

Mehta and Patel (1985) conducted the experiment on 40 genotypes of garlic and reported that, the high heritability was observed for all the traits except length of clove. However clove weight and yield of bulb per plant showed high heritability and high genetic advance indicating that the selection may also help in improving these characters.

Shaha et al. (1990) studied the 32 diverse genotypes of garlic and reported that, the high heritability along with high genetic advance was observed for plant height and weight of 50 cloves.

Vijay (1990) studied seven genotypes of garlic and reported that, the high heritability was observed for plant

height and number of leaves per plant. However, the size index of cloves exhibited the highest genetic advance followed by weight of bulb.

Ghetia and Singh (2000) studied 26 genotypes of onion and reported that, the high heritability was observed for bulb weight whereas, the rest of the characters showed moderate coefficient of variation except days to maturity of bulbs. However, it was low in plant height and dry matter of bulb.

Godhani and singh (2000) reported that, the heritability values were high for days to maturity, number of cloves per bulb, yield per plot and weight of bulb, while it was moderate for height of plant.

Killadi et al. (2000) studied thirty genotypes of garlic and found very high heritability (>85%) for plant height, number of leaves, 10 bulb weight, bulb diameter, number of cloves per bulb, yield per plot, 10 clove weight.

Kohli and Prabal (2000) studied the twenty six divergent clones of garlic and found that heritability was high for bulb diameter and number of aerial bulbils.

Mishra and Gautum (2000) studied 25 genotypes of garlic and observed that, the heritability and genetic advance was high for average weight of bulb (9.40) followed by ascorbic acid content (7.49).

Mohanty and Das (2000) studied 12 varieties of onion and revealed that, the high heritability with moderate to high GCV and genetic gain were recorded for number of leaves per plant, weight of bulb and neck thickness. However, moderate to high heritability with low GCV and genetic gain were observed for plant height, bulb diameter and bulb yield.

Raghuram et al. (2000) studied 50 lines of onion and observed the high heritability for bulb diameter, number of leaves and yield per plot.

Shridhar (2000) studied 17 diverse genotypes of garlic and observed the high heritability along with genetic advance for bulb yield, weight of 50 cloves and number of cloves.

Mohanty (2002) studied 12 genotypes of onion and observed the high heritability for neck thickness and weight of bulb, while it was moderate for plant height, number of leaves per plant, diameter of bulb and bulb yield.

Khar et al. (2005) studied 47 elite genotypes of garlic and showed that heritability was high for total yield (88%), weight of 50 cloves (81%) and weight of 5 bulbs (82%).

Gurjar and Singhanian (2006) studied 30 varieties of onion and reported that, the high heritability with moderate to high GCV and genetic gain for neck thickness, bulb weight and bulb yield. However, moderate to high heritability with

low GCV and genetic gain were observed for plant height, days to maturity, number of leaves per plant and bulb diameter.

Trivedi et al. (2006) studied heritability in 22 onion genotypes and observed that, the heritability was high for bulb yield and bulb diameter with very low genetic advance.

Haydar et al (2007) conducted the experiment on 10 varieties of onion and reported that, the plant height, number of leaves per plant, bulb length and bulb yield has high heritability.

Dubey et al. (2010). Studied heritability of 19 diverse genotypes of garlic of revealed that, the high heritability was found by clove size index (97.78%), followed by marketable yield (94.61%), weight of 50 cloves (94.56%), bulb size index (93.19%), days for harvesting (92.19%) and gross yield (87.38%). Remaining all characters showed moderate heritability.

Jabeen et al. (2010). Studied 25 genotypes of garlic and revealed that, the high heritability was found for plant height, average bulb weight and bulb yield. While number of cloves per bulb and clove length showed moderate heritability values (51.01 and 57.28 respectively) and the heritability is very low for bulb diameter (7.56).

Singh et al. (2010). Studied 16 genotypes of red onion and revealed that, high heritability were obtained for

days for harvesting (82.06%), gross yield (73.26%), weight of 20 bulb (66.71%), plant height (45.81%), and bulb diameter (33.56%). However, moderate for other attributes.

2.3 Genetic advance

Heritability gives information only on the magnitude of inheritance of quantitative characters but by the genetic advance we can evaluate the selection procedures. Higher the value of genetic advance, better will be the progress in the succeeding generations under directional selection. Heritability serves as a component in the estimation of genetic advance.

Padda et al. (1972) estimated high genetic advance for dry weight of bulb and bulb size whereas, Randhawa et al. (1974) noted genetic advance ranged from 2.6 to 44.1 percent for bulb yield.

Singh (1981) observed the high genetic advance in garlic for all the characters studied viz. plant height, number of cloves per bulb, number of leaves per plant, clove weight and weight of bulb except leaf length.

Ghetia and Singh (2000) studied the 26 genotypes of onion and showed that, the high genetic advance expressed in percentage of mean was observed for bulb weight, moderate genetic advance observed for bulb yield, equatorial diameter of bulb, and number of leaves. However, the low genetic advance

noted for days to maturity, plant height, neck thickness of bulb and polar diameter of bulb.

Godhani and Singh (2000) studied 25 genotypes of garlic and reported that, the genetic advance was higher for days to maturity followed by weight of bulb, height of plant, while moderate values were recorded for dry matter of cloves.

Kholi and Prabal (2000) studied twenty six divergent clones of garlic and showed that, the genetic advance was high for bulb weight, yield per plot and number of cloves per bulb.

Mohanty (2002) studied 12 genotypes of onion and observed high genetic advance for neck thickness and number of leaves per plant, whereas it was moderate for weight of bulb.

Khar et al. (2005) studied 47 elite genotypes of garlic and showed that, genetic advance was the highest for weight of 50 cloves, total yield, weight of five bulbs and total number of cloves.

Dubey et al. (2010) studied genetic advance of 19 diverse genotypes of garlic and revealed that, high genetic advance was showed by weight of 50 cloves (56.54%) followed by marketable yield (36.92), cloves per bulb (35.69%), clove size index (34.87%) clove diameter (30.35%) and rest of the traits showed moderate to low genetic advance.

Jabeen et al. (2010) studied 25 genotypes of garlic and revealed that, the genetic advance was high for plant height, average bulb weight and bulb yield.

Singh et al. (2010). Studied 16 genotypes of red onion and revealed that, the genetic advance was high for marketable yield (22.80%) and gross yield (17.26%). However, plant height, bulb size index, bulb diameter and bulb weight showed low genetic advance.

2.4 Correlation studies

Correlations are helpful to ascertain the real components of yield which is a complex character. It is often observed that certain characters are correlated with each other. This association of characters is a useful indication to the plant breeders for using them in selection. The association between any two characters was calculated with the help of statistical procedure and expressed as 'r' the correlation coefficient.

The original concept of correlation was presented by Galton (1889) and later elaborated by Fisher (1936) and Wright (1921). Several workers have worked on the correlation in different crops for various characters.

Correlation studies have also been done on some characters contributing towards yield in garlic. Contis and

Ferraresi (1974) found significant correlation between clove weight and bulb yield.

Johnson et al. (1955) observed that, the phenotypic correlations were lower than the genotypic ones, which indicated that the environment plays important role in masking the inherent relationship between these characters.

Moravec et al. (1976) observed strong association between bulb weight and stem weight. However, weak correlation for number of cloves, stem length, sheath length and sheath breadth with yield.

Korla and Rastogi (1979) studied eleven cultivars over two seasons and reported that, the bulb girth alone was correlated with yield per plot. They also found negative correlation between number of cloves per bulb and weight of 20 cloves.

Singh (1981) while studying correlations in garlic with nine cultivars found that, the bulb weight per plant was highly and positively correlated with clove weight, leaf length, height of the plant, number of leaves per plant and number of cloves per bulb.

Zhila (1981) studied the correlations between phenotypic traits in garlic and reported the positive association of plant height and number of leaves with bulb weight.

Kaloo et al. (1982) studied 22 cultivars of garlic for bulb yield and seven yield related characters and observed that, the height of plant, bulb weight, bulb diameter, clove weight and clove length were positively correlated with bulb yield. They also reported that, the genotypic correlation was higher than the phenotypic correlation.

Lokhande and Pawar (1988) reported that, the bulb weight was positively and significantly associated with length and breadth of leaves and leaf number.

Netrapal et al. (1988) reported that, the bulb yield had positive and significant correlations with plant height, number of leaves, bulb weight and size of bulb .

Shaha et al. (1990) studied the correlation of 32 diverse genotypes of garlic and showed that, the polar bulb diameter, number of cloves, weight of 50 cloves and plant height were positively correlated with equatorial bulb diameter. However, plant height and number of leaves per plant had positive association between them.

Kohli and Fageria (1992) studied the correlation in fourteen clones of garlic and observed that, the plant height, dry leaf weight, bulb weight, and number of cloves per bulb were positively and significantly correlated with yield. They also reported that, the plant height is positively correlated with dry leaf weight and number of cloves. However, clove length had negative association with plant height and number

of cloves. While, association among rest of characters were found to be non-significant amongst the varieties studied.

Shrivastava et al. (1993) studied the genetic association in garlic for various characters and revealed that, the highly significant positive association of bulb weight with all the traits except number of leaves per plant and number of cloves per bulb at genotypic and phenotypic levels respectively. The remaining characters showed significant positive association among themselves.

Selvaraj et al. (1997) studied correlation in garlic and observed that, the height of plant showed highly significant positive correlation with all the other characters studied.

Thakur et al. (1997) studied the correlation in 53 clones of garlic and indicated that, the yield was positively and significantly associated with weight of bulb, plant height, leaves per plant, leaf length and leaf breadth.

Agarwal and Tiwari (2000) studied the correlation in 16 garlic genotypes and reported that, the yield was positively and significantly associated with number of leaves per plant, length of leaves, diameter and weight of bulbs, length and weight of cloves and crop duration. The plant height and neck diameter also showed positive correlation with yield but of low magnitude.

Ghetia and Singh (2000) studied 26 genotypes of onion and reported that, the bulb yield per plot was found to be highly significant and positively correlated with plant height, number of leaves per plant, bulb weight and diameter of bulb. However, the total onion bulb yield was negatively correlated with bulb neck thickness and dry matter of bulb.

Godhani and Singh (2000) conducted experiment on 25 genotypes of garlic and reported that, the bulb yield per plot was positive and highly significantly correlated with number of leaves per plant, weight of bulb at both genotypic and phenotypic levels, the characters like plant height, number of leaves per plant were significantly and positively associated among themselves at genotypic level, indicating that selection made on the basis of these traits would help in increasing the bulb yield.

Killadi et al. (2000) studied correlation in 30 genotypes of garlic and showed that, the yield per plot was significantly and positively correlated with plant and bulb characters.

Kohli and Prabal (2000) conducted the correlation studies in 26 divergent clones of garlic and reported that, the correlation between yield, leaf size and bulb diameter was positive and highly significant.

Mohanty and Das (2000) studied 12 varieties of onion and reported that, the bulb yield showed positive and

significant phenotypic and genotypic association with plant height, number of leaves per plant and weight of bulb.

Raghuram et al. (2000) reported that, the yield per plot was significantly and positively correlated with plant height, number of leaves, neck thickness, bulb weight and bulb diameter in 50 lines of onion.

Sarangamath et al. (2000) studied correlation in eight onion genotypes and reported that, the bulb yield had significant positive correlation with plant height, number of leaves per plant, bulb length, and bulb diameter.

Shridhar (2000) conducted the experiment on 17 diverse genotypes of garlic and reported that, the bulb weight has significant positive association with bulb diameter and weight of 50 cloves. Whereas, number of cloves was negatively correlated with clove diameter and weight of 50 cloves. Plant height was also negatively correlated with maturity and number of cloves per bulb.

Khar et al. (2005) studied the correlation of 47 elite line of garlic and observed that, the marketable and total yield of garlic was highly correlated with all the characters under study in positive direction except for the total number of cloves.

Gurjar and Singhania (2006) studied correlation in 30 varieties of onion and reported that, the bulb yield showed

positive and significant phenotypic and genotypic association with plant height, number of leaves per plant, neck thickness, weight of bulb and bulb diameter.

Trivedi et al. (2006) studied correlation in 22 genotypes of onion and reported that, the yield was positively and significantly associated with bulb weight and bulb diameter.

Haydar et al. (2007) studied the correlation in 10 varieties of onion and indicated that, the bulb yield had highly positive significant correlation with bulb length and bulb diameter. However, bulb diameter also had positive significant association with plant height, weight of bulb and bulb length.

Dubey et al. (2010). Studied correlation in 19 diverse genotypes of garlic and revealed that, the gross yield was positively and significantly correlated with plant height, bulb diameter, bulb size index, cloves per bulb, weight of 20 bulbs and days for harvesting and negatively and significantly correlated with clove diameter.

Singh et al. (2010). Studied correlation in 16 diverse genotypes of red onion and revealed that, the gross yield had strong positive correlation between bulb diameters, bulb size index and bulb weight at both genotypic and phenotypic levels. However, the bulb diameter had negative correlation with number of leaves per plant and neck thickness at genotypic level.

2.5 Genetic divergence studies

Genetic architecture of a population is the result of prolonged selection by nature. The populations which live in heterogenous environment and which have mastered many ecological niches should be genetically more diverse and accumulated enormous genetic variability as compared to populations occupying ecologically marginal habitats.

The concept of D^2 statistics for measuring the divergence between populations was introduced by Mahalanobis (1936). It gives a result based on the magnitude of divergence and is independent on the size of samples.

The utility of D^2 analysis in discriminating populations belonging to diverse genetic and geographic origins has been discussed by Arunachalam and Ram (1967).

Murthy and Arunachalam (1966) reported that, the genetic diversity among genotypes of common geographical origin could be due to heterogeneity, genetic architecture, past history of selection, developmental traits and general combining ability. Although general combining ability in case of garlic may be ruled out due to it's sexual mode of propagation.

Shaha (1985) evaluated forty-two onion cultivars obtained from different geographic regions for their morphological and biochemical variability and genetic

diversity in bulb characters. The D^2 statistics showed that, there was adequate diversity among the cultivars with D^2 values ranging from 46.23 to 6773.56. On the basis of these values 42 onion cultivars were grouped under 14 clusters. Clustering pattern of the cultivars does not necessarily follow the geographical distribution.

Gvozdanovic (1997) identified height of the above ground part i.e., plant height, number of leaves, mass of the bulb, mass of the clove and yield as the characteristics which contributed significantly to the clustering of garlic ecotypes.

Matus et al. (1999) reported that, the duration of growth period, quantitative characteristics of the bulb (diameter and weight of bulb) and plant characteristic's (height and number of green leaves) explained maximum amount (29.9%) of the variation present in the garlic germplasm.

Khar et al. (2006) conducted experiment on 47 genotypes of garlic on the basis of their vigour and observed the significant difference between the genotypes for all the characters under study. The highest contribution towards genetic diversity was contributed by marketable yield (36.91) followed by weight of five bulbs and plant height. The population formed six clusters with cluster II having the genotypes (18) and cluster IV and VI having minimum number of genotypes (2). Maximum inter- cluster distance was

recorded between cluster IV and VI and maximum intra-cluster distance was recorded in cluster distance was recorded between cluster IV (20.50).

2.6 Path coefficient studies

Path analysis helps to understand the direct and indirect effects of different components on yield. The direct effect of any character on yield gives an idea about how reliable selection can be made for a particular character to bring improvement in yield.

Singh (1981) studied the path analysis in nine cultivars of garlic and showed that, the clove weight and leaf length had high direct positive effect on bulb weight and their indirect contribution via each other indicated if other factors are held constant, an increase in these traits would be reflected in an increased bulb weight.

Kaloo et al. (1982) studied the path co-efficient analysis in 22 genotypes of garlic and revealed that, the weight of bulb, clove number and plant height during first year, whereas plant height, bulb diameter, weight of cloves and number of cloves per bulb in second year contributed maximum direct effects towards yield. However, indirect effect has indicated that, the diameter of bulb, plant height, length of clove and weight of clove contributed maximum via weight of bulb during first year.

Mehta and Patel (1985) studied the path analysis of 40 genotypes of garlic and showed that, the clove weight had highest direct positive effect on bulb yield per plot. They further suggested that, the clove weight was the most important character and would serve as good selection index for further improvement of garlic.

Rahman and Das (1985) studied path analysis in garlic and reported that, the higher positive direct effect was exerted by bulb diameter followed by number of leaves per plant on bulb yield in garlic. However, maximum positive indirect effect was found for fresh weight per bulb through plant height on bulb yield.

Shrivastava et al. (1993) studied path analysis and indicated maximum positive direct effects of plant height on bulb weight. However, its indirect effects via leaf width, number of leaves per plant and bulb diameter were negative and of considerable magnitude. Also bulb diameter and clove diameter showed positive direct effects on bulb weight.

Selvaraj et al. (1997) reported that, the indirect effect via plant height was the major contributing factor followed by diameter of bulbs on yield in garlic. However, its direct effect was moderate.

Agarwal and Tiwari (2000) conducted the experiment on 16 genotypes of garlic and reported that, the characters except neck diameter, clove length showed positive

direct effect on yield. While indirect effects via clove weight, number of leaves per plant and crop duration were major contributing factors for all the characters.

Ghetia and Singh (2000) estimated the direct and indirect effect of path coefficients in 26 genotypes of onion and reported that, the plant height expressed negative direct effect of low magnitude on bulb yield. However, it had significant positive correlation with bulb yield. Days to maturity and dry matter of bulb showed moderate negative direct effect on bulb yield per plot.

Godhani and Singh (2000) conducted the experiment on path analysis of 25 garlic genotypes and reported that, the weight of bulb, number of leaves per plant had high positive direct effect on bulb yield per plot. The bulb weight exerted the highest positive direct effect on bulb yield. The weight of clove showed high positive indirect effect via bulb weight on yield.

Killadi et al. (2000) studied the path coefficient analysis for various quantitative traits of garlic and indicated that, the plant height, 10 clove weight, 10 bulb weight and clove length had maximum direct effect on yield of garlic.

Mohanty and Das (2000) studied the path analysis in Kharif onion and showed that, the weight of bulb and number of leaves per plant had high positive direct effect on yield and positive indirect effect through each other on yield.

Raghuram et al. (2000) studied 50 lines of onion and reported that, the bulb weight and number of leaves per plant had the highest direct effect on yield per plot.

Mohanty (2002) studied path analysis in 12 varieties of onion and showed that, the plant height and number of leaves per plant produced high positive direct effect on yield and high positive indirect effect through each other on yield.

Khar et al. (2005) studied the path analysis in the 47 elite lines of garlic and showed that, the indirect effects of total yield had masked the direct or indirect effects in almost all the character except total number of cloves and the indirect effects were in negative direction via plant height, number of leaves, equatorial diameter, neck thickness, weight of bulb and weight of cloves which resulted in non-significant correlation with marketable yield.

Gurjar and Singhania (2006) showed that, the plant height, number of leaves per plant, neck thickness, bulb weight and bulb diameter had high positive direct effect through each other on yield in onion.

3. MATERIAL AND METHODS

The present investigation entitled, “Genetic Variability and Path analysis studies in Garlic (*Allium sativum* L.)” was conducted at All India Co-ordinated Vegetable Improvement Project, Department of Horticulture, Central Campus, Mahatma Phule Krishi Vidyapeeth, Rahuri during *Rabi* 2009-10.

The details of the material used, methods adopted and statistical procedures followed during the course of this investigation were described in this chapter.

3.1 Experimental site

The present investigation was carried out during *Rabi* season of 2009-10 at AICRP on vegetable crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Geographically, central campus of the Mahatma Phule Krishi Vidyapeeth, Rahuri is situated in between 19°17' to 19°57' north latitude and between 74°19' and 74°32' east longitude. It is situated at about 525 m above the mean sea level.

Climatically, this area falls in semi-arid, sub-tropical zone with the annual rainfall varying from 307 to 619 mm. The average annual rainfall is being 560 mm. Most of the

rainfall is received through South-West monsoon. The annual mean maximum and minimum temperature is 34.5°C and 18.3°C respectively.

3.2 Soil

The soil of experimental plot was medium black. The topography of experimental site was uniform and leveled.

3.3 Experimental details

The object of present investigation was to study the variability, correlation, degree of divergence, heritability, genetic advance and path analysis for different characters of garlic genotypes. The experimental details were as follows:

- 1 Name of the crop : Garlic (*Allium sativum* L.)
- 2 Design : Randomized Block Design
- 3 Treatments : 45 genotypes
- 4 Spacing : 15 x 10 cm
- 5 Fertilizer dose : 20 ton FYM + 100 : 50:50 kg NPK per ha.
- 6 Replications : Two
- 7 Plot size : 3 x 2 m.

3.4 Fertilizer application

Before planting, the experimental area was manured with a basal dose of 20 tons of FYM per hectare, which is

Table 1. Different garlic genotypes with their sources

Code No.	Genotypes	Source
G-1	RHRG-1	AICVIP, MPKV, Rahuri
G-2	RHRG-2	AICVIP, MPKV, Rahuri
G-3	RHRG-3	AICVIP, MPKV, Rahuri
G-4	RHRG-4	AICVIP, MPKV, Rahuri
G-5	RHRG-5	AICVIP, MPKV, Rahuri
G-6	RHRG-6	AICVIP, MPKV, Rahuri
G-7	RHRG-7	AICVIP, MPKV, Rahuri
G-8	RHRG-8	AICVIP, MPKV, Rahuri
G-9	RHRG-9	AICVIP, MPKV, Rahuri
G-10	RHRG-10	AICVIP, MPKV, Rahuri
G-11	RHRG-11	AICVIP, MPKV, Rahuri
G-12	RHRG-12	AICVIP, MPKV, Rahuri
G-13	RHRG-13	AICVIP, MPKV, Rahuri
G-14	RHRG-14	AICVIP, MPKV, Rahuri
G-15	RHRG-15	AICVIP, MPKV, Rahuri
G-16	RHRG-16	AICVIP, MPKV, Rahuri
G-17	RHRG-17	AICVIP, MPKV, Rahuri
G-18	RHRG-18	AICVIP, MPKV, Rahuri
G-19	RHRG-19	AICVIP, MPKV, Rahuri
G-20	RHRG-20	AICVIP, MPKV, Rahuri
G-21	RHRG-21	JNKKV, Jabalpur (MP) *
G-22	RHRG-22	JNKKV, Jabalpur (MP) *
G-23	RHRG-23	GAU, Junagarh (Gujrat) *
G-24	RHRG-24	GAU, Junagarh (Gujrat) *
G-25	RHRG-25	GAU, Junagarh (Gujrat) *
G-26	RHRG-26	NHRDF, Nashik *
G-27	RHRG-27	NHRDF, Nashik *
G-28	RHRG-28	NHRDF, Nashik *
G-29	RHRG-29	Pithorgarh (Uttaranchal) *
G-30	RHRG-30	Pithorgarh (Uttaranchal) *
G-31	RHRG-31	Pithorgarh (Uttaranchal) *
G-32	RHRG-32	Sabour ,Bihar Agril. College, Bhagalpur *
G-33	RHRG-33	Almora *
G-34	RHRG-34	VPKS *
G-35	RHRG-35	VPKS *
G-36	RHRG-36	Kalyanpur, CSAUAT, Kanpur *
G-37	RHRG-37	Ludhiana, PAU (Punjab)
G-38	RHRG-38	ARS, Pimpalgaon (B), Nashik
G-39	RHRG-39	ARS, Pimpalgaon (B), Nashik
G-40	RHRG-40	ARS, Pimpalgaon (B), Nashik
G-41	RHRG-41	NRC, Onion and Garlic, Rajgurunagar *
G-42	RHRG-42	ARS, Pimpalgaon (B), Nashik
G-43	RHRG-43	ARS, Pimpalgaon (B), Nashik
G-44	RHRG-44	NRC, Onion and Garlic, Rajgurunagar *
G-45	RHRG-45	UAT, Shrinagar (J and K) *

*- The garlic genotypes received in co-ordinated trials were maintained and used for present investigation.

common to the all treatments/genotypes. Besides, half of nitrogen and entire dose of phosphorus and potassium were applied through Urea (46.6%N), Single Super Phosphate (16% P₂O₅) and Muriate of Potash (60% K₂O) respectively, at the time of planting. The remaining half dose of nitrogen was applied one and half month after planting of garlic genotypes.

3.5 Preparatory tillage

The soil of experimental plot was prepared to a fine tilth by giving two crosswise ploughings to a depth of 20 cm followed by discing and harrowings. Farm Yard Manure was applied before last harrowing as a basal dose and mixed with soil. With the help of marker, marking was done and experimental plots of required size were prepared for planting the garlic genotypes.

3.5.1 Planting

The planting of forty five genotypes of garlic was done on 24th November, 2009. Before planting the bulbs of different genotypes were selected which were healthy and free from diseases. The cloves were used for planting purpose and diseased, empty cloves discarded at the time of planting.

3.5.2 Irrigation and after care.

The first irrigation was given immediately after the planting followed by second light irrigation after three days. The further irrigations were followed as per requirement of

crop. However, the irrigation interval of 10-12 days was maintained up to the final harvesting of the crop.

In order to keep the plot clean and weed free two hand weeding were given to entire experimental plot. Similarly, the plant protection measures were adopted as and when required for good growth of crop and better development of garlic bulbs. The crop was harvested when possessing the sign and symptoms of maturity.

3.6 Observations recorded

The following observations were recorded on individual plant basis for both growth and bulb characters in respect of five observational plants from each treatment/genotype. The five plants per genotype in each replication were randomly selected excluding border plants for recording the observations.

3.6.1 Quantitative characters

1. Number of leaves per plant

This was determined by the counting the total number of leaves at maturity from randomly selected each observational plant and average was worked out.

2. Plant height (cm)

The height of plant was recorded in centimeters, from ground level to the tip of plant of randomly selected plants with the help of metric scale.

3. Neck thickness (cm)

The neck thickness of bulb was measured in centimeters by using Vernier Calliper from randomly selected observations plants and average was worked out.

4. Average bulb weight (g)

The weight of five randomly selected bulbs was recorded individually in grams with the help of electronic weighing balance and average weight of bulb was worked out.

5. Average bulb length (cm)

The length of bulb was measured with the help of Vernier caliper in centimeters. The length of bulb of randomly selected bulb of observational plants was recorded and average was calculated.

6. Average bulb diameter (cm)

The diameter of bulb of five randomly selected observational plants was measured using Vernier caliper and was averaged.

7. Average weight of 10 cloves (g)

Ten cloves were taken from each of the five randomly selected bulbs and average weight of 10 cloves weighed and was averaged.

8. Number of cloves per bulb

The number of cloves in each bulb were counted for same five bulbs selected for recording the observation of weight of bulb and average was worked out.

9. Yield per plot (kg)

It was recorded by harvesting entire plot of each replication. The harvested bulbs were weighed along with green tops and expressed in kilograms and average yield of bulb per plot was worked out.

10. Yield per hectare (q)

The weight of harvested bulb per replication and per plot was recorded and yield per hectare was calculated by using hectare factor and expressed in quintal.

11. Days required for harvest

The date on which the harvesting was done and was recorded and days from planting were worked out.

3.6.2 Morphological/Qualitative characters

The observations like colour of leaves and size of leaves were recorded at peak growing period while, colour of bulb was recorded after harvesting of crop.

1. Colour of leaves : Dark green, Pale green
2. Colour of bulb : White, Violet
3. Size of leaves : Broad, small

3.7 Statistical analysis

3.7.1 Analysis of variance

The data available on studied characters were subjected to the statistical analysis commonly applicable to the randomized block design. The data was analyzed as per method suggested by Panse and Sukhatme (1985). The analysis of variance was done according to the table as given below.

Sr No.	Source of variation	Degrees of freedom	Mean square	Expected mean sum of square
1	Replication	r-1	RMS	$\sigma^2e + \sigma^2r$
2	Genotype	g-1	GMS	$\sigma^2e + r\sigma^2g$
3	Error	(r-1)(g-1)	EMS	σe^2
	Total	(rg-1)		

Where,

r = number of replications

e = error

g = number of genotypes

MS = Mean square

The genotype mean square (GMS) was tested against error mean square (EMS) by F test $n_1 = (g-1)$ and $n_2 = (r-1) (g-1)$ degrees of freedom.

3.7.2 Estimation of mean and range

The mean value for each character was worked out by using the following formula

$$\bar{X} = (\sum x_i)/n$$

Where,

$\sum x_i$ = Sum of total of the characters and

n = Number of observations

The lowest and the highest value from mean of each character were recorded as range.

3.7.3 Estimation of standard error of mean, standard error of difference and critical difference.

i) The standard error of difference was calculated as,

$$\text{S.E. mean} = [\text{S.E. (m)}] = \sqrt{\sigma^2 e / r}$$

ii) The standard error of difference between two means was

$$\text{calculated as, SE difference} = [\text{SE (d)}] = \text{SE (m)} \times \sqrt{2}.$$

iii) The critical difference between any two means was calculated as,

$$\text{C.D.} = \text{SE (d)} \times 't' \text{ at error d.f.}$$

3.7.4 Estimation of components of variation

The phenotypic and genotypic variances were calculated by utilizing the responsive mean square values from the variance table. (Johnson *et al.*, 1955)

i. Environmental variance = $\sigma^2_e = \text{EMS}$

ii. Genotypic variance = $\sigma^2_g = \frac{\text{GMS} - \text{EMS}}{r}$

iii. Phenotypic variance = $\sigma^2_p = \sigma^2_g + \sigma^2_e$

Where,

GMS = Genotypic mean sum square

EMS = Error mean sum of square and

R = Number of replication

3.7.5 Estimation of coefficient of variation

The genotypic and phenotypic coefficients of variation were calculated by the formulae as suggested by Burton and De Vane (1953).

i. Phenotypic coefficient of variation (PCV)

$$\text{PCV} = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

Where,

σ^2_p = Phenotypic variance

$\bar{X}$ = General mean of character

ii. Genotypic coefficient of variation (GCV)

$$\text{GCV} = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100$$

$$\bar{X}$$

Where,

σ^2g = Genotypic variance

$\bar{X}$ = General mean of character

3.7.6 Estimation of Heritability (b. s.)

Heritability in broad sense was estimated for the various characters as per the formulae suggested by Burton and De Vane (1953).

$$h^2 \text{ (b. s.)} = \frac{VG}{VP} \times 100$$

Where, VG = Genotypic variance

VP = Phenotypic variance

3.7.7 Estimation of genetic advance (G. A.)

The genetic advance (G. A.) was calculated in per cent by formula suggested by Johnson *et al.* (1955).

$$G. A. = \frac{\sigma^2g}{\sigma^2p} \times \sigma_p \times K$$

Or

$$G. A. = K \times h^2 \times \sigma_p$$

$$G. A. \text{ as percentage of mean} = \frac{G. A.}{\bar{X}} \times 100$$

Where,

$\sigma^2 g$ = Genetic variance

$\sigma^2 p$ = Phenotypic variance

σ_p = Phenotypic standard deviation

K = Selection differential at 5 per cent selection

intensity (i.e. 2.06)

$\bar{X}$ = Mean of character

3.7.8 Estimation of correlation coefficient

Analysis of covariance was carried out by taking two characters at a time. The plot error was used as environmental covariance. The phenotypic and genotypic co-variances were derived as detailed below.

Sr.No.	Source of variation	Degree of freedom	Mean product
1	Replication	r-1	
2	Genotype	g-1	GMP
3	Error	(r-1) (g-1)	EMP
	Total	rg - 1	

Where,

r = Number of replications.

GMP = Genotype sum of product.

g = Number of genotypes.

EMP = Error sum of product.

The genotype and phenotype co-variances were calculated as per the formulae given by Singh and Choudhary (1977).

a. Environmental co-variance

$$(\text{cov.}_e 1.2) = \text{EMP}$$

b. Genotypic co-variance

$$(\text{cov.}_g 1.2) = \frac{\text{GMP} - \text{EMP}}{r}$$

c. Phenotypic Co-Variance

$$(\text{cov.}_p 1.2) = (\text{cov.}_e 1.2) + (\text{cov.}_g 1.2)$$

The appropriate variances and co-variances were used for calculating phenotypic, genotypic and environmental correlation coefficients (Johnson *et al*, 1955).

1. Phenotypic correlation coefficients (rp)

It is derived by

$$rp_{1.2} = \frac{(\text{cov.p } 1.2)}{\sqrt{(\sigma^2 p_1) \cdot (\sigma^2 p_2)}}$$

Where,

$rp_{1.2}$ = Phenotypic correlation between character 1 and 2.

(cov.p 1.2) = Phenotypic co-variance between character 1 and 2.

$\sigma^2 P_1$ and $\sigma^2 P_2$ = Phenotypic co-variance between character 1 and 2, respectively.

2. Genotypic correlation coefficient (rg)

It is derived by

$$rg_{1.2} = \frac{(\text{cov.g } 1.2)}{\sqrt{(\sigma^2 g_1) \cdot (\sigma^2 g_2)}}$$

Where,

$rg_{1.2}$ = Genotypic correlation between character 1 and 2.
 (cov.g 1.2) = Genotypic co-variance between character 1 and 2

$\sigma^2 g_1$ and $\sigma^2 g_2$ = Genotypic co-variance between character 1 and 2, respectively.

The significance of the phenotypic and genotypic correlation coefficients were tested by 't' test. (Panse and Sukhatme, 1985)

$$t = r \sqrt{(n-2)/(1-r^2)}$$

Where,

r = Correlation coefficients

n = Total number of observations.

The calculated 't' value was tested with table 't' value for respective $(n-2)$ degrees of freedom for significance.

3.7.9 Path Coefficient Analysis

To establish a cause and effect relationship, the genotypic and phenotypic correlation coefficients were partitioned into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959). The first step in the path analysis is to prepare a path diagram based on cause and effect.

The concept behind path analysis is that yield is the function of various components like X_1 , X_2 , and X_3 etc. It means that yield is the result of X_1 , X_2 and X_3 and some other undefined factors designated by 'R'.

In Fig.1, The double arrowed lines indicates mutual association as compared as measured by correlation coefficients and the single arrowed lines represents direct influence as measured by path coefficient P_{ij} .

Path coefficients were obtained by solving a set of simultaneous equation of the form:

$$r_{ny} = p_{ny} + r_{n2} + r_{n2}p_{y2} + r_{n3} + \dots$$

Where,

r_{ny} = represents correlation between one component and yield.

pn_y = represents path coefficient between that character and yield.

rn_2 = represents correlation between that character and each of the other components in turn.

$$\begin{array}{cc} \textbf{Matrix 'A'} & \textbf{Matrix 'B'} \\ \left(\begin{array}{c} r_{1y} \\ r_{2y} \\ r_{ny} \end{array} \right) & \left(\begin{array}{cccc} 1 & r_{1.2} & r_{1.3} & \text{-----} r_{1n} \\ r_{2.1} & 1 & r_{2.3} & \text{-----} r_{2n} \\ r_{n1} & r_{n2} & r_{n3} & \text{-----} 1 \end{array} \right) \end{array}$$

Where,

$$r_{1.2} = r_{2.1} \text{ and so on and}$$

$$r_{1y} = \text{Correlation between one character and yield.}$$

The 'B' matrix was inverted (B^{-1}) and path coefficient (P_{ij}) were obtained as ,

$$(P_{ij}) = ax (B^{-1}).$$

The indirect effect of a particular character through other character was obtained by multiplication of direct path effects and particular correlation coefficients between those characters separately.

$$\text{Indirect effect} = r_{ij} \times P_{ij}$$

Where,

$$I = 1 \text{ to } 6$$

$$J = 1 \text{ to } 6, \text{ and}$$

$$P_{ij} = P_1Y_1, P_2Y_2 \text{ -----} P_{ny}$$

The residual factors i.e. variation in yield unaccounted for these associations was calculated from following formula.

$$\text{Residual effect (R)} = \sqrt{1 - R^2}$$

Where,

$$R^2 = P_{1y} \cdot r_{1y} + P_{2y} \cdot r_{2y} + P_{3y} \cdot r_{3y} + \dots + P_{ny} \cdot r_{ny}$$

Where,

$P_{1y}, P_{2y}, \dots, P_{ny}$ = Path values

$R_{1y1}, r_{2y1}, \dots, r_{ny}$ = Correlation coefficient.

3.7.10 Genetic diversity

Mahalanobis (1936) defined the generalized distance between two populations as,

$$\Delta^2 = \sum \sum \lambda_{ij} \sigma_i \sigma_j$$

Where,

λ_{ij} is the reciprocal matrix to the common dispersion matrix and σ_i was the difference between the mean values of the two populations from the j^{th} character. This quantity was estimated by the D^2 statistics.

$$D^2 = \sum \sum S_{ij} \sigma_i \sigma_j$$

Where,

S_{ij} is the sample estimate of (λ_{ij}) and of σ_i .

Since this formula for computation required the inversion of 15th order determinant and the evaluation of 15 (15-1)/2, term whose sum was D^2 , transformation of the original correlated unstandardised character means of standardized, uncorrelated variables was done.

1. Determination of group constellation

No rules can be laid down for finding the clusters because a cluster is not well defined term. The only criterion appeared to be that any two groups belonging to the same cluster should at least on the average showed a smaller D^2 value than those belonging to two different clusters. A simple device suggested by Tocher (Rao, 1952) was to start with two closely associated groups which was smaller average D^2 value from first two, Similarly, the fourth was chosen to have smallest average D^2 value from the first three and so on. At any stage, the average D^2 value of a group should not fit in with former groups and was, therefore taken to be outside the former cluster. The group of the first cluster was then omitted and rests were treated similarly. It was also helpful to calculate the change in average D^2 value within a cluster due to inclusion of an additional group. If the change was appreciable, then the newly added group had to be considered as outside the cluster. The computational scheme was as given below.

Population added to a cluster.	D^2	Number of terms (n)	Increase in D^2 / Increase in 'n'.	Average $D^2 = d^2/n$	Cluster

2. Average intra-cluster distance

The intra-cluster distances were calculated as $\sum D_i^2 / n$; Where, $\sum D_i^2$ was sum of distances between all

possible combinations (n) of the population included in a cluster.

3. Average inter-cluster distance

The procedure followed for calculating the inter cluster distance was first to measure the distance between cluster I and II, between I and III and I and IV and so on. Likewise the clusters were taken one by one and the distance from other clusters were calculated. The average inter-cluster distances were then calculated as, $\sum D_{ij}^2 / (n_i n_j)$ where, n_i was the number of populations in cluster I and n_j was the number of populations in cluster II.

4. Cluster diagram

With the help of D^2 values between the clusters, a diagram showing the relationship between different populations was drawn.

4. EXPERIMENTAL RESULTS

The results of the present investigation entitled; “Genetic variability and path analysis studies in garlic (*Allium sativum* L.)” were described in this chapter under suitable headings.

4.1 Qualitative Characters

The observations recorded on qualitative characters namely colour of leaves, colour of bulb and size of leave was presented in table 2.

4.2 Analysis of variance

The analysis of variance (Table 3) revealed highly significant differences among the genotypes for all the characters under study, suggesting a presence of variability for all the 11 characters in 45 genotypes of garlic.

4.3 Mean performance

The mean performance for 11 characters in 45 genotypes of garlic is presented in Table 4.

4.3.1 Number of leaves per plant

The population mean for this character was 8.37. The 22 genotypes (48.89 percent) exhibited more mean values

Table 2. Qualitative characters of the garlic genotypes.

Sr. No.	Name of Genotypes	Qualitative characters		
		Colour of leaves	Colour of bulb	Size of leaves
1	RHRG-1	Pale green	Violet	Small
2	RHRG-2	Pale green	Violet	Small
3	RHRG-3	Pale green	Violet	Small
4	RHRG-4	Pale green	Violet	Small
5	RHRG-5	Dark green	Violet	Small
6	RHRG-6	Dark green	Violet	Small
7	RHRG-7	Pale green	White	Broad
8	RHRG-8	Pale green	Violet	Broad
9	RHRG-9	Pale green	White	Small
10	RHRG-10	Dark green	Violet	Broad
11	RHRG-11	Dark green	Violet	Small
12	RHRG-12	Dark green	Violet	Broad
13	RHRG-13	Dark green	Violet	Broad
14	RHRG-14	Dark green	Violet	Broad
15	RHRG-15	Pale green	Violet	Broad
16	RHRG-16	Dark green	Violet	Broad
17	RHRG-17	Dark green	White	Broad
18	RHRG-18	Dark green	White	Broad
19	RHRG-19	Dark green	Violet	Broad
20	RHRG-20	Pale green	White	Small
21	RHRG-21	Pale green	Violet	Broad
22	RHRG-22	Pale green	Violet	Broad
23	RHRG-23	Dark green	White	Broad
24	RHRG-24	Dark green	White	Broad
25	RHRG-25	Dark green	White	Broad
26	RHRG-26	Dark green	Violet	Broad
27	RHRG-27	Pale green	White	Broad
28	RHRG-28	Pale green	Violet	Broad
29	RHRG-29	Pale green	White	Small
30	RHRG-30	Dark green	Violet	Broad
31	RHRG-31	Dark green	White	Broad
32	RHRG-32	Dark green	Violet	Broad
33	RHRG-33	Dark green	Violet	Broad
34	RHRG-34	Pale green	White	Broad
35	RHRG-35	Dark green	Violet	Broad
36	RHRG-36	Dark green	White	Broad
37	RHRG-37	Pale green	White	Small
38	RHRG-38	Pale green	Violet	Broad
39	RHRG-39	Pale green	White	Small
40	RHRG-40	Pale green	Violet	Small
41	RHRG-41	Pale green	Violet	Broad
42	RHRG-42	Pale green	Violet	Small
43	RHRG-43	Dark green	Violet	Broad
44	RHRG-44	Dark green	White	Broad
45	RHRG-45	Dark green	White	Broad

than population mean. The highest number of leaves was observed for the genotype G-45 (9.70) followed by G-39 (9.50), G-38 along with G-25 (9.40). The genotype G-12 showed least number of leaves per plant (7.00).

4.3.2 Plant height (cm)

The genotype G-7 recorded significantly maximum plant height (59.20) however, it was at par with genotype G-25 (57.50). The minimum plant height was observed in G-3 (41.60) followed by G-42 (44.10) and G-16 (44.70). The 22 genotypes (48.89 percent) had plant height more than population mean of 50.90.

4.3.3 Neck thickness (cm)

Twenty genotypes (44.44 percent) have more neck thickness than population mean (0.88). The genotype G-8 recorded significantly maximum neck thickness (1.18) however, it was at par with genotypes G-38 (1.16) and G-29 (1.09). The genotype G-2 had the minimum neck thickness (0.65) followed by G-3 (0.68).

4.3.4 Average bulb weight (g)

The population mean for this character was 23.48. Twenty genotypes (44.44 percent) exhibited more mean values than population mean. Significantly the highest average bulb weight was observed for genotype G-29 (40.50) followed by G-24 (35.70) and G-38 (35.40). The lowest average bulb weight

Table 3. Analysis of variance (M.S.S.) for 11 characters in garlic.

Sr. No.	Name of Characters	Mean sum of squares		
		Replication	Treatment	Error
1	Number of leaves/plant	1.040	0.890**	0.210
2	Plant height (cm)	5.770	30.82**	7.290
3	Neck thickness (cm)	0.008	0.030**	0.004
4	Average bulb weight (g)	5.600	70.61**	2.930
5	Average bulb length (cm)	0.001	0.270**	0.010
6	Average bulb diameter (cm)	0.023	0.260**	0.026
7	Average Weight of 10 cloves (g)	0.100	36.88**	0.170
8	Number of cloves/ bulb	0.004	21.97**	0.330
9	Days required for harvest	0.001	35.96**	0.001
10	Yield/plot (kg)	0.100	8.200**	1.070
11	Yield/ha (q)	28.170	2279.82**	298.88

** - Significance at 5%.

Table 4. Mean performance of different characters of 45 genotypes of garlic.

Genotypes	Number of leaves / plant	Plant height (cm)	Neck thickness (cm)	Average bulb weight (g)	Average bulb length (cm)	Average bulb diameter (cm)	Average Weight of 10 cloves (g)	Number of cloves/ bulb	Yield/ plot (kg)	Yield/ ha (q)	Days required for harvest
RHRG-1	9.20	55.10	0.89	21.60	3.21	3.40	9.20	23.47	6.065	101.100	117.0
RHRG-2	8.30	49.40	0.65	14.62	2.83	3.24	9.30	15.72	5.350	89.180	117.0
RHRG-3	7.90	41.60	0.68	13.80	2.88	3.24	10.00	13.80	3.925	65.425	117.0
RHRG-4	8.40	47.40	0.70	15.40	2.86	3.56	9.20	16.74	5.242	87.390	117.0
RHRG-5	9.00	45.00	0.80	17.20	2.95	3.22	10.80	15.92	5.475	91.265	117.0
RHRG-6	9.00	55.40	0.99	20.40	3.47	3.64	9.80	20.82	5.560	92.680	117.0
RHRG-7	8.30	59.20	1.02	27.80	3.10	3.97	9.40	29.57	5.950	99.180	127.0
RHRG-8	8.50	46.80	1.18	30.20	3.62	4.12	13.40	22.54	8.900	148.358	123.0
RHRG-9	8.80	48.20	0.79	18.80	3.54	3.78	11.60	16.21	8.251	137.540	117.0
RHRG-10	8.40	49.90	0.90	24.50	3.55	4.06	10.60	23.11	8.000	133.355	123.0
RHRG-11	8.50	47.00	0.80	20.00	3.45	3.58	12.60	15.87	8.955	149.275	117.0
RHRG-12	7.00	52.20	0.87	25.00	2.95	4.03	7.00	35.71	8.250	137.520	127.0
RHRG-13	8.20	52.80	0.84	23.60	3.00	3.98	7.00	33.71	6.225	103.765	127.0
RHRG-14	7.40	48.40	0.78	18.80	2.76	3.66	9.20	20.43	6.750	112.515	127.0
RHRG-15	7.50	50.90	0.84	21.00	2.77	3.95	9.60	21.87	5.925	98.765	127.0
RHRG-16	8.70	44.70	0.79	19.30	2.82	3.67	10.80	17.87	6.125	102.100	127.0
RHRG-17	7.80	48.10	0.78	18.10	2.76	3.72	9.00	20.11	7.600	126.685	127.0
RHRG-18	7.80	49.60	0.74	18.80	2.74	3.76	9.40	20.00	7.200	120.020	127.0
RHRG-19	7.70	45.00	0.86	18.60	3.03	3.87	9.20	20.22	7.900	131.690	127.0
RHRG-20	8.40	51.60	0.86	21.70	3.24	3.74	13.40	16.20	8.100	135.020	123.0
RHRG-21	7.70	48.30	0.82	21.40	2.90	3.67	11.60	18.45	8.000	133.355	127.0
RHRG-22	8.90	54.70	0.96	25.00	2.81	4.22	11.00	22.73	9.825	163.780	127.0
RHRG-23	8.30	49.70	0.92	22.20	3.31	3.93	11.80	18.81	9.500	158.360	123.0
RHRG-24	9.30	50.60	1.07	35.70	3.90	4.44	13.00	27.46	11.950	199.200	123.0
RHRG-25	9.40	57.50	1.00	32.00	3.04	4.38	11.40	28.07	9.100	151.690	127.0
RHRG-26	7.60	49.50	0.88	22.80	2.94	3.90	7.00	32.57	9.150	152.525	127.0

Continued Table 4 -----

Genotypes	Number of leaves / plant	Plant height (cm)	Neck thickness (cm)	Average bulb weight (g)	Average bulb length (cm)	Average bulb diameter (cm)	Average Weight of 10 cloves (g)	Number of cloves/ bulb	Yield/ plot (kg)	Yield/ ha (q)	Days required for harvest
RHRG-27	8.10	52.50	0.92	27.20	2.90	3.95	11.00	24.73	10.600	176.695	127.0
RHRG-28	7.40	56.30	0.90	28.80	2.98	4.14	9.00	32.00	8.000	133.355	127.0
RHRG-29	8.80	52.20	1.09	40.50	4.16	5.07	22.20	18.24	11.775	196.285	123.0
RHRG-30	8.10	55.10	0.73	24.40	3.11	3.58	9.20	26.52	10.400	173.360	127.0
RHRG-31	9.30	55.30	0.91	33.90	3.19	4.06	12.00	28.25	11.125	185.450	127.0
RHRG-32	8.10	55.90	1.01	25.30	3.46	4.16	11.60	21.81	10.600	176.700	123.0
RHRG-33	7.80	52.90	0.85	21.20	2.88	3.86	8.60	24.65	8.525	142.105	127.0
RHRG-34	7.80	51.10	0.91	22.00	2.84	3.83	9.20	23.91	8.550	142.525	127.0
RHRG-35	7.90	54.50	0.95	27.30	2.99	4.17	10.00	27.30	7.850	130.855	127.0
RHRG-36	9.00	53.20	0.97	31.00	2.88	4.12	13.60	22.79	7.875	131.270	127.0
RHRG-37	7.20	56.30	0.72	18.60	3.17	3.65	9.00	20.67	5.070	84.510	117.0
RHRG-38	9.40	54.10	1.16	35.40	4.09	4.48	15.00	23.60	11.250	187.535	123.0
RHRG-39	9.50	48.80	0.88	21.40	3.42	3.64	9.00	23.77	5.330	88.845	117.0
RHRG-40	8.85	47.80	0.81	23.00	3.55	3.53	11.70	19.66	6.925	115.435	117.0
RHRG-41	8.30	48.70	0.86	24.20	3.41	3.56	15.60	15.51	8.925	148.775	123.0
RHRG-42	8.00	44.10	0.77	13.00	2.74	3.20	9.60	13.54	4.145	69.095	117.0
RHRG-43	8.60	52.70	0.85	22.10	2.74	4.01	9.60	23.02	9.725	162.110	127.0
RHRG-44	9.00	48.60	1.00	24.30	3.69	4.04	12.60	19.28	8.125	135.435	123.0
RHRG-45	9.70	52.10	1.08	24.85	3.51	3.90	33.70	7.37	7.300	121.690	127.0
General Mean	8.37	50.91	0.88	23.48	3.16	3.86	11.30	20.13	7.897	131.639	123.4
S.E.±	0.33	1.91	0.05	1.21	0.07	0.11	0.29	0.40	0.733	12.225	0.00
C.D. at 5%	0.93	5.44	0.13	3.45	0.20	0.32	0.83	1.15	2.090	34.843	N.S.
C.V. (%)	5.50	5.31	7.56	7.30	3.10	4.15	3.63	2.84	13.132	13.133	0.00

Table 5. Genetic variability Parameters of 45 genotypes in garlic.

Sr. No.	Character	Range	Mean	P. C. V.	G. C. V.	Heritability (%) in b.s.	Genetic advance (G. A.)	Expected Gen. Adv. as % of mean
1.	Number of leaves per plant	7.00 – 9.70	8.37	8.89	6.99	61.86	0.94	11.33
2	Plant height (cm)	41.60 – 59.20	50.90	8.57	6.73	61.72	5.55	10.90
3	Neck thickness (cm)	0.64 – 1.18	0.88	14.85	12.78	74.11	0.20	22.67
4	Average bulb weight (g)	13.00 – 40.50	23.48	25.82	24.77	92.01	11.49	48.94
5	Average bulb length (cm)	2.74 – 4.16	3.16	11.97	11.56	93.28	0.72	23.00
6	Average bulb diameter (cm)	3.20 – 5.07	3.86	9.83	8.91	82.21	0.64	16.65
7	Average weight of 10 cloves (g)	7.00 – 33.70	11.30	38.08	37.91	99.09	8.78	77.75
8	Number of cloves per bulb	7.37 – 35.71	20.13	16.59	16.34	97.07	6.67	33.17
9	Days required for harvest	117 – 127	123.44	3.43	3.43	100.00	8.73	7.07
10	Yield/plot (kg)	3.92 – 11.95	7.89	27.27	23.90	76.82	3.40	43.16
11	Yield/ha (q)	65.42 – 199.20	131.64	27.27	23.90	76.82	56.82	43.16

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

was observed for genotype G-42 (13.00) followed by G-3 (13.80), G-2 (14.62) and G-4 (15.40).

4.3.5 Average bulb length (cm)

The range of 2.74 (G-18) and 4.16 (G-29) was recorded for average bulb length. Significantly the highest average bulb length was observed for genotype G-29 (4.16) however, it was at par with genotype G-38 (4.09). The genotype G-18 (2.74) along with G-42 (2.74), G-43 (2.74), G-14 (2.76) and G-17 (2.76) showed lower mean values. Nineteen genotypes (42.22 percent) had more mean values than population mean (3.16).

4.3.6 Average bulb diameter (cm)

A narrow range of 3.20 (G-42) to 5.07 (G-29) was observed for average bulb diameter. Significantly the highest average bulb diameter was recorded by genotype G-29 (5.07), followed by G-38 (4.48), G-24 (4.44) and G-25 (4.38) showed higher mean values. The genotype G-42 (3.20) followed by G-5 (3.22), G-2 (3.24) and G-3 (3.24) showed lower mean values. Twenty four genotypes (53.33 percent) had average bulb diameter more than population mean (3.86).

4.3.7 Average weight of 10 cloves (g)

The population mean for this character was 11.30. Seventeen genotypes (37.78 percent) exhibited more mean values than population mean. Significantly the highest

average weight of 10 cloves was observed for genotype G-45 (33.70) followed by G-29 (22.20). The lowest average weight of 10 cloves was observed for genotypes G-12 (7.00), G-13 (7.00) and G-26 (7.00).

4.3.8 Number of cloves per bulb.

Significantly the maximum number of cloves per bulb was observed for genotype G-12 (35.71) followed by G-13 (33.71) and G-26 (32.57). The minimum number of cloves per bulb were observed for genotype G-45 (7.37) followed by G-3 (13.80) and G-2 (15.72). There were twenty-six genotypes (57.77 percent) having more number of cloves per bulb than population mean of 20.13.

4.3.9 Yield per plot (kg)

Significantly the maximum bulb yield per plot was observed for genotype G-24 (11.950) however, it was at par with genotypes G-29 (11.775), G-38 (11.250), G-31 (11.125) and G-27 (10.600). The genotype G-3 (3.925) recorded minimum yield per plot followed by G-42 (4.145) and G-37 (5.070). Twenty-five genotypes (55.56 percent) had more yield per plot than population mean (7.89).

4.3.10 Yield per hectare (q)

The genotype G-24 recorded significantly the highest yield per hectare (199.20). However, it was at par with genotypes G-29 (196.28), G-38(187.53) and G-31 (185.45).

The lowest yield per hectare was recorded for genotype G-3 (65.425) followed by G-42 (69.095), G-37 (84.510) and G-4 (87.390). The population mean for this character was 131.64. The twenty-five genotypes (55.56 percent) exhibited more yield per hectare than population mean.

4.3.11 Days required for harvest.

The genotypes G-1, G-2, G-3, G-4, G-5, G-6, G-9, G-11, G-37, G-39, G-40 and G-42 was earlier for harvesting (117). The genotypes G-7, G-12, G-13, G-14, G-15, G-16, G-17, G-18, G-19, G-21, G-22, G-25, G-26, G-27, G-28, G-30, G-31, G-33, G-34, G-35, G-36, G-43 and G-45 had taken maximum days (127). The population mean for this character was 123.44. The twenty-two genotypes (48.88 percent) exhibited less days required for harvest than population mean.

4.4 Parameters of genetic variability

The parameters of genetic variability viz; variability, range, GCV, PCV, heritability (b. s.), genetic advance, expected genetic advance as % of mean are summarized in Table 5.

4.4.1 Coefficient of variation

The magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for 10 characters except days required for harvest under study. The highest GCV was observed for average weight of 10

cloves (37.91) followed by average bulb weight (24.77) whereas, the PCV was higher for average weight of 10 cloves (38.08) followed by yield per ha (27.27) and yield per plot (27.27). The lowest GCV, as well as PCV was recorded for days required for harvest and it was 3.43 and 3.43 respectively.

The maximum difference between GCV and PCV was noted for yield per plot (3.37) and yield per hectare (3.37).

4.4.2 Heritability (b. s.)

The heritability (board sense) percentage ranged between 61.72 (plant height) to 100.00 (days required for harvest). High heritability (b. s.) percentage was observed for days required for harvest (100.00) followed by average weight of 10 cloves (99.09), and number of cloves per bulb (97.07). These characters had high magnitude of heritability. The high (above 30 percent) heritability was recorded for all characters under study.

4.4.3 Genetic Advance

The genetic advance was maximum for trait, like yield per hectare (56.82) followed by average bulb weight (11.49), average weight of 10 cloves (8.78) and days required for harvest (8.73). The lowest genetic advance was noted for neck thickness (0.20) followed by average bulb diameter (0.64), average bulb length (0.72) and number of leaves per plant (0.94). The highest expected genetic advance as percent

of mean was observed for average weight of 10 cloves (77.75) followed by average bulb weight (48.94), yield per plot along with yield per hectare (43.16) and number of cloves per bulb.

4.5 Correlation

The correlation coefficients between the characters at both, genotypic as well as phenotypic level are presented in Table 6. The magnitude of genotypic correlation coefficient in general was higher than the phenotypic correlation coefficient.

Number of leaves per plant showed significant and positive correlation with neck thickness, average bulb weight, average bulb length and average weight of 10 cloves at both genotypic and phenotypic levels. It showed non-significant and positive correlation with plant height, average bulb diameter, yield per plot and yield per hectare at both genotypic and phenotypic levels. Number of leaves per plant had significant and negative association with number of cloves per bulb at both genotypic and phenotypic levels. While, it showed negative and significant correlation at genotypic level however, negative and non-significant correlation at phenotypic level with days required for harvest.

The plant height was significantly and positively correlated with neck thickness, average bulb weight, average bulb diameter, yield per plot, yield per hectare and days required for harvest at both genotypic and phenotypic levels.

Table 6. Estimates of Phenotypic (P) and Genotypic (G) correlations of 11 different characters in garlic.

Characters		Number of leaves / plant	Plant height (cm)	Neck thickness (cm)	Average bulb weight (g)	Average bulb length (cm)	Average bulb diameter (cm)	Average Weight of 10 cloves (g)	Number of cloves / bulb	Yield/ plot (kg)	Yield/ ha (q)	Days required for harvest
Number of leaves per plant	P	0.000	0.025	0.402**	0.365**	0.460**	0.155	0.447**	-0.375**	0.184	0.184	-0.234
	G	0.000	0.220	0.572**	0.412**	0.642**	0.240	0.594**	-0.469**	0.225	0.225	-0.298*
Plant height (cm)	P			0.379**	0.488**	0.136	0.439**	0.032	0.221	0.320*	0.320*	0.309*
	G			0.460**	0.632**	0.076	0.561**	0.018	0.315*	0.532**	0.532**	0.393**
Neck thickness (cm)	P				0.744**	0.581**	0.708**	0.459**	-0.100	0.466**	0.466**	0.263*
	G				0.871**	0.684**	0.814**	0.536**	-0.106	0.630**	0.630**	0.306*
Average bulb weight (g)	P					0.550**	0.825**	0.374**	0.118	0.675**	0.675**	0.392*
	G					0.603**	0.924**	0.397**	0.142	0.989**	0.989**	0.408**
Average bulb length (cm)	P						0.466**	0.518**	-0.253*	0.329*	0.329*	-0.298*
	G						0.477**	0.531**	-0.266*	0.416**	0.416**	-0.309*
Average bulb diameter (cm)	P							0.306*	0.152	0.621**	0.621**	0.485**
	G							0.329*	0.188	0.839**	0.839**	0.535**
Average weight of 10 cloves (g)	P								-0.695**	0.242	0.242	0.041
	G								-0.707**	0.277*	0.277*	0.041
Number of Cloves per bulb	P									0.160	0.160	0.246
	G									0.197	0.197	0.250
Yield/plot (kg)	P										1.000**	0.457**
	G										1.000**	0.521**
Yield/ha (q)	P											0.457**
	G											0.521**
Days required for harvest	P											0.000
	G											0.000

*, ** significance at 5 and 1% levels, respectively.

It recorded positive and non-significant correlation with average bulb length and average weight of 10 cloves at both genotypic and phenotypic levels. It was positively significant correlation at genotypic level and positively non-significant correlation at phenotypic level with number of cloves per bulb.

Neck thickness showed positive and significant correlation with average bulb weight, average bulb length, average bulb diameter, average weight of 10 cloves, yield per plot, yield per hectare, and days required for harvest at both genotypic and phenotypic levels. It showed negative and non-significant association with number of cloves per bulb at both genotypic and phenotypic levels.

Average bulb weight was positively and significantly correlated with average bulb length, average bulb diameter, average weight of 10 cloves, yield per plot, yield per hectare and days required for harvest while, it showed positive and non-significant correlation with number of cloves per bulb at both genotypic and phenotypic levels.

Average bulb length showed positive and significant correlation with average bulb diameter, average weight of 10 cloves, yield per plot and yield per hectare at both genotypic and phenotypic levels. It showed negative and significant correlation with number of cloves per bulb and days required for harvest at both genotypic and phenotypic levels.

Average bulb diameter was positively and significantly correlated with average weight of 10 cloves, yield per plot, yield per hectare and days required for harvest at both genotypic and phenotypic levels. It showed positive and non-significant correlation with number of cloves per bulb at both genotypic and phenotypic levels.

Average weight of 10 cloves exhibited negative and significant correlation with number of cloves per bulb while, it showed positive and non-significant correlation with days required for harvest at both genotypic and phenotypic levels. It showed positive and significant correlation at genotypic level and positive and non-significant correlation at phenotypic level with yield per plot and yield per hectare.

Number of cloves per bulb showed positive and non-significant correlation with yield per plot, yield per hectare and days required for harvest at both genotypic and phenotypic levels.

Yield per plot showed positive and highly significant correlation with yield per hectare and days required for harvest. Yield per hectare also showed positive and highly significant correlation with days required for harvest at both genotypic and phenotypic levels.

4.6 Path Analysis

The path analysis suggested by Deway and Lu (1959) was used to reveal the direct and indirect contribution of each character to yield. The path analysis on major yield contributing components was carried out to have a clear view of individual characters contribution to yield per hectare.

Among the phenotypic and genotypic correlation coefficients, genotypic correlation coefficients were used to work out path coefficients as these are more important than phenotypic correlation coefficients. The direct and indirect effects of 9 characters on yield per hectare were presented in Table 7.

4.6.1 Direct effects

In the present investigation, it was found that among the 9 traits under path analysis study average bulb diameter (0.7693) exhibited maximum direct effect on yield per hectare followed by average bulb length (0.6467) and days required for harvest (0.5920). All these traits have significant and positive correlation with yield per hectare.

Along with these desirable contributors, other characters viz; number of leaves per plant, plant height, average bulb weight, average weight of 10 cloves and number of cloves per bulb exhibited low positive direct effect on yield

Table 7. Direct (diagonal) and indirect effects for yield and yield components in garlic.

Character	Number of leaves / plant	Plant height (cm)	Neck thickness (cm)	Average bulb weight (g)	Average bulb length (cm)	Average bulb diameter (cm)	Average Weight of 10 cloves (g)	Number of cloves/ bulb	Days required for harvest	Correlation value of yield/ha at genotypic level
Number of leaves /plant	<u>0.2891</u>	0.0350	-0.3675	-0.1033	0.4150	0.1845	0.0204	-0.0719	-0.1764	0.2249
Plant height (cm)	0.0637	<u>0.1591</u>	-0.2952	-0.1585	0.0492	0.4316	0.0006	0.0483	0.2328	0.5316**
Neck thickness (cm)	0.1655	0.0732	<u>-0.6421</u>	-0.2185	0.4423	0.6262	0.0184	-0.0162	0.1811	0.6299**
Average bulb weight (g)	0.1190	-0.1995	-0.5590	<u>0.2510</u>	0.3897	0.7110	0.0136	0.0218	0.2418	0.9894**
Average bulb length (cm)	0.1855	0.0121	-0.4392	-0.1512	<u>0.6467</u>	0.3672	0.0182	-0.0407	-0.1827	0.4159**
Average bulb diameter (cm)	0.0693	0.0893	-0.5227	-0.2320	0.3087	<u>0.7693</u>	0.0113	0.0289	0.3165	0.8387**
Average weight of 10 cloves (g)	0.1717	0.0028	-0.3444	-0.0996	0.3431	0.2528	<u>0.0344</u>	-0.1083	0.0246	0.2771*
Number of Cloves per bulb	-0.1355	0.0502	0.0680	-0.0357	-0.1718	0.1449	-0.0243	<u>0.1533</u>	0.1481	0.1971
Days required for harvest	-0.0862	0.0626	-0.1965	-0.1025	-0.1996	0.4113	0.0014	0.0383	<u>0.5920</u>	0.5209**

Underlined and bold value denotes direct effect

Residual value (R) = 0.4362

per hectare. While, neck thickness (-0.6421) had negative direct effects on yield per hectare.

4.6.2 Indirect effects.

4.6.2.1 Number of leaves per plant

The indirect effects for number of leaves per plant via plant height, average bulb length, average bulb diameter and average weight of 10 cloves were positive, where as it had negative contribution through neck thickness, average bulb weight, number of cloves per bulb and days required for harvest.

4.6.2.2 Plant height (cm)

The indirect effects of plant height via number of leaves per plant, average bulb length, average bulb diameter, average weight of 10 cloves, number of cloves per bulb and days of required for harvest were positive, while the indirect effects via neck thickness and average bulb weight were negative.

4.6.2.3 Neck thickness (cm)

It had positive indirect effects via number of leaves per plant, plant height, average bulb length, average bulb diameter, average weight of 10 cloves and days required for harvest. It had negative indirect effects via average bulb weight and number of cloves per bulb.

4.6.2.4 Average bulb weight (g)

It had positive indirect effects via number of leaves per plant, average bulb weight, average length of bulb, average bulb diameter, average weight of 10 cloves, number of cloves per bulb and days required to harvest. It had negative indirect effects via neck thickness and plant height.

4.6.2.5 Average bulb length (cm)

The indirect effects of average bulb length via number of leaves per plant, plant height, average bulb diameter and average weight of 10 cloves were positive. It had negative indirect effects via neck thickness, average bulb weight, number of cloves per bulb and days required for harvest.

4.6.2.6 Average bulb diameter (cm)

It had positive indirect effects via number of leaves per plant, plant height, average bulb length, average weight of 10 cloves, number of cloves per bulb and days required for harvest. It had negative indirect effects via neck thickness and average bulb weight.

4.6.2.7 Average weight of 10 cloves (g)

The indirect effects of average weight of 10 cloves via number of leaves per plant, plant height, average bulb length, average bulb diameter and days required for harvest

were positive. It had negative indirect effects via neck thickness, average bulb weight and number of cloves per bulb.

4.6.2.8 Number of cloves per bulb (g)

It had positive indirect effects via plant height, neck thickness, average bulb diameter and days required for harvest. It had negative indirect effects via number of leaves per plant, average bulb weight, average bulb length and average weight of 10 cloves.

4.6.2.9 Days required for harvest

The indirect effects of days required for harvest via plant height, average bulb diameter, average weight of 10 cloves and number of cloves per bulb. It had negative indirect effects via number of leaves per plant, neck thickness, average bulb weight and average bulb length.

4.7 Genetic Divergence

The data generated on 45 genotypes for different characters was subjected to Mahalanobis D^2 statistics, to assess the divergence among lines used. The genetic distance recorded by 45 genotypes from one another are presented in Table 8.

4.7.1 Cluster formation

The clustering was done as per Tochers method, as suggested by Rao (1952). The 45 genotypes were grouped into seven clusters (Table 9). Cluster B comprises maximum number of genotypes (19), followed by cluster A (13), Cluster C (7) and cluster E (3). Cluster D, F, and G contain only one genotype each.

4.7.2 Intra- and inter- cluster distances

The intra and inter cluster distances were worked out by D^2 statistics. The mean D^2 values of cluster elements were used as measure of intra and inter cluster distances (Table 10).

The maximum intra cluster distance was found in cluster C ($D^2=155.75$) followed by cluster A ($D^2=99.00$), cluster B ($D^2=96.63$) and cluster E ($D^2=63.20$). The clusters D, F and G were monogenotypic and recorded the least value ($D^2=0$).

The maximum inter cluster distance of cluster A was observed with cluster G ($D^2=4725.18$) followed by cluster F ($D^2=1578.47$), cluster D ($D^2=520.29$) and cluster C ($D^2=339.66$).

Table 8. Value of D square

	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9	G-10	G-11
G-1	0.00	53.53	76.65	57.79	59.63	13.04	231.10	319.03	104.55	135.74	136.63
G-2	53.53	0.00	32.76	5.52	60.91	92.21	277.36	477.37	171.51	219.92	206.32
G-3	76.65	32.76	0.00	34.88	24.55	93.73	343.98	374.99	121.61	213.54	136.30
G-4	57.79	5.52	34.88	0.00	67.46	90.99	265.73	462.48	167.41	203.33	208.33
G-5	59.63	60.91	24.55	67.46	0.00	70.61	356.23	284.84	70.36	204.33	71.69
G-6	13.04	92.21	93.73	90.99	70.61	0.00	241.75	254.94	85.53	205.66	112.76
G-7	231.10	277.36	343.98	265.73	356.23	241.75	0.00	359.58	457.43	108.48	461.39
G-8	319.03	477.37	374.99	462.48	284.84	254.94	359.58	0.00	220.02	142.44	154.72
G-9	104.55	171.51	121.61	167.42	70.36	85.53	457.43	220.02	0.00	190.54	16.97
G-10	135.74	219.92	213.54	203.33	204.33	105.66	108.48	142.44	190.54	0.00	188.24
G-11	136.63	206.32	136.30	208.33	71.69	112.76	461.39	154.72	16.97	188.24	0.00
G-12	314.06	319.05	412.42	295.87	485.85	345.80	89.88	587.07	562.40	204.85	612.78
G-13	221.54	226.74	313.91	207.29	371.10	256.26	81.98	258.21	448.50	178.07	513.88
G-14	261.31	210.05	268.60	199.42	327.39	287.59	55.93	468.24	470.91	155.96	478.41
G-15	205.17	161.76	209.03	146.58	246.23	238.07	70.28	409.09	362.99	153.83	381.90
G-16	232.32	216.30	184.03	211.69	153.34	262.53	381.56	361.92	186.30	304.58	209.57
G-17	211.68	176.76	203.52	168.29	215.18	258.84	292.94	487.49	256.59	287.65	312.30
G-18	248.24	185.86	254.72	173.74	305.88	282.51	67.41	484.10	443.24	167.60	458.85
G-19	201.72	191.23	217.79	171.97	260.86	205.28	70.05	342.27	335.59	82.85	354.01
G-20	189.83	224.85	196.16	224.85	146.26	170.58	196.95	115.49	183.07	92.82	132.59
G-21	190.61	188.01	167.92	184.89	142.84	207.90	208.34	222.61	184.71	159.55	174.44
G-22	242.03	234.45	297.21	216.51	274.81	271.01	103.71	345.98	347.26	170.47	350.75
G-23	115.85	171.93	149.28	162.11	107.77	101.03	191.99	111.80	88.99	59.59	79.48
G-24	413.66	607.86	546.48	586.34	465.11	340.94	323.26	73.88	378.18	134.54	314.29

Table 8. continued

	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9	G-10	G-11
G-25	419.99	473.19	559.06	451.95	526.69	425.65	99.72	377.30	584.26	189.88	552.94
G-26	361.73	360.09	460.34	336.99	538.96	384.01	90.51	624.62	640.52	212.68	680.63
G-27	313.33	331.43	385.19	318.13	381.42	323.62	52.64	309.54	466.06	123.16	434.26
G-28	295.31	313.43	394.99	293.51	432.88	319.09	24.32	439.08	521.59	143.26	532.16
G-29	1693.5	1904.4	1722.3	1883.9	1518.2	1557.3	1517.9	695.82	1383.4	1179.8	1157.1
G-30	213.35	241.99	318.31	239.25	335.26	234.50	48.18	375.38	382.72	93.86	396.26
G-31	470.23	550.31	600.17	537.31	564.38	458.28	132.56	321.41	624.08	181.30	561.33
G-32	147.80	227.75	241.35	212.54	207.39	125.53	109.06	134.96	191.39	26.19	178.81
G-33	407.34	377.93	485.83	361.23	553.55	427.84	77.65	629.99	700.54	232.56	711.03
G-34	327.82	306.74	385.12	290.53	434.24	344.60	44.55	490.28	574.12	168.16	573.06
G-35	202.35	225.27	272.46	206.68	277.32	220.71	35.68	295.25	340.09	95.85	347.27
G-36	396.78	427.82	428.37	417.60	368.39	297.73	178.31	224.39	460.01	211.73	386.12
G-37	43.04	35.65	80.03	33.52	117.92	68.13	210.25	435.85	178.98	156.01	223.96
G-38	536.31	759.38	670.19	742.22	539.54	445.70	510.39	72.11	405.44	252.92	318.92
G-39	25.54	99.95	98.26	93.50	92.37	13.92	234.18	271.59	107.75	89.26	139.94
G-40	96.72	192.55	129.30	194.45	79.37	66.59	358.88	125.44	46.03	114.87	29.02
G-41	397.39	484.16	365.99	493.73	250.91	359.21	574.42	112.229	205.22	321.66	121.73
G-42	93.76	39.85	19.94	43.52	36.92	125.78	412.22	469.30	144.67	305.61	175.56
G-43	254.31	219.87	310.61	203.53	328.96	292.33	74.20	466.22	429.23	178.26	449.70
G-44	196.65	317.96	255.27	307.00	189.63	143.17	260.28	37.56	132.13	61.16	100.80
G-45	5070.7	5171.0	4749	5215.9	4313.0	4941.6	5438.5	3644.1	4215.7	4869.8	3850.9

Table 8. continued

	G-12	G-13	G-14	G-15	G-16	G-17	G-18	G-19	G-20	G-21	G-22	G-23
G-1	314.06	221.54	261.31	205.17	232.32	211.68	248.24	201.72	189.83	190.61	242.03	115.85
G-2	319.05	226.74	210.05	161.76	216.30	176.76	185.86	191.23	224.85	188.01	234.45	171.93
G-3	312.42	313.91	268.60	209.03	184.03	203.52	254.72	217.79	196.16	167.92	297.21	149.28
G-4	295.87	207.29	199.42	146.58	211.69	168.29	173.74	171.97	224.855	184.89	216.51	162.11
G-5	485.85	371.10	327.39	246.23	153.34	215.18	305.88	260.86	146.26	142.84	274.81	107.77
G-6	345.80	256.26	287.59	238.07	265.53	258.84	282.51	205.28	170.58	207.90	271.01	101.03
G-7	89.88	81.98	55.93	70.28	381.56	292.94	67.41	70.05	196.95	208.34	103.71	191.99
G-8	587.07	548.21	468.24	409.09	361.92	487.49	484.10	342.27	115.49	222.61	345.98	111.80
G-9	562.40	448.50	470.91	362.99	186.30	256.59	443.24	335.59	183.03	184.71	347.26	88.99
G-10	204.85	178.07	155.96	153.83	304.58	287.65	167.60	82.85	92.82	159.55	170.47	59.59
G-11	612.78	513.88	478.41	381.90	209.57	312.30	458.85	354.01	132.59	174.44	350.75	79.48
G-12	0.00	25.66	80.49	102.91	457.23	259.14	95.93	84.49	408.40	307.56	195.36	307.15
G-13	25.66	0.00	77.56	68.86	329.77	170.75	76.44	67.37	354.59	237.44	156.06	248.60
G-14	80.49	77.56	0.00	31.56	342.34	233.94	7.73	29.69	216.79	187.18	107.09	212.35
G-15	102.91	68.86	31.56	0.00	194.71	118.70	19.30	39.42	183.20	96.04	51.95	147.46
G-16	457.23	329.77	342.34	194.71	0.00	56.35	297.78	260.85	231.42	49.95	196.23	134.38
G-17	259.14	170.75	233.94	118.70	56.35	0.00	197.54	177.39	307.50	83.18	154.37	166.14
G-18	95.93	76.44	7.73	19.30	297.78	197.54	0.00	35.57	208.66	163.71	76.93	199.45
G-19	84.49	67.37	29.69	39.42	260.85	177.39	35.57	0.00	174.97	134.98	104.76	127.84
G-20	408.40	354.59	216.79	183.20	231.42	307.50	208.66	174.97	0.00	95.02	139.84	47.12
G-21	307.56	237.44	187.18	96.04	49.95	83.18	163.71	134.98	95.02	0.00	89.35	50.78
G-22	195.36	156.06	107.09	51.95	196.23	154.37	76.93	104.76	139.84	89.35	0.00	117.42
G-23	307.15	248.60	212.35	147.46	134.38	166.14	199.45	127.84	47.12	50.78	117.42	0.00
G-24	553.56	548.79	479.98	477.56	596.95	678.52	508.48	377.44	186.52	381.58	406.49	212.52

Table 8. continued

	G-12	G-13	G-14	G-15	G-16	G-17	G-18	G-19	G-20	G-21	G-22	G-23
G-25	234.94	260.83	167.74	194.10	537.48	468.70	167.48	192.63	211.42	302.51	109.87	251.94
G-26	22.21	59.16	69.19	135.71	566.55	363.26	92.72	84.79	419.37	379.34	227.84	353.69
G-27	153.92	175.29	70.90	94.34	391.70	327.16	78.44	89.81	139.64	182.92	70.20	165.92
G-28	43.68	67.16	51.00	69.76	426.98	294.48	60.98	73.14	261.59	238.68	111.48	233.64
G-29	2093.9	2101.3	1722.8	1692.7	1685.7	2044.5	1735.5	1620.7	883.44	1344.6	1423.3	1143.9
G-30	69.97	67.92	59.98	80.54	338.44	226.46	64.76	54.53	196.80	178.00	105.55	155.60
G-31	325.73	359.41	221.32	278.38	641.66	617.67	238.18	241.27	200.12	364.08	214.39	288.13
G-32	226.82	206.04	164.33	141.21	279.40	265.55	162.12	100.94	63.84	125.70	106.54	38.15
G-33	91.75	128.51	50.27	137.47	619.94	449.45	69.76	104.99	357.59	392.75	202.10	371.53
G-34	87.49	110.03	22.29	81.46	482.74	356.17	36.97	58.54	253.97	276.96	132.74	267.11
G-35	93.22	76.86	60.70	28.54	229.07	161.24	54.62	50.04	147.82	98.38	36.59	108.31
G-36	425.30	402.90	233.17	202.26	356.93	426.41	224.34	248.20	87.69	174.54	118.18	180.20
G-37	218.22	157.41	190.50	150.12	274.40	193.05	179.29	161.55	240.60	210.68	235.35	161.25
G-38	815.11	790.42	690.83	655.00	660.37	813.34	705.84	554.67	227.51	453.01	522.40	269.49
G-39	308.79	227.55	267.86	238.03	293.84	276.16	269.92	185.94	193.66	234.29	290.26	118.84
G-40	519.81	433.35	406.96	347.38	271.94	356.13	404.95	296.17	117.75	201.61	350.54	82.72
G-41	864.89	768.42	625.53	512.32	282.88	492.81	605.79	511.84	130.80	206.38	418.84	165.53
G-42	465.10	346.19	331.45	237.91	156.47	169.51	303.74	277.75	271.20	183.94	318.80	194.19
G-43	101.87	83.18	44.71	33.56	279.75	172.65	26.51	64.53	210.66	153.80	29.45	178.96
G-44	446.34	387.52	332.94	290.57	273.10	355.45	339.11	220.25	63.15	157.54	249.08	47.30
G-45	6493.5	6229.4	5562.9	5212.2	4193.1	5105.6	5458.9	5392.4	3799.9	4156.4	4712.3	4218.5

Table 8. continued

	G-24	G-25	G-26	G-27	G-28	G-29	G-30	G-31	G-32	G-33	G-34
G-1	413.66	419.99	361.73	313.33	295.31	1693.5	213.35	470.23	147.80	407.34	327.82
G-2	607.86	473.19	360.09	331.43	313.43	1904.4	241.99	550.31	227.75	377.93	306.74
G-3	546.48	559.06	460.34	385.19	394.99	1722.3	318.31	600.17	241.35	485.83	385.12
G-4	586.34	451.95	336.99	318.13	293.51	1883.9	239.25	537.31	212.54	361.23	290.53
G-5	465.11	526.69	538.96	381.42	432.88	1518.2	335.26	564.38	207.39	553.55	434.24
G-6	340.94	425.65	384.01	323.62	319.09	1557.3	234.50	458.28	125.53	427.84	344.60
G-7	323.26	99.72	90.51	52.64	24.32	1517.9	48.18	132.56	109.06	77.65	44.55
G-8	73.88	377.30	624.62	309.54	439.08	695.82	375.38	321.41	134.96	629.99	490.28
G-9	378.18	584.26	640.52	466.06	521.59	1383.4	382.72	624.08	191.39	700.54	574.12
G-10	134.54	189.88	212.68	123.16	143.26	1179.8	93.86	181.30	26.19	232.56	168.16
G-11	314.29	552.94	680.63	434.26	532.16	1157.1	396.26	561.33	178.81	711.03	573.06
G-12	553.56	234.94	22.21	153.92	43.68	2093.9	69.97	325.73	226.82	91.75	87.49
G-13	548.79	260.83	59.16	175.29	67.16	2101.3	67.90	359.41	206.04	128.51	110.03
G-14	479.98	167.74	69.19	70.90	51.00	1722.8	59.98	221.32	164.33	50.27	22.29
G-15	477.56	194.10	135.71	94.34	69.76	1692.7	80.54	278.38	141.21	137.47	81.46
G-16	596.95	537.48	566.55	391.70	426.98	1685.8	338.44	641.66	279.40	619.94	482.74
G-17	678.52	468.70	363.26	327.16	294.48	2044.5	226.46	617.67	265.55	449.45	356.17
G-18	508.48	167.48	92.72	78.44	60.98	1735.5	64.76	238.18	162.12	69.76	36.97
G-19	377.44	192.63	84.79	89.81	73.14	1620.69	54.53	241.27	100.94	104.99	58.54
G-20	186.52	211.42	419.37	139.64	261.59	883.44	196.80	200.12	63.84	357.59	253.97
G-21	381.58	302.51	379.34	182.92	238.68	1344.6	178.00	364.08	125.70	392.75	276.96
G-22	406.49	109.87	227.84	70.20	111.48	1423.3	105.55	214.39	106.54	202.10	132.74
G-23	212.52	251.94	353.69	165.92	233.64	1143.9	155.60	288.13	38.15	371.53	267.11
G-24	0.00	282.16	554.59	278.05	386.21	631.50	343.83	191.48	152.48	539.99	446.84

Table 8. continued

	G-24	G-25	G-26	G-27	G-28	G-29	G-30	G-31	G-32	G-33	G-34
G-25	282.16	0.00	210.21	32.24	98.78	1165.5	120.22	40.73	137.09	141.43	111.36
G-26	554.59	210.21	0.00	141.56	53.11	2061.9	77.28	278.66	242.35	38.03	49.26
G-27	278.05	32.24	141.56	0.00	50.54	1234.9	60.54	63.69	89.76	94.62	51.31
G-28	386.21	98.78	53.11	50.54	0.00	1630.8	42.20	150.91	138.47	58.29	37.53
G-29	631.50	1165.5	2061.9	1234.9	1630.8	0.00	1596.1	939.91	1095.3	1838.3	1653.3
G-30	343.83	120.22	77.28	60.54	42.20	1596.11	0.00	164.46	95.35	93.15	66.99
G-31	191.48	40.73	278.66	63.69	150.91	939.91	164.46	0.00	157.21	188.52	152.05
G-32	152.48	137.09	242.35	89.76	138.47	1095.3	95.35	157.21	0.00	241.11	166.38
G-33	539.99	141.43	38.03	94.62	58.29	1838.3	93.15	188.52	241.11	0.00	13.69
G-34	446.84	111.36	49.26	51.31	37.53	1653.3	66.99	152.05	166.38	13.69	0.00
G-35	319.02	107.18	128.95	46.49	35.92	1452.3	47.19	173.47	74.03	138.36	80.40
G-36	241.68	110.27	432.04	91.17	222.77	823.12	236.82	109.33	153.00	328.21	233.44
G-37	509.97	415.08	270.59	290.81	226.57	1875.0	180.73	484.20	172.99	318.01	263.57
G-38	44.01	421.70	824.37	426.66	599.32	438.23	523.69	317.82	233.78	788.87	660.08
G-39	323.38	416.51	337.50	315.48	298.09	1597.3	215.67	438.28	137.88	393.16	322.74
G-40	219.19	480.76	565.32	371.89	437.89	1133.0	324.18	450.76	139.83	593.41	476.42
G-41	290.41	580.63	931.61	478.11	673.38	697.50	548.51	533.38	275.87	890.96	712.12
G-42	695.47	654.47	535.36	470.09	466.74	1952.4	387.62	737.54	311.41	577.44	465.53
G-43	487.28	111.57	112.74	61.28	62.05	1692.5	59.00	220.68	141.07	97.91	62.86
G-44	90.94	302.77	470.87	236.22	337.34	879.70	245.70	275.89	69.83	476.14	366.32
G-45	4164.9	5022.9	6609.4	4963.5	5759.1	2199.2	5537.1	4810.2	4598.0	6209.5	5742.5

Table 8. continued

	G-35	G-36	G-37	G-38	G-39	G-40	G-41	G-42	G-43	G-44	G-45
G-1	202.35	396.78	43.04	536.31	25.54	96.72	397.39	93.76	254.31	196.65	5070.7
G-2	225.27	427.82	35.65	759.38	99.95	192.55	484.16	39.85	219.87	317.96	5171.0
G-3	272.46	428.37	80.03	670.19	98.26	129.30	365.99	19.94	310.61	255.27	4749.0
G-4	206.68	417.60	33.52	742.22	93.50	194.45	493.73	43.52	203.53	307.00	5215.9
G-5	277.32	368.39	117.92	539.54	92.37	79.37	250.91	36.92	328.96	189.63	4313.0
G-6	220.71	397.73	68.13	445.70	13.92	66.59	359.21	125.78	292.33	143.17	4941.6
G-7	35.68	178.31	210.25	510.39	234.18	358.88	574.42	412.22	74.20	260.28	5438.5
G-8	295.25	224.39	435.85	72.11	271.59	125.44	112.29	469.30	466.22	37.56	3644.1
G-9	340.04	460.01	178.98	405.44	107.75	46.03	205.22	144.67	429.23	132.13	4215.6
G-10	95.85	211.73	156.01	252.92	89.26	114.87	321.66	305.61	178.26	61.16	4869.8
G-11	347.27	386.12	223.96	318.92	139.94	29.02	121.73	175.56	449.70	100.80	3850.9
G-12	93.22	425.30	218.22	815.11	308.79	519.81	864.89	465.10	101.87	446.34	6493.5
G-13	76.86	402.90	157.41	790.42	227.55	433.35	768.42	346.19	83.18	387.52	6229.4
G-14	60.70	233.17	190.50	690.83	267.86	406.96	625.53	331.45	44.71	332.94	5562.9
G-15	28.54	202.26	150.12	655.00	238.03	347.38	512.32	237.91	33.53	290.57	5212.2
G-16	229.07	359.93	274.40	660.37	293.84	271.94	282.88	156.47	279.75	273.10	4193.1
G-17	161.24	426.41	193.05	813.34	276.16	356.13	492.81	169.51	172.65	355.45	5105.6
G-18	54.62	224.34	179.29	705.84	269.92	404.95	605.79	303.74	26.51	339.11	5458.9
G-19	50.04	248.20	161.55	554.67	185.94	296.17	511.84	277.75	64.53	220.25	5392.4
G-20	147.82	87.69	240.60	227.51	193.66	117.75	130.80	271.20	210.66	63.15	3799.9
G-21	98.38	174.54	210.68	453.01	234.29	216.61	206.38	183.94	153.80	157.54	4156.4
G-22	36.59	118.18	235.35	522.40	290.26	350.54	418.84	318.80	29.45	249.08	4712.3
G-23	108.31	180.20	161.25	269.49	118.84	82.72	165.53	194.19	178.96	47.30	4218.5
G-24	319.02	241.68	509.97	44.01	323.38	219.19	290.41	695.47	487.28	90.94	4164.9

Table 8. continued

	G-35	G-36	G-37	G-38	G-39	G-40	G-41	G-42	G-43	G-44	G-45
G-25	107.18	110.27	415.08	421.70	416.51	480.76	580.63	654.47	111.57	302.77	5022.9
G-26	128.95	432.04	270.59	824.37	337.50	565.32	931.61	535.36	112.74	470.87	6609.4
G-27	46.49	91.17	290.81	426.66	315.48	371.89	478.11	470.09	161.28	236.22	4963.5
G-28	35.92	222.77	226.57	599.32	298.09	437.89	673.38	466.74	62.05	337.34	5759.1
G-29	1452.3	823.12	1875.0	438.23	1597.3	1133.0	697.50	1952.4	1692.5	879.70	2199.2
G-30	47.19	236.82	180.73	523.69	215.67	324.18	548.51	387.62	59.00	245.70	5537.0
G-31	173.47	109.33	484.20	317.82	438.28	450.76	533.38	737.54	220.68	275.89	4810.2
G-32	74.03	153.00	172.99	233.78	137.88	139.83	275.87	311.41	141.07	69.83	4598.0
G-33	138.36	328.21	318.01	788.87	393.16	593.41	890.96	577.44	97.91	476.14	6209.5
G-34	80.40	233.44	263.57	660.08	322.74	476.42	712.12	465.53	62.86	366.32	5742.5
G-35	0.00	141.95	175.99	474.06	220.51	300.42	446.49	318.29	38.73	210.30	5081.7
G-36	141.95	0.00	434.48	307.83	415.70	353.15	279.40	511.97	198.45	209.33	3831.4
G-37	175.99	434.48	0.00	681.69	70.06	180.83	527.98	104.14	207.69	287.72	5511.3
G-38	474.06	307.83	681.69	0.00	460.75	264.33	214.40	810.56	664.11	123.64	3515.7
G-39	220.51	415.70	70.06	460.75	0.00	73.61	411.84	149.45	288.85	149.76	5185.0
G-40	300.42	353.15	180.83	264.33	73.61	0.00	168.54	196.75	420.40	68.66	4171.2
G-41	446.49	279.40	527.98	214.40	411.84	168.54	0.00	426.74	591.60	136.82	2806.4
G-42	318.29	511.97	104.14	810.56	149.45	196.75	426.74	0.00	343.71	343.22	4815.1
G-43	38.73	198.45	207.69	664.11	288.85	420.40	591.60	343.71	0.00	327.85	5373.9
G-44	210.30	209.33	287.72	123.64	149.76	68.66	136.82	343.22	327.85	0.00	3980.5
G-45	5081.7	3831.4	5511.3	3515.7	5185.0	4171.2	2806.4	4815.1	5373.9	3980.5	0.00

Cluster G was farthest from Cluster B ($D^2=5487.84$), which was followed by cluster F ($D^2=1605.60$) and cluster C ($D^2=392.04$). The maximum inter cluster distance of cluster C was observed with cluster G ($D^2=3677.20$) followed by cluster F ($D^2=721.46$), cluster E ($D^2=381.81$) and cluster D ($D^2 = 278.55$). The maximum inter cluster G ($D^2=4809.42$) followed by cluster F ($D^2=940.03$) and cluster E ($D^2=541.02$). Cluster G was farthest from cluster E ($D^2=4484.98$) followed by cluster F ($D^2=1691.67$). Cluster F was farthest from cluster G ($D^2=2198.67$). Cluster G had maximum inter cluster distance from cluster B ($D^2=5487.84$) which was highest for any other inter cluster distances.

4.8 Cluster means

The cluster means for different characters studied was given in Table 11.

4.8.1 Number of leaves per plant

The cluster mean for this trait was the highest in cluster G (9.70) followed by cluster D (9.30), cluster C (8.84) and cluster F (8.80). While, cluster B had minimum value (8.00) followed by cluster E (8.06).

4.8.2 Plant height (cm)

The genotypes in cluster E (47.03) recorded the lowest value for this character followed by cluster A (48.90).

The genotypes in cluster D (55.30) recorded the highest value followed by cluster B (52.66), cluster F (52.20) and cluster G (52.10).

4.8.3 Neck thickness (cm)

Very narrow range of variation was observed for this character. Neck thickness of cluster F (1.09) was the highest followed by cluster G (1.08) and cluster C (1.01). Cluster E recorded the lowest value (0.79) followed by cluster A (0.80).

4.8.4 Average bulb weight (g)

Cluster mean of cluster F (40.50) was the highest for average bulb weight followed by cluster D (33.90) and cluster C (28.92). Cluster A (18.46) recorded lowest value followed by cluster E (19.60).

4.8.5 Average bulb length (cm)

The cluster F (4.16) has a maximum average bulb length followed by cluster C (3.54) and cluster G (3.51). Cluster E (2.82) has smallest average bulb length followed by cluster B (2.97).

4.8.6 Average bulb diameter (cm)

The cluster F (5.07) recorded the highest cluster mean followed by cluster C (4.07) and cluster D (4.06). Cluster

A (3.50) observed the lowest average bulb diameter followed by cluster E (3.68) and cluster G (3.90).

4.8.7 Average weight of 10 cloves (g)

The cluster mean of cluster G (33.70) was the highest for average weight of 10 cloves followed by cluster F (22.20). Cluster B (9.42) recorded the lowest cluster mean followed by cluster A (10.27) and cluster E (10.46).

4.8.8 Number of cloves per bulb

The cluster G (5.50) had the lowest number of cloves per bulb followed by cluster E (16.26). The highest cluster mean was recorded for cluster D (23.90) followed by cluster B (22.37) and cluster F (19.90).

4.8.9 Yield per plot (kg)

The cluster mean for yield per plot was maximum in cluster F (11.77) followed by cluster D (11.12). The lowest cluster mean was observed in cluster A (6.13) followed by cluster E (7.24) and cluster G (7.30).

4.8.10 Yield per hectare (q)

Wide range was observed for this trait. The yield per hectare ranged between 102.3 (cluster A) and 196.28 (cluster F). The remaining clusters had intermediate values of this trait.

Table 9. Distribution of 45 genotypes of garlic in a 7 clusters.

Cluster	Genotype number	No. of genotypes
A	G-2	13
	G-4	
	G-3	
	G-42	
	G-5	
	G-1	
	G-37	
	G-6	
	G-39	
	G-9	
	G-40	
	G-23	
	G-11	
B	G-14	19
	G-18	
	G-15	
	G-19	
	G-43	
	G-35	
	G-34	
	G-28	
	G-7	
	G-30	
	G-27	
	G-22	
	G-13	
	G-12	
	G-26	
	G-33	
	G-25	
	G-32	
	G-10	
C	G-8	7
	G-44	
	G-24	
	G-38	
	G-20	
	G-41	
	G-36	
D	G-31	1
E	G-16	3
	G-21	
	G-17	
F	G-29	1
G	G-45	1

Table 10. Average intra and inter cluster D² and D values.

	A	B	C	D	E	F	G
A	99.00 (9.95)	317.20 (17.81)	339.66 (18.43)	520.29 (22.81)	207.07 (14.39)	1578.47 (39.73)	4725.18 (68.74)
B		96.63 (9.83)	392.04 (19.80)	199.04 (14.11)	277.22 (16.65)	1605.60 (40.07)	5487.84 (74.08)
C			155.75 (12.48)	278.55 (16.69)	381.81 (19.54)	721.46 (26.86)	3677.20 (60.64)
D				0.00 (0.00)	541.02 (23.26)	940.03 (30.66)	4809.42 (69.35)
E					63.20 (7.95)	1691.67 (41.13)	4484.98 (66.97)
F						0.00 (0.00)	2198.67 (46.89)
G							0.00 (0.00)

* Figure in the parenthesis indicates D values.

4.8.11 Days required for harvest

The genotypes in cluster D,E and G showed maximum cluster mean (127.00) while, the genotypes in cluster A (117.46) showed the lowest cluster mean for days required for harvest followed by cluster F (123.00) and cluster C (123.57).

Table 11. Mean performance of seven clusters for various characters in garlic.

Characters/ clust- er	Number of leaves / plant	Plant height (cm)	Neck thick- ness (cm)	Average bulb weight (g)	Average bulb length (cm)	Average bulb diameter (cm)	Average Weight of 10 cloves (g)	Number of cloves/ bulb	Yield/ plot (kg)	Yield/ ha (q)	Days required for harvest
	1	2	3	4	5	6	7	8	9	10	11
A	8.53	48.90	0.80	18.46	3.18	3.50	10.27	18.98	6.13	102.31	117.46
B	8.00	52.66	0.88	24.01	2.97	3.97	9.42	22.37	8.49	141.58	126.57
C	8.84	50.51	1.01	28.92	3.54	4.07	13.80	19.40	8.89	148.29	123.57
D	9.30	55.30	0.91	33.90	3.19	4.06	12.00	23.90	11.12	185.45	127.00
E	8.06	47.03	0.79	19.60	2.82	3.68	10.46	16.26	7.24	120.71	127.00
F	8.80	52.20	1.09	40.50	4.16	5.07	22.20	19.90	11.77	196.28	123.00
G	9.70	52.10	1.08	24.85	3.51	3.90	33.70	5.50	7.30	121.68	127.00

5. DISCUSSION

Success of any breeding programme will mainly depend on available variability and intensity of selection imposed. Various analytical techniques of statistics help to assess the available variability. Genotypic and phenotypic coefficient of variation allows to estimate the extent of variability present in material under investigation, while heritability suggest the relative role of genetic factors in expression of phenotypes (Falconer, 1960) and also acts as an index of transmissibility of particular trait to it's offspring. However, knowledge of heritability alone does not help in formulating concrete breeding programme. Genetic advance along with heritability will help to ascertain the possible genetic control for any particular trait. All these genetic parameters suggest breeding path to be adopted, whereas the association analysis and path coefficient explain the nature of dependency of yield and yield contributing characters on each others. The D² statistics and clustering helps to search out genetical diverse types for hybridization programme.

The present investigation, entitled, "Genetic Variability and Path analysis studies in garlic (*Allium sativum* L.)" attempts were made to study the variability for 11 different quantitative characters among the 45 genotypes, the association between the dependent and independent variables along with their direct and indirect effects and also genetic diversity among

them. The results obtained were discussed in this chapter, under the appropriate sub-headings:

5.1 Estimates of variability and genetic parameters

5.1.1 Variability

The assessment of available germplasm for its nature and magnitude of genetic variability is an important pre-requisite for breeding new variety with the desired physical and biochemical characteristics along with high yield potential. This helps the breeder to assess and identify superior genotypes before initiating the breeding programme for improvement of any crop.

In the present investigations, involving 45 garlic genotypes, a wide range of variability was observed in respect of number of cloves per bulb, plant height, average bulb weight yield per hectare and yield per plot and also in other characters which indicated a profound scope for its exploitation. These observations are in agreement with those reported by Korla et al. (1981), Contis and Ferraresi (1974), Mehta and Patel (1985), Vijay (1990), Thakur et al. (1997), Kohli and Prabal (2000), and Khar et al. (2005)

5.1.2 Genotypic and phenotypic coefficients of variation

The genotypic coefficient of variation (GCV) was lower than the phenotypic coefficient of variation (PCV) for the 10 characters except days required for harvest (Table 5) indicating the predominant role of environment in the expression of the traits studied.

The higher genotypic and phenotypic coefficients of variation were observed for the average weight of 10 cloves, average bulb weight, yield per plot and yield per hectare. Thus, these characters can be improved through selection.

These results confirmed the findings of Shaha et al. (1990), Killadi et al. (2000), Dubey et al. (2010) for average weight of 10 cloves, Trivedi et al. (2006), Hayder et al. (2007) for average bulb weight. The results of yield per plot and yield per hectare are in agreement with those obtained by Mehta and Patel (1985), Godhani and Singh (2000), Shridhar (2000) and Singh et al. (2010).

The genotypic as well as phenotypic coefficients were moderate to lower for other remaining characters viz; number of cloves per bulb, neck thickness, average bulb diameter, number of leaves per plant, plant height, average bulb length and days required for harvest. These results are in close agreement with those obtained by Godhani and Singh (2000), Mohanty and Das (2000) and Singh et al. (2010), suggesting little role of

environment in expression of these traits and one may rely on mean phenotypic values for direct selection.

5.1.3 Heritability and genetic advance

The genotypic coefficient of variation gives little idea of the total variation that is heritable. The relative amount of heritable portion of variation can be assessed through suitable heritability estimates. Swarup and Chaugule (1962) suggested that, the genotypic coefficient of variation is not sufficient to determine the amount of variation which is heritable. Burton (1951) suggested that, the heritable variation cannot be estimated through genotypic coefficient of variation and as such the genotypic coefficient of variation together with heritability would furnish the most reliable information.

Johnson et al. (1955) cautioned that both the heritability value and the genetic advance could be considered more than heritability alone. According to Hanson et al. (1956) heritability and genetic advance are two complementary concepts while making selection. The character with high heritability when associated with high genetic gain may be attributed to the additive gene effects (Panse, 1957), which can easily be improved by selection. On the other hand, high heritability and low genetic advance may be attributed to the non-additive gene action. These characters may be improved through hybridization, while low heritability estimates suggest that selection for the character under consideration will not be effective. In the light of this

explanation, heritability was calculated to assist the breeder in choosing the character that can be relied upon for selection.

In the present study most of the traits showed very high estimates of heritability. The high estimates of heritability was observed for days required for harvest (100.00), average weight of 10 cloves (99.09) and number of cloves per bulb (97.07). Evidently, it is possible to improve these characters through proper selection. The results obtained in the present study were in close agreement with those reported by Singh (1981), Mehta and Patel (1985), Godhani and Singh (2000), Killadi et al. (2000), Dubey et al. (2010) and Singh et al. (2010). Similar findings were also reported by Korla et al. (1981) and Shridhar (2000) in respect of number of cloves per bulb.

In the present study, the characters viz., yield per hectare, average bulb weight, average weight of 10 cloves and days required for harvest had high values for percentage genetic advance coupled with high heritability values. This is in conformity with the findings of Khar et al. (2005), Dubey et al. (2010) for yield per hectare. Singh (1981), Ghetia and Singh (2000), Kohli and Prabal (2000) and Jabeen et al. (2010) for average bulb weight and Godhani and Singh (2000) for days required for harvest. High heritability with low percentage of genetic advance for neck thickness, average bulb diameter, average bulb length and number of leaves per plant indicated the importance of non-additive gene action and therefore direct selection may not be effective for these traits. These results

confirmed with the findings of Ghetia and Singh (2000) and Dubey et al. (2010).

5.2 Correlation studies

The knowledge of inter relationship among the characters is useful to the breeder for improving the efficiency of selection. The correlations among the various characters are of interest for the three reasons, viz., first in connection with the changes brought about by selection which is important to know how the improvement of one character causes simultaneous changes in other character, second, in connection with natural selection and third, in connection with the genetic cause of correlation (Falconer, 1960).

In the present investigations, the estimates of genotypic correlations in general, were slightly higher than phenotypic correlations, showing the little masking effects of the environment on the full expression of the characters under study (Nandapuri et al. 1973). However, in general the genotypic correlations were very high for most of the characters indicating that, the role of environment was limited in expression of these traits (Table 6).

The most important traits, yield per plot and yield per hectare showed positive and significant correlation with days required for harvest, average weight of 10 cloves, average bulb diameter, average bulb length, average bulb weight, neck thickness and plant height. It also showed positive correlation

with number of leaves per plant at both genotypic and phenotypic levels. Similar results were reported by Kalloo et al. (1982), Netrapal et al. (1988), Kohli and Fageria (1992), Shrivastava et al. (1993), Thakur et al. (1997), Agarwal and Tiwari (2000), Godhani and Singh (2000), Killadi et al. (2000), Kohli and Prabal (2000), Mohanty and Das (2000), Raghuram et al. (2000), Sarangmath et al. (2000), Khar et al. (2005), Gurjar and Singhania (2006), Trivedi et al. (2006), Hayder et al. (2007), Dubey et al. (2010) and Singh et al. (2010).

In the present investigations average bulb weight was positively and significantly correlated with number of leaves per plant, plant height, neck thickness, average bulb diameter, average weight of 10 cloves, average bulb length and days required for harvest. This was in agreement with findings of Zhila (1981), Singh (1981), Lokhande and Pawar (1988), Shrivastava et al. (1993), Kohli and Prabal (2000), Shridhar (2000) and Hayder et al. (2007). However, it showed positive correlation with number of cloves per bulb at both genotypic and phenotypic levels. This was in agreement with findings of Singh (1981) and Shrivastava et al. (1993).

In the present investigations plant height was positively and significantly correlated with neck thickness and average bulb diameter. The results of present study conforms the findings of Selvaraj et al. (1997) and Hayder et al. (2007). However, it showed positive correlation with number of leaves per plant and number of cloves per bulb. This was in accordance

with those obtained by Shaha et al. (1990), Kohil and Fageria (1992) and Godhani and Singh (2000).

In the present investigations average bulb diameter showed positive correlation with average bulb length, average weight of 10 cloves and number of cloves per bulb. These results were in agreement with the findings of Shaha et al. (1990).

In addition high and positive inter correlationship was observed between yield components both at genotypic and phenotypic levels. Thus it can be inferred that selection based on any one of these characters either alone or in combination would result in identifying the genotypes with high yield. These results are in agreement with the findings of Suthanthirapandian and Muthukrishnan (1980) in onion.

5.3 Path analysis

Correlation coefficient appears to be inadequate measure in selection as it does not provide sufficient information to decide the breeding procedure to be adopted or making simultaneous selection for crop improvement. Therefore, the path coefficient analysis as proposed by Dewey and Lu (1959) was adopted to estimate the direct and indirect contributions.

Correlation coefficient along with their path coefficient reveals about the selection strategy to be followed. If correlation between casual factor and direct effect is more or less of equal magnitude, it explains true and perfect relationship between the

characters and direct selection through these traits would be effective. However, if the correlation coefficient is positive and direct effect is negative or negligible then the direct casual factors were to be considered in simultaneous selection (Singh and Kaker, 1977). The information about characters and their relative importance could also be judged by path coefficient analysis.

In the present investigation, among the 9 traits under path analysis study, it was observed that, the average bulb diameter exhibited maximum direct effect on yield per hectare followed by average bulb length and days required for harvest. Similar findings were reported by Rahman and Das (1985). All these traits have significant and positive correlation with yield per hectare, indicate the true relationship between them and suggested direct selection base on this may help in improving yield.

Along with these desirable contributors, other characters viz., number of leaves per plant, plant height, average bulb weight, average weight of 10 cloves and number of cloves per bulb exhibited low positive direct effects on yield per hectare while, neck thickness had negative direct effects on yield per hectare. This character may be contributing indirectly to some other trait.

5.4 Genetic divergence

The most important and difficult task in initiation of hybridization programme by selecting genotypes with high performance for yield and yield contributing components with suitable genetic divergence among them. From the genetic variability estimates it would be possible to identify desirable genotypes but unless we have sound knowledge about divergence between them.

D^2 statistics, a concept developed by Mahalanobis (1936) is important tool to plant breeder. It is useful in quantifying degree of divergence between biological population at genotypic level and to assess the relative contribution of different components to the total divergence at both, intra-and inter-cluster levels. Rao (1952), suggested the application of this technique for the assessment of genetic diversity in plant breeding.

5.4.1 Clusters, intra-and inter-cluster distance and mean performance

The basic idea behind formation of clusters was to get the intra-and inter-cluster distances. This serves as index for selection of parents with diverse origin. The intra- and inter-cluster values were means derived from D^2 values of cluster elements. The crossing between the genotypes placed in the clusters with large inter-cluster distance would prove to be a more correct approach to get desirable results.

The genotypes G-45 and G-26 were genetically distances as they show maximum D^2 value (6609.44) between them and were placed in different clusters, while G-4 and G-2 were most closely related ($D^2 = 5.52$) and placed in same clusters (Table 8). This indicated the relationship between genotypes, individual distances from each other with clustering pattern.

The seven different clusters formed in the present study indicated that, the available genotypes possess variability for different characters under study. The cluster B was largest with 19 genotypes followed by cluster A, C and E with 13, 7 and 3 genotypes, respectively. Clusters D, F and G were monogenotypic. There findings were similar to those recorded by Shaha (1985) 14 clusters and Khar et al. (2006) 6 clusters.

Genotypes falling in cluster C exhibited maximum intra-cluster distance (Table 10), while genotypes falling in clusters D, F and G were monogenotypic and recorded the least value ($D^2 = 0$). This implies that, the cluster C has the genotype with varied genetic architecture while, genotypes of clusters D, F and G were genetically resembling to each other and might have came from common gene pool. The cluster G and B recorded maximum inter-cluster distance (5487.84) indicating that, the genetic make up of genotypes falling in this cluster may be entirely different form one another. Cluster D and B exhibited lowest inter-cluster distance (199.09) suggesting that, the genotypes in the clusters were the genetically very close to each other. The cluster D, F and G were monogenotypic. These results

were in close agreement with those reported by Khar et al. (2006).

The highest cluster mean for yield per hectare (196.28) recorded by cluster F and appeared to be due to contribution of component character viz., average bulb weight (40.50), average weight of 10 cloves (22.20), number of cloves per bulb (19.90), number of leaves per plant (8.80) and average bulb diameter (5.07). The yield per hectare of cluster D (185.45) and cluster C (148.29) were next to cluster F as they had maximum average bulb weight i.e. 33.90 and 28.92 respectively and maximum average bulb diameter i. e. 4.06 and 4.07 respectively.

5.4.2 Relative contribution of characters towards divergence

In present investigation character average weight of 10 cloves showed maximum (36.46%) contribution to divergence followed by number of cloves per bulb (26.77%), days required for harvest (17.37%) and average bulb length (14.34%) indicating that these characters considerably responsible for total divergence in the material under study (Table 12).

The D2 analysis carried, thus proved to be a very useful technique in isolating diverse groups in available material under study.

6. SUMMERY AND CONCLUSION

The present investigation entitled, “Genetic Variability and Path analysis studies in Garlic (*Allium sativum* L.)” was undertaken with the following objectives.

1. To study the variability in different garlic genotypes.
2. To study the correlation of different characters with yield.
3. To study the degree of divergence in different genetic stock of garlic.
4. To study the heritability, genetic advance and path analysis in garlic genotypes.

The 45 genotypes were planted on 24th November, 2009 in randomized block design with two replications. The genotypes were evaluated for 11 diverse characters to have clear view of yield contributing characters.

The treatment mean sum of squares for analysis of variances were significant for all characters studied, suggesting the presence of variability in genotypes evaluated. The estimates of GCV and PCV were of high magnitude for average weight of 10 cloves, yield per plot, yield per hectare and average bulb weight indicating the presence of good amount of variability for these characters. The maximum difference between GCV and PCV was noted for yield per plot and yield per hectare. No difference was recorded for days required for harvest (0.00). The heritability (board sense) percentage was ranged between 61.72 (plant height) and 100.00 (days required for harvest). Comparatively,

high heritability (b. s.) percentage was observed for days required for harvest (100.00) followed by average weight of 10 cloves (99.09), and number of cloves per bulb (97.07). It indicates that these characters are least influenced by environmental effects. Selection for improvement of such character may not be useful because broad sense heritability is based on genetic variance which includes both fixable and non fixable variances. The genetic advance was maximum for the trait yield per hectare followed by average bulb weight. It shows that these characters are governed by additive genes and selection will be rewarding for improvement of such traits while, the lowest genetic advance was noted for neck thickness. However, the highest expected genetic advance as percent of mean was observed for average weight of 10 cloves followed by average bulb weight.

The estimates of genotypic correlations, in general were slightly higher than phenotypic correlation, indicating little masking or modifying effects of environment on the expression of character. The yield per plot and yield per hectare exhibited positive and significant correlation with plant height, neck thickness, average bulb weight, average bulb length, average bulb diameter, and days required for harvest. However, it showed positive correlation with number of leaves per plant, average weight of 10 cloves and number of cloves per bulb.

The path analysis of one dependant variable revealed very clean distinction for the character contribution to yield per hectare. Among the 9 traits under path analysis study average

bulb diameter exhibited maximum direct effect on yield per hectare followed by average bulb length while, neck thickness had negative direct effects on yield per hectare.

The 45 genotypes were grouped into seven clusters. Cluster B comprises maximum number of genotypes followed by cluster A. while, cluster D, F and G were monogenotypic. The maximum intra-cluster distance was found in cluster C ($D^2 = 155.75$) followed by cluster A and cluster B. However, the maximum inter-cluster distance was observed between cluster cluster G and B (5487.84). In general G-29, G-24 and G-38 genotypes possessing high per se performance for average bulb weight and yield per hectare genetically diverse following cluster F and C should be further exploited by selection procedure for development of high yielding variety in garlic.

7. LITERATURE CITED

- Agarwal, A. and Tiwari, R. S. 2000. Correlation and path coefficient studies on yield attributing factors in garlic (*Allium sativum* L.). National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 27-29.
- *Allard, R. W. 1960. Principles of Plant Breeding. John Wiley and Sons, New York and London, pp. 89-98.
- Anonymous. 2009. Area and production of vegetable crops for the year 2008-09 by NHRDF, Nashik website www.nhrdf.org.in.
- *A. O. A. C. 1975. Official Methods of Analysis of Association of Official Agricultural Chemists, Washington, D.C.
- Arunachalam, V. and Ram, J. 1967. Geographical diversity in relation to genetic divergence in cultivated sorghum. Indian J. Gen. 27: 369-380.
- Burton, G. W. 1951. Quantitative inheritance in pearl millet (*Pennisetum glaucum*). Agron. J. 43: 409-417.
- Burton, G. W. and De Vane, E. H. 1953. Estimating heritability in tall Fescue (*Festuca* spp.) from replicated clonal materials Agron. J. 45 (9): 478-481.

- *Charles, D. R. and Smith, H. H. 1939. Dinstinguishing beetween two types of gene action in quantitative inheritance. *Genetics*, 24 (3): 34-38.
- *Contis, S. and Ferraresi, A. 1974. Biometric analysis of clones and provenances of garlic in relation to breeding. *Revista di. Agronomis*. 8(1): 47-57.
- *Craxton, F. E. and Cowden. 1964. *Applied general statistics*. Prentice Hall of India, New Delhi.
- *Dewey, D. R. and Lu, K. H. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*: 515-518.
- Dubey, B. K., Singh, R. K. and Bhonde, S. R. 2010. Variability and selection parameters for yield and yield contributing traits in garlic. *Indian Journal of Agricultural sciences* 80(8): 737-41.
- *Falconer, D. S. 1960. *Correlated characters, Introduction to Quantitative Genetics*. Publ. London group Ltd. London: pp. 312.
- *Fisher, R. A. 1936. The correlation between relatives on the supposition of Mendelian inheritance. *Trans. Roy. Soc. of Edinburgh*. 52: 399-433.
- *Galton, F. 1889. *Natural Inhertiance*. Mac Millan, London.
- Ghetia, J. M. and Singh, S. P. 2000. Genetic variability, correlation and path coefficient analysis in onion

(*Allium cepa* L.). National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 11-13.

Godhani, P. V. and Singh, S. P. 2000. Genetic variability correlation and path coefficient studies in garlic (*Allium sativum* L.). National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 44-47.

Gurjar, R. S. S. and Singhania, D. L. 2006. Genetic variability correlation and path analysis of yield and yield components in onion. Indian J. Hort. 63(1): 53-58.

*Gvozdanovic, V. J. 1997. Genetic diversity of garlic genotypes (*Allium sativum* L.). Novi sad P: 76.

*Hanson, G. H., Robinson, H. F. and Comstock, R. E. 1956. Biometric studies in segregating populations of Korean Lespedes. Agron. J. 48: 268-272.

Haydar, A., Sharkar, N., Ahmend, M. B., Hannam, M. M., Razvy, M. A., Hossain, M., Haque, A and Karim R. 2007. Genetic variability and interrelationship in onion (*Allium cepa* L.). Middle-East Journal of scientific Research 2 (3-4): 132-34.

- Hayes, H. K. and Johnson, I. J. 1939. The breeding of improved selfed lines of corn. J. Amer. Soc. Agron., 31: 710-724.
- Hutchinson, J. B. 1940. The application of genetics to plant breeding. The genetic interpretation of plant breeding problems. J. Genet., 40: 271-282.
- Jabeen, N., Khan, S. H., Chattoo, M. A., Mufti, S. and Hussain, K. 2010. Genetic variability for various traits in garlic. Indian Journal of Arecanut, Spices and Medicinal plants vol-12 (1): 13-17.
- Johnson, H. W., Robinson, A. F. and Comstock, R. E. 1955. Estimates of environmental variability in soybean. Agron. J. 45: 374-378.
- Joshi, A. B. and Dhawan, N. L. 1960. Genetic improvement of yield with special reference to self fertilizing crops. Indian J. Genet. 26A: 101-113.
- Kaloo, G. K., Pandey, V. C., Lal, S. and Pandita, M. L. 1982. Correlation and path analysis studies in garlic. Haryana J. Hort. Sci. 11(1-2): 97-101.
- Khar, A., Ashadevi, A., Mahajan, V. and Lawande, K. E. 2005. Genetical studies in elite lines of garlic (*Allium sativum* L.). J. Maharashtra. Agric. Univ. 30(3): 277-280.

- Khar, A., Ashadevi, A., Mahajan, V. and Lawande, K. E. 2006. Genetic divergence analysis in elite lines of garlic (*Allium sativum* L.). J. Maharashtra. Agric. Univ. 31(1): 52-55.
- Killadi Bharati, Netrapal and Singh Narendra. 2000. Genetic variability in garlic. National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 193.
- Kohli, U. K. and Fageria, M. S. 1992. Correlation studies of some important traits in garlic collection. J. Res. APAU 20: 164-166.
- Kohli, U. K. and Prabal. 2000. Variability and correlation studies on some important traits in garlic clones. Haryana J. Hort. Sci. 29 (3 and 4): 209-211.
- Korla, B. N. and Rostogi, K. B. 1979. Performance studies of some garlic (*Allium sativum*, L.) clones, Haryana J. Hort. Sci. 8(1/2): 69-92.
- Korla, B. N. Singh, A. K. and Kalia, P. 1981. Genetic variability in garlic. Haryana J. Hort. Sci. 10(1-2): 77-80.
- Lokhande, G. D. and Pawar, B. B. 1988. Correlation studies in garlic. J. Maharashtra Agri. Univ. 13 (1): 110-111.

- *Lush, G. L. 1949. Heritability of quantitative characters in farm animals. Proc. VIII Int. Cong. Genet. 1948. Hereditas (Supt.).
- *Mahalanobis, P. C. 1936. On the generalized distance in statistics. Proc. Nat. Inst. Sci. Indian. 2: 49-55.
- *Mahalanobis, P. C., Mujumdar, D. M. and Rao, C. R. 1949. Anthropometric survey of the United Provinces, 1941. A Statistical study Sunkhya. 9: 90.
- *Matus, I., Gonzalez, M. I. and Pozo, A. de. 1999. Evaluation of phenotypic variation in a Chilean collection of garlic clones using multivariate analysis. Plant genetic Resources news letter 117: 31-36.
- Mehta, K. G. and Patel, R. H. 1985. Genetic variability and path analysis in garlic. Madras Agric. J. 72(12): 691-695.
- Mishra, D. P. and Gautam, N. C. 2000. Variability correlation and path coefficient analysis for yield and quality traits in garlic. National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 194.
- Mohanty, B. K. and Das, J. N. 2000. Variability, Heritability, character association and path analysis in Kharif onion. National symposium on onion and garlic

production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 22-26.

Mohanty, B. K. 2002. Variability, Heritability, inter-relationships and path analysis in onion. Haryana J. Hort. Sci. 31 (1 and 2): 84-87.

*Moravec, J., Kvasnicka, S. and Velcka, O. C. 1976. Correlation between bulb weight and other characters in varieties of the world collection of bolting garlic. Bulletin, Vyzkumy Ustav, Zhlinarsky Olamove No. 18: 15-23.

*Mujumdar, D. N. and Rao, C. R. 1958. Bengal Anthropometric Survey, 1945. A Statistical study Sunkhya. 19: 201-208.

Murthy, B. R. and Arunchalam, V. 1966. The nature of genetic divergence in relation to breeding system in crop plants. Ind. J. Genet 26 A: 188-190.

Nadkarni, K. M. 1927. Indian Materia Media Pub. by Nadkarni and Co. Bombay.

Nandapuri, K. S., Singh, S. and Lal, T. 1973. Studies on the genetic variability and correlation of economic characters in tomato. J. Res. PAU. 10: 316-21.

Netrapal, Singh and Chaudhary, B. 1988. Correlation and path coefficient studies in onion Indian J. Hort. 45(3-4): 295-299.

- *Nilsson-Ehle, M. 1909. Kreuzung Untersuchtungaman Hater and Weizen Jands. University Asseter N. F. Afal. 2 Bd., N. Sr. 2: 1-22.
- Padma, D. S., Singh, G., and Saimbhi, M. S. 1972. Genetic variability and correlation studies in onion. Ind. J. Hort. 30 (1 and 2): 391-93.
- Panse, V. G. 1957. Genetics of quantitative characters in relation to plant breeding. Indian J. Genet. Pl. Breed. 17(2): 318-328.
- Panse, V. G. and Sukhatme, P. V. 1985. Statistical methods for agril. Workers. ICAR, New Delhi. 4th Edn.
- Patil, J. D. 1984. Genetic variability and correlation studies in onion (*Allium caps* L.). M.Sc. (Agri.) Thesis, MPKV, Rahuri.
- Raghuram, Netrapal and Singh Narendra. 2000. Studies on genetic variability in onion. National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 189.
- *Rahman, A. K. M. M. and Das, M. K. 1985. Correlation and path analysis in garlic. Bangladesh J. Agric. Res., 10(1): 50-54.

- Randhawa, K. S., Sandhu, J. S., Thakur, J. C. and Singh, D. 1974. Variability and heritability of some important quantitative characters in onion. *Punjab Hort. J.* 14: 147-53.
- *Rao, C. R. 1952. Advanced statistical methods in biometrics research. John Wiley and Sons. Inc. (New York), Chapman and Hall Ltd. London pp. 293.
- Rao, H. and Purwal, S. S. 1957. Onion and garlic cultivation in India. *Farm Bulletin No.* 3.
- Robinson, H. F., Comstock, R. E. and Harvey, P. H. 1949. Estimates of heritability and the degree of dominance in corn. *Agron. Jour.* 41: 353-359.
- Sarangamath, O. Deepa, Hiremath, S. M., Chetti, M. B. and Hosamani, R. M. 2000. Correlation studies between morphological, physiological, biophysical and biochemical parameters in onion. National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 191.
- Selvaraj, N., Irulappan, I and Vedamuthu, P. G. B. 1997. Path coefficient analysis of yield attributing factors in garlic. *South Indian Hort.* 45: 75-77.
- Shaha, S. R. 1985. Variability and correlation studies in garlic. MSc. Agri. Thesis, MPKV, Rahuri.

- Shaha, S. R., Kale, P. N., Dhankhar, B. S. and Shirsath, N. S. 1990. Variability and correlation studies in garlic. Haryana J. Hort. Sci. 19(3-4): 313-317.
- Shridhar. 2000. Genetic variability and character association in garlic. National symposium on onion and garlic production and post harvest management, challenges and strategies held at Nashik on 19-21 Nov.: 193.
- Shrivastava, B. P., Dubey, A. K. and Srivastava, J. P. 1993. Genetic association and path analysis in garlic. Haryana J. Hort. Sci. 22: 85-88.
- Singh, R. K. and Choudhary, B. D. (1977). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, pp. 200-223.
- *Singh, R. K. and Kaker, S. N. 1977. Control of individual trait means during index selection. Proc. Third cong. SABRAO, Canberra, 3: 22-25.
- Singh, R. P. 1981. Genetic evaluation and path analysis in garlic, Madras Agric. J. 68(9): 618-622.
- Singh, R. K., Dubey, B. K., Bhonde, S. R. and Gupta, R. P. 2010. Estimates of genetic variability and correlation in red onion advance lines. Indian Journal of Agricultural sciences 80(2): 160-63.
- Swarup, V. and Chaugule, D. S. 1962. Studies on genetic variability in sorghum II. Correlation of some

important quantitative characters contributing towards yield and application of some selection indices for varietal selection. Indian J. Genet. 22: 37-41.

Thakur, J. C., Bhatal, G. S. and Gill, S. P. S. 1997. Genetic variability and correlation studies in garlic. J. Res. Punjab Agric. Univ. 34(1): 40-44.

Trivedi, A. P., Dhumal, K. N. and Lawande, K. E. 2006. Genetic variability, correlation and path analysis study in storage life of onion. Indian J. Genetics., 66(4): 349-350.

Vijay, O. P. 1990. Note on genetic variability in garlic (*Allium sativum* L.) Indian J. Hort. 47(4): 431-433.

*Wright, S. J. 1921. Correlation and Cauzation. J. agric. Res., 20: 557-585.

*Zhila, F. D. 1981. Correlation between Phenotypic traits in garlic of bolting type. Tsitsi, Genet. 15(4): 46-48.

* **Originals not seen.**

8. VITA

Mr. Gidmare Punam Pundlik

A candidate for the degree

of

MASTER OF SCIENCE (HORTICULTURE)

in

Vegetable Science

2011

Title of thesis : “GENETIC VARIABILITY AND PATH ANALYSIS
STUDIES IN GARLIC (*Allium sativum* L.)”

Major field : Horticulture

Biographical information

Personal data : Born on 8th August, 1987 at Isapur, Tal. Lakhani, Dist. Bhandara. Son of Shri. Pundlik Duryodhan Gidmare and Sau. Vandana Pundlik Gidmare.

Educational

Information : Completed S.S.C. from Samarth Vidyalay, Lakhani, Dist. Bhandara .

: Completed H.S.C. from Samarth Vidyalaya and Junior College, Lakhani, Dist. Bhandara.

: Received Bachelor of Science (Agriculture) degree in first class from College of Agriculture, Nagpur (Dr. P. D. K. V. Akola) in 2009.

Extracurricular activities : Participated in State level, Inter-university Basketball tournament held at YCMOU, Nashik in 2007.

:Completed “A” and “B” NCC Certificate
with “A” grade

: Participated in All India, Inter-
university Hockey tournament held
at Mumbai University in 2011.

Experience

: Six months experience to work as a
field Worker at CICR, Nagpur.

: Work as a member of student council of
PGI, MPKV, Rahuri during 2009-2011.

Selection

: Selected as a Police Sub-inspector in
feb. 2011.

Permanent Address

: A/P Ganganagar Lakhani (Murmadi),
Tal. Lakhani, Dist. Bhandara, Pin :
441804.

e-mail Address

: padmakargidmare@gmail.com

