

**GENETIC EVALUATION OF LOCAL GENOTYPES
OF GARLIC (*Allium sativum* L.) UNDER LOW
HILL CONDITIONS OF HIMACHAL PRADESH**

Thesis

by

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(NH-2019-44-M)**

submitted to



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CERTIFICATE-I

This is to certify that the thesis titled, “**Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hill conditions of Himachal Pradesh**” submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE** in the discipline of **HORTICULTURAL SCIENCES** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173230 is a bonafide research work carried out by **Ms. Jasdeep Kaur (NH-2019-44-M)** daughter of Shri Gagan Singh under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

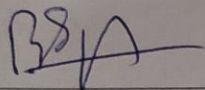
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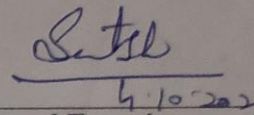
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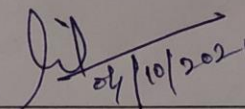
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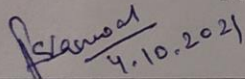


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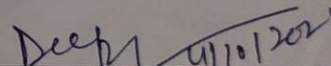


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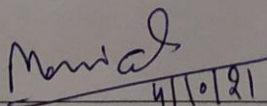
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This is to certify that all the mistakes and errors pointed out by internal examiner have been incorporated in the thesis titled “**Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hill conditions of Himachal Pradesh**” submitted by **Ms. JASDEEP KAUR (NH- 2019-44-M)** daughter of Shri Gagan Singh to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P)-173230 in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE**.

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Place: Neri, Hamirpur

Dated:

(Jasdeep Kaur)

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ABBREVIATIONS

%	:	Per cent
=	:	Equal to
×	:	Multiplication
°C	:	Degree Celsius
ANNOVA	:	Analysis of Variance
C.V.	:	Coefficient of Variation
CD	:	Critical Difference
Cm	:	Centimeter
<i>et al.</i>	:	co-workers
etc.	:	<i>et cetera</i>
G	:	Gram
H.P	:	Himachal Pradesh
<i>i.e.</i>	:	that is
m ²	:	Meter square
Max	:	Maximum
Mg	:	Milli gram
Min	:	Minimum
Mm	:	Milli meter
NHB	:	National Horticulture Board
RHS	:	Royal Horticulture Society
SE	:	Standard error
UHF	:	University of Horticulture and Forestry
CoH&F	:	College of Horticulture and Forestry
<i>viz.</i>	:	Videlicet (namely)
PCV	:	Phenotypic coefficient of variation
GCV	:	Genotypic coefficient of variation
TSS	:	Total Soluble Solids
GAM	:	Genetic Advance as per cent of mean
°B	:	Brix
ha	:	Hectare
MT	:	Metric Tonne
m	:	Meter
cm	:	Centimeter
ERMA	:	Electronic Recording Machine Accounting
pH	:	Pouvoir hydrogen

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Chapter-1

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important remunerative bulbous spice and medicinal crops grown all over the world. It is the second most widely cultivated bulb crop after onion, which belongs to family Alliaceae, with diploid chromosome number $2n=2x=16$. The primary centre of origin of garlic is Central Asia and Southern Europe whereas, Mediterranean region is considered as its secondary centre of origin. The most probable wild progenitor of garlic is *Allium longicuspis* (Vvedensky, 1944).

Globally, China is the leading country in area and production followed by India and Egypt. In India, garlic occupies an area of 354 thousand hectares with an annual production of 2836 thousand metric tonnes (Anonymous, 2018-19). In Himachal Pradesh, garlic is grown over an area of 4.57 thousand hectares with an annual production of 9.35 thousand tonnes. Lately, the cultivation of garlic in Himachal Pradesh has become more popular amongst the farmers of Kullu, Mandi, Sirmaur and Kangra districts on account of its relative ease in cultivation and higher profit margins. Compact silver white with white creamy flesh garlic is preferred in India and also for export.

Botanically, economic part of garlic is bulb composed of densely packed elongated side cloves. Garlic is herbaceous annual for bulb production. Leaves have solid thin blades. Some varieties produce flowers but these flowers fails to set seed. There are some varieties which produce vegetative bulb on the top called bulbils. They are also used for propagation in some cases. It displays variability with respect to morphological features, yield, quality as well as resistance to important insect pests and diseases. It also shows adaptation to wide range of soil temperature and day length making its farming possible from tropics to temperate latitudes.

Garlic has higher nutritive values than other bulb crops. Garlic contains carbohydrate, sugar dietary fibers, fat, protein, thiamine, niacin, Vitamin C and calcium. It also contains sulphur and essential oils which impart strong flavour (Memane *et al.* 2008). The fresh garlic odour is due to allicin and the flavour in garlic is due to diallyl disulphide. It has also been considered as 'Nectar

of life' in Ayurveda. It has hypocholesterolemic action and reduces the cholesterol concentration in human blood. It has antibacterial, antifungal and antiviral properties (Reuter *et al.* 1996). It also increases immunity and protects against cardiovascular diseases. Garlic oil or its juice is found useful in cases of pulmonary tuberculosis, rheumatism, sterility, impotency, cough and redness of eyes.

Garlic is propagated by vegetative means using cloves and bulbils. So, clonal selection is the most important breeding method for the improvement of this crop. Superior varieties/germplasm with specific quantitative and qualitative traits can be developed by exploring the genetic variability. For effective breeding program the knowledge of different genetic parameters viz. variability, heritability, genetic advance with respect to a particular trait is must. The association of different horticultural traits among themselves and with yield provides better chances for selection. Similarly, the magnitude and nature of association among different traits can be ascertained by path analysis. Therefore, keeping in view all these above facts, the present investigation “**Genetic evaluation of local genotypes of Garlic (*Allium sativum L.*) under low hill conditions of Himachal Pradesh.**” was carried out during rabi season of year 2020-2021 at Experimental Farm of College of Horticulture and Forestry, Neri for the evaluation of various garlic genotypes with the following objectives:

- a) To assess the performance and the extent of genetic variability in various garlic genotypes.
- b) To work out heritability and genetic advance.
- c) To work out correlation and path analysis in garlic genotypes.
- d) To identify promising genotype.

Chapter-2

REVIEW OF LITERATURE

In the present investigation entitled, “**Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hill conditions of Himachal Pradesh.**”, an attempt has been made to review the work done on genetic variability, heritability, genetic gain, correlation and path analysis studies in garlic. A brief description of available literature pertaining to the investigation has been presented under the following sub heads:

- 1. Genetic Variability Studies**
- 2. Heritability and Genetic gain**
- 3. Correlation studies**
- 4. Path coefficient analysis**

1. GENETIC VARIABILITY STUDIES:

The scope of crop improvement depends on the basic requirements of variability. There are two types of variability observed in crop plants viz., phenotypic and genotypic. It is the genetic variability which is the pre-requisite for any successful breeding programme. The phenotypic variability is the result of genetic and environmental interactions. The study of genetic variability was made for the first time by the great Biologist Fisher (1918) and subsequently the estimates of genotypic and phenotypic variation was used to predict the expected genetic response. The information available in genetic variability is reviewed as followed:

Khar *et al.* (2005) conducted genetic studies on 47 genotypes of garlic and observed a wide range of variability. Phenotypic and genotypic coefficients of variation were high for neck thickness, number of leaves, weight of bulb, weight of clove and yield. Futane *et al.* (2006) evaluated eight garlic genotypes and recorded the highest values for number of leaves per plant, bulb fresh weight, bulb diameter, total soluble solids and bulb yield.

Kumar *et al.* (2006) reported genetic variability in 20 different genotypes of garlic and observed high variability for average weight of cloves, diameter of cloves and yield per plant. Panthee *et al.* (2006) carried out genetic variability study on 179 accessions of garlic and reported high variability for number of cloves per bulb, maturity duration, plant height, bulb weight, bulb diameter, bulb outer scale number and yield.

Yadav *et al.* (2006) reported maximum amount of genotypic coefficient of variation (GCV) for number of cloves per bulb, weight of bulb, number of leaves per plant, width of cloves, plant height, length of bulb, width of bulb and length of cloves. Gupta *et al.* (2007) carried out study on 14 different collections of garlic and observed significant variability for days to sprout, days to harvest, plant height, leaf length, leaf number, neck diameter, neck height, clove diameter, clove number, bulb weight and yield.

Alam *et al.* (2010) conducted a field experiment on 20 garlic genotypes under dry land condition and results revealed that the plant height, number of leaves per plant, fresh and dry bulb weight, length and diameter of bulb, total number of cloves, yield per plot and yield per hectare had significant variability among the genotypes. Tsega *et al.* (2011) evaluated twenty five local garlic accessions for bulb yield and yield related traits and found significant variability among the accessions. Wide range of variation and slight differences were observed between genotypic and phenotypic coefficients of variation for all the traits.

Singh *et al.* (2012) conducted a field experiment on thirty two diverse genotypes of garlic and observed wide range of variability for yield, weight of cloves, cloves per bulb, weight of bulbs and clove diameter. Phenotypic coefficient of variation and genotypic coefficient of variation were high for weight of clove, cloves per bulb, marketable yield and clove size index. Yadav *et al.* (2012) examined fifty six genotypes of garlic and observed high phenotypic and genotypic coefficient of variation for bulb yield per plant, bulb yield per hectare, bulb yield per plot and average weight of 10 cloves. However, days to maturity, number of leaves per plant, days after planting, leaf length, plant height, days after planting and polar diameter were found to exhibit low estimates of phenotypic and genotypic coefficients of variation.

Dhall and Brar (2013) recorded the maximum values of genotypic coefficient of variation and phenotypic coefficient of variation for clove weight, cloves per bulb and clove diameter. Vatsyayan *et al.* (2013) studied genetic variability among forty five diverse genotypes of garlic for different characters to identify elite genotypes. The results showed high genotypic and phenotypic coefficient of variation for bulb weight, yield per plot and number of scales per bulb.

Gehani and Kanbar (2013) evaluated fifteen garlic genotypes for genetic variability of different characters like leaf number, plant height, false stem length and weight, fifth leaf length, width and weight, leaf area, total dry weight, bulb diameter, bulb height, cloves per bulb and bulb yield. Analysis of variance showed significant differences among the genotypes for all the traits. Pervin *et al.* (2014) observed significant differences among different genotypes for plant height, number of leaves per plant, leaf length, fresh weight of bulb, dry weight of leaves, dry weight of bulb, diameter of bulb, number of cloves and yield of bulb per hectare. The genotypic and phenotypic coefficient of variance were found low to moderate.

Khar *et al.* (2015) revealed significant differences among the genotypes for all the traits in garlic except for number of leaves per plant, leaf length, dry matter content, total soluble solids and equatorial diameter indicating greater variability in the germplasm. PCV and GCV were high for pseudostem diameter, plant height, average weight of cloves, average bulb weight, yield per ha and leaf length.

Kumar *et al.* (2015) evaluated forty one genotypes of garlic, collected from different agro climate zone of Jammu, for yield and other agronomic characters. The analysis of variance revealed greater variability for all the traits except number of leaves per plant, leaf length, dry matter content and total soluble solids. Sandhu *et al.* (2015) evaluated 40 diverse genotypes of garlic and reported that phenotypic coefficients of variation were higher in magnitude than genotypic coefficients of variation.

Sharma *et al.* (2016) studied one hundred and thirty one garlic genotypes for twelve horticulture traits and reported significant genetic differences for all the traits indicating the presence of variability in the germplasm. High estimates of the genotypic coefficient of

variance and phenotypic coefficient of variance were observed for plant height, bulb weight, leaf length, number of cloves per bulb and plant height.

Bhatt *et al.* (2017) carried out an experiment with sixteen diverse indigenous genotypes of garlic and reported significant genetic diversity. High genotypic coefficient of variance and phenotypic coefficient of variance were observed for volume of bulbs followed by weight of ten uniform cloves in comparison of other characters. Moderate genotypic coefficient of variance and phenotypic coefficient of variance were observed for dry weight of bulb, neck thickness, number of cloves per bulb, plant height and bulb yield.

Hasan and Obiadalla (2017) studied eighty genotypes of garlic for yield and its contributing characters. Analysis of variance indicated presence of considerable variability for all the twelve characters. The estimates of phenotypic co-efficient of variation (PCV) were higher than the genotypic co-efficient of variation (GCV) for all the characters. High GCV and PCV were observed for number of cloves per bulb, diameter of clove, weight of clove, neck thickness of bulb, width of leaf and length of clove.

Singh *et al.* (2017) assessed genetic variability among thirty genotypes of garlic for bulb yield and yield contributing traits. High GCV and PCV were observed for neck thickness, dry matter content and number of fleshy scale leaves. Singh *et al.* (2018) assessed thirty five genotypes of garlic and reported higher magnitude of coefficient of variation at phenotypic as well as genotypic levels for bulb diameter, clove length, bulb yield per plant and number of cloves per bulb. Moderate coefficient of variation at phenotypic as well as genotypic level were observed for plant height, leaf length and neck thickness. Hussien *et al.* (2019) evaluated twenty one genotypes of garlic for number of leaves per plant, bulb diameter, bulb weight, TSS content and total yield. The phenotypic coefficients of variation were higher in number of leaves per plant, TSS and total yield.

2. HERITABILITY AND GENETIC ADVANCE:

Fisher (1918) was the first to partition continuous variation exhibited by metric traits into heritable and non-heritable components. Broad sense heritability is defined as the ratio of genotypic variance to total variance. A knowledge of heritability for different component traits seems to be essential for any crop improvement programme, because the heritable component

is the sequence of genotype and is inherited from generation to generation. The amount of progress expected through selection for obtaining the best individual cannot be made on the basis of heritability alone. The genetic progress would enhance with an increase in heritability estimate. Hence, the heritability estimate could be best utilized in conjunction with genetic advance in predicting genetic gain. Genetic advance denotes the improvement in the genotypic value of the new population. So, the knowledge of genetic advance, to be expected by applying selection pressure to a segregating and variable population is useful in designing an effective breeding programme.

Kumar *et al.* (2006) studied the genetic variability in twenty lines of garlic in three artificially created environments. Average weight of cloves, diameter of cloves and yield per plant exhibited high heritability and genetic advance as per cent of mean indicating the importance of clonal selection based on phenotypic performance of characters.

Gupta *et al.* (2007) experimented with fourteen different collections of garlic and observed high heritability for all the characters except for days to sprout. High genetic gain was observed for neck diameter, bulb weight, yield, clove number and neck height. Jabeen *et al.* (2010) studied twenty five genotypes of garlic to estimate heritability and genetic advance for various economic traits to aid in selection programme and to study the environmental influence. It was concluded that plant height, average bulb weight and bulb yield indicated predominance of additive gene effects hence, selection for these traits lead to further improvement in yield.

Tsega *et al.* (2011) examined twenty five local garlic accessions and found comparatively high heritability coupled with high genetic advance as percent of mean for different bulb yield characters. Singh *et al.* (2012) conducted study with thirty two garlic lines to identify suitable genotypes of garlic for cultivation. The results revealed that heritability in broad sense ranged from 43.9 to 95.0%. High value of heritability was recorded for plant height followed by cloves per bulb, leaves per plant, weight of 50 cloves, weight of 20 bulbs, marketable yield, bulb size index and neck thickness. A high estimate of genetic advance was showed by cloves per bulb followed by weight of 50 cloves, marketable yield and weight of 20 bulbs.

Sonkiya *et al.* (2012) computed heritability and genetic advance for ten genotypes for different horticultural traits in garlic. High heritability coupled with high genetic advance as percent of mean was observed for leaf area and weight of 10 cloves indicating predominance of additive gene effects for these traits. Yadav *et al.* (2012) reported high heritability coupled with high genetic advance as percent of mean for equatorial diameter of bulb, average weight of ten cloves and plant height at 60 DAP. High heritability with moderate genetic gain was recorded for pseudo stem diameter and polar diameter of bulb. High heritability associated with low genetic advance as percent of mean was exhibited by days to maturity.

Panse *et al.* (2013) studied fifty six garlic genotypes and results revealed that high estimates of heritability were observed for pseudo stem diameter, days to maturity, polar diameter of bulb, equatorial diameter of bulb, average weight of 10 cloves and plant height. Average weight of 10 cloves, number of cloves per bulb, bulb yield per hectare, equatorial diameter of bulb and plant height exhibited higher value of genetic advance as percent of mean. High heritability coupled with high genetic advance as percent of mean was observed for equatorial diameter of bulb, average weight of 10 cloves and plant height at 60 days after planting (DAP) suggesting that they can be improved through selection.

Pervin *et al.* (2014) studied the field performance and genetic variation of twenty five genotypes of garlic. High heritability was observed for plant height, length of leaves, fresh weight of leaves, yield of bulb per hectare, fresh weight of root, dry weight of root, number of cloves per bulb. Esho (2015) carried out an experiment with five garlic genotypes. Results showed that Heritability in broad sense was higher for most of traits. While genetic advance was maximum for most of characters except for number of leaves per plant and plant height. High heritability coupled with high genetic advance was observed for bulb diameter, bulb weight. It emphasised the importance of selection of high yielding genotype as these traits are governed by additive gene action.

Sandhu *et al.* (2015) reported that the bulb weight per plant, bulbils size, number of bulbils per umbel, clove weight and total sugars recorded high heritability. High heritability coupled with moderate genetic gain was expressed for number of cloves per bulb, leaf width,

alcohol insoluble solids and allicin content. Sharma *et al.* (2016) studied one hundred thirty one garlic genotypes for twelve morpho-agronomic traits. High heritability coupled with moderate genetic advance was recorded for clove weight, bulb weight per plant, pseudostem height, polar diameter of bulb, equatorial diameter of bulb and number of cloves per bulb.

Bhatt *et al.* (2017) carried out an experiment with sixteen diverse indigenous genotypes of garlic and high heritability was observed for bulb yield, weight of ten cloves, number of cloves per bulb, dry weight of bulb and TSS. Kumar *et al.* (2017) evaluated thirty genotypes of garlic and reported high heritability along with high genetic advance as percent of mean for number of cloves per bulb, bulb yield and weight of cloves. Hussien *et al.* (2019) examined twenty five local garlic accessions and found high heritability coupled with high genetic advance for number of leaves per plant, bulb diameter, bulb weight, TSS and total yield. This indicates higher response of selection for high yielding genotypes as these traits are governed by additive gene action.

3. Correlation studies

The concept of correlation was given by Galton (1889) and later extended by Fisher (1918). Correlation coefficient is the important selection parameter in plant breeding. Correlation coefficient is used to find out the degree (strength) and direction of relationship between two or more variables. In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. Yield is very complex phenomenon; it is not only polygenic in nature but is also affected by environment. Hence, the selection of superior plants based on the performance of yield as such is usually not very effective. For selection of superior genotypes the breeder has to select the genotypes on the basis of its phenotypic expression. For most of the traits, the knowledge about degree of phenotypic and genotypic correlations of the traits is important (Robinson *et al.*, 1951). The earlier research work conducted on correlation studies in garlic is being reviewed as under:

Naruka and Dhaka (2004) carried out an experiment on thirty genotypes of garlic and reported that plant height, number of leaves per plant, chlorophyll content of leaves, fresh

weight of leaves, maturity period and neck thickness of bulb showed highly positive and significant correlation with number of cloves per bulb, weight of twenty cloves, harvest index and bulb yield per hectare. However bulb: leaf ratio had negative and significant correlation with harvest index and bulb yield per hectare.

Khar *et al.* (2005) conducted correlation studies in garlic germplasm and reported that the yield had highly significant positive association with plant height, leaves per plant, polar diameter, equatorial diameter, neck thickness, weight of 5 bulbs and weight of 50 cloves. Baghalian *et al.* (2006) evaluated 24 garlic genotypes and reported that yield had significant and positive correlation with leaf number, clove weight and bulb mean weight.

Golani *et al.* (2006) carried out a correlation study in garlic and showed that there was significant and positive association of bulb yield with number of leaves per plant, bulb length, bulb girth and bulb weight. Singh *et al.* (2006) evaluated 30 genotypes of garlic and observed significant positive association of equatorial diameter, leaf breadth, leaves per plant, average clove weight, days to maturity, clove length and clove diameter with bulb yield.

Hossain *et al.* (2008) conducted an experiment using seven varieties of garlic and reported positive and significant phenotypic correlation coefficient of bulb length, bulb diameter, fresh weight of bulb, plant height and number of leaves with seed yield. Agarwal and Tiwari (2009) carried out study on twenty one genotypes of garlic and observed significant and positive correlation of bulb yield both at genotypic and phenotypic levels with bulb weight, clove weight, bulb diameter, clove length, leaf area index and neck diameter. Significant negative correlations of bulb yield at genotypic level were observed with purple blotch severity index and number of cloves per bulb.

Awale *et al.* (2011) reported that the bulb yield was positively and significantly associated with plant height, leaf length, leaf sheath length, leaf sheath diameter, bulb length, bulb diameter, bulb dry weight, biological yield per plant and marketable yield per plant at both phenotypic and genotypic levels. Singh *et al.* (2011) carried out a field experiment on thirty two diverse genotypes of garlic and revealed that at both genotypic and phenotypic

levels. Marketable yield was positively and significantly correlated with leaves per plant, bulb diameter, bulb size index, weight of bulb and cloves per bulb.

Barad *et al.* (2012) conducted a field experiment comprising of forty one genotypes of garlic and observed higher value of genotypic correlation coefficients than phenotypic correlation coefficients. Bulb yield was positively and significantly correlated with bulb weight, polar diameter, equatorial diameter and number of cloves per bulb. Patil *et al.* (2012) conducted a field experiment on 41 genotypes of garlic and reported that neck thickness, average bulb weight, bulb length, bulb diameter, average weight of cloves and days to harvesting were positively and significantly correlated with yield.

Agarwal and Tiwari (2013) screened twenty one genotypes of garlic for purple blotch susceptibility and yield. They concluded that yield was negatively correlated with purple blotch incidence. Dhall and Brar (2013) conducted an experiment with 25 genotypes of garlic and observed that bulb weight was positively and significantly correlated with bulb equatorial diameter, clove weight, clove length, bulb polar diameter and plant height at both genotypic and phenotypic levels. Singh *et al.* (2013) evaluated twenty genotypes of garlic and found that bulb yield showed positive and significant genotypic and phenotypic associations with bulb equatorial diameter, clove weight, clove length, bulb polar diameter and plant height. Pervin *et al.* (2014) revealed that correlation analysis for yield of bulb per hectare was significantly correlated with length of leaves and number of cloves per bulb.

Ijaz *et al.* (2015) carried out a study to understand the genetic association between yield and its related traits among garlic genotypes. They reported that, garlic bulb yield was positively associated with plant biomass, bulb diameter, number of bulbs and number of cloves per bulb. Esho (2015) carried out an experiment on genetic variability in garlic and reported that total yield was positively and significantly correlated with plant height, bulb weight, bulb diameter, bulb length, clove weight, clove diameter and TSS. Plant height and bulb diameter were negatively and significantly correlated with number of cloves per bulb.

Khar *et al.* (2015) reported that average bulb weight showed positive and significant correlation with number of leaves per plant, leaf length, average weight of cloves, equatorial

diameter, while it was negatively and significantly correlated with total soluble solids hence indicating genetic improvement of bulb yield in garlic by selection for number of leaves per plant, leaf length, average weight of cloves and equatorial diameter of bulbs. Prajapati *et al.* (2016) evaluated thirty genotypes and reported that leaf length, equatorial diameter of bulb, leaf width, plant height, pseudostem diameter, polar diameter of bulb, average weight of bulb and days to maturity were positively and significantly associated with bulb yield per plant.

Sharma *et al.* (2016) reported that average bulb weight showed positive and significant correlation with numbers of leaves per plant, leaf length, average weight of clove, equatorial diameter while negatively and significantly correlated with total soluble solids. Bhatt *et al.* (2017) evaluated sixteen diverse indigenous genotypes of garlic and reported that gross bulb yield was significantly and positively associated with number of cloves per bulb and weight of ten cloves. Gebremichael *et al.* (2019) reported that bulb yield was highly significant and positively correlated with plant height, leaf number, leaf length and bulb diameter.

4. PATH COEFFICIENT ANALYSIS

The path coefficient analysis is simply a standardized partial regression which may be useful in choosing the characters(s) that have direct and indirect effects on yield. Such a study may be useful and effective in selection for simultaneous improvement of the component characters that contribute towards yield. Path analysis was initially suggested by Wright (1921) but was applied for the first time in plant breeding by Dewey and Lu (1959). Research works conducted on correlation and path analysis in garlic and its related species are being reviewed as under:

Gurjar and Singhania (2006) evaluated 30 varieties and local land races of garlic and revealed that plant height, number of leaves per plant, neck thickness, bulb weight, equatorial and polar bulb diameter had high positive direct effect on yield. Singh *et al.* (2006) evaluated thirty genotypes of garlic and revealed maximum indirect effect of leaf breadth on bulb weight per plant followed by average clove weight, cloves per bulb, plant height, clove length and dry matter content thus suggesting that these traits should be considered for selection

Meena *et al.* (2007) tested 25 genotypes of garlic and reported that bulb weight, fresh weight of leaves, dry weight of bulb, circumference of bulb, neck thickness, volume of bulb, sulphur content and vitamin C had positive direct effect on bulb yield. Fresh weight of leaves, dry weight of bulb, circumference of bulb, neck thickness, volume of bulb, sulphur content and vitamin C showed high and positive indirect effect towards bulb yield. Yadav *et al.* (2007) carried out a study with forty genotypes of garlic and revealed that length of cloves had the highest indirect effects on weight of bulb followed by number of leaves per plant, plant height, width of bulb, number of cloves per bulb, width of cloves and length of bulb.

Tsega *et al.* (2011) studied path coefficient analysis in 25 genotypes of garlic and found that all characters except leaf length, dry weight above ground and bulb dry weight exerted positive direct effect on bulb yield per plant at phenotypic level. Barad *et al.* (2012) conducted a study comprising of 41 genotypes of garlic and observed positive and direct effect of number of cloves per bulb whereas, indirect effect via plant height, number of leaves per plant, bulb weight and equatorial diameter of bulb on bulb yield.

Patil *et al.* (2012) evaluated 45 genotypes of garlic and reported that number of cloves, bulb weight, plant height, average bulb diameter and weight of cloves showed positive indirect effect on yield. Sonkiya *et al.* (2012) studied path analysis in garlic and observed that the bulb yield had positive direct effect on number of leaves, neck thickness, weight of bulbs, number of cloves per bulb, length of cloves, equatorial diameter, days to maturity, TSS and sulphur content. Panse *et al.* (2013) observed that plant height, polar diameter of bulb, average weight of clove, cloves per bulb and pseudo stem diameter had the positive direct effect on bulb yield in garlic.

Singh *et al.* (2013) carried out path analysis studies in twenty genotypes of garlic for nine important characters. Path analysis indicated direct effect of bulb weight and equatorial bulb diameter and indirect effect of plant height, number of leaves per plant, pseudo stem length, polar bulb diameter, number of cloves per bulb and average weight of cloves on total bulb yield. Kumar *et al.* (2015) evaluated forty one genotypes of garlic and results revealed that average weight of bulb had exerted indirect effect on average weight of ten cloves per bulb, dry matter, equatorial diameter, leaf length and plant height.

Satesh *et al.* (2015) evaluated forty one garlic genotypes for yield, quality and other traits. Path analysis revealed positive direct effect of average weight of bulb for average weight of 10 cloves per bulb, dry matter, equatorial diameter, leaf length and plant height.

Prajapati *et al.* (2016) carried out study on thirty genotypes and reported that number of cloves per bulb, pseudostem diameter, number of leaves per plant, leaf width, pseudostem length, equatorial diameter and days to maturity had positive direct effect on bulb yield per plant. It was also observed that yield was negatively and directly affected by leaf length, plant height, average weight of ten cloves and polar diameter. Sharma *et al.* (2016) evaluated forty one garlic genotypes and reported positive direct association of bulb yield with average weight of ten cloves per bulb, dry matter, equatorial diameter, leaf length and plant height.

Bhatt *et al.* (2017) studied path analysis in sixteen diverse indigenous genotypes of garlic and reported maximum positive direct effect on bulb yield via number of cloves per bulb followed by ascorbic acid. Maximum negative direct effect on bulb yield was exerted by sulphur content followed by volume of bulb, plant height at 90 days after sowing, neck thickness, TSS, and weight of ten uniform cloves. Gebremichael *et al.* (2019) studied path coefficient analysis and revealed that plant height, leaf number, leaf length, bulb diameter and mean bulb weight exhibited positive direct effect on total bulb yield.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled “**Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hill conditions of Himachal Pradesh.**” was carried out at Experimental Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (HP). The details of the experiment and experimental material used during the course of investigation have been described below:

3.1 SITE OF EXPERIMENT

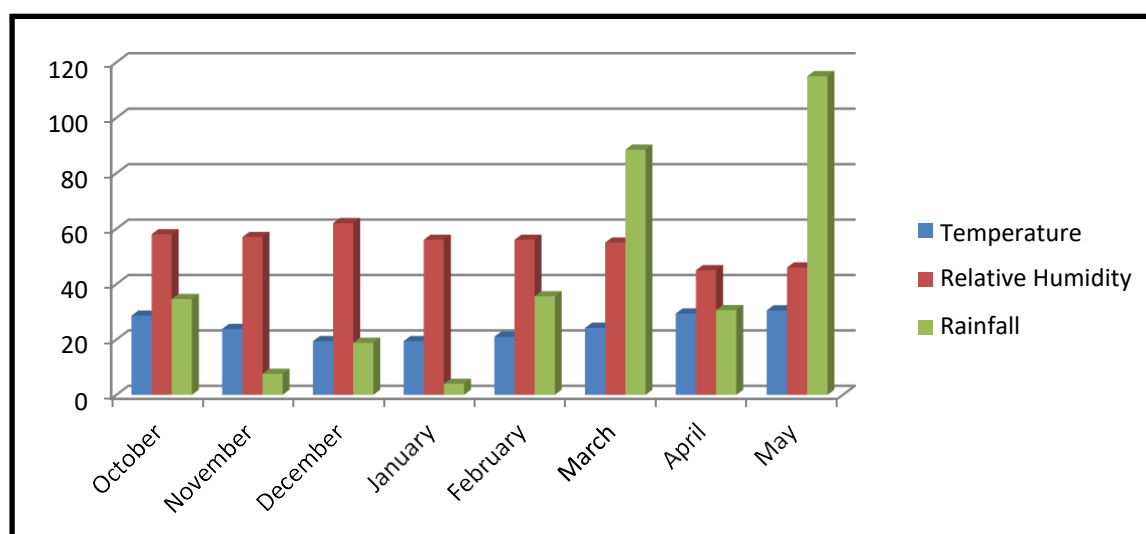
3.1.1 Location

Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (H.P.) is located at low hill zone of Himachal Pradesh at an altitude of 650 m above mean sea level, having longitude and latitude of 72°28’6.3” E and 31°41’47.6” N, respectively. It comes under the subtropical zone of Himachal Pradesh.

3.1.2 Climatic and soil

The place experiences hot summer and mild winters. Weather conditions which prevailed during growing season are presented in Table 3.1. Maximum rainfall was recorded during July-August. The crop was grown on sandy loam soil rich in organic matter and having good drainage capacity.

Appendix-1: Agro-meteorological data during cropping period



Source: Department of soil science and water-management, COHF, Neri, Hamirpur, H.P. (177001)

3.2 EXPERIMENTAL MATERIALS

Thirty eight diverse genotypes of garlic (*Allium sativum* L.) including check variety Kandaghat Selection were used as experimental material. These genotypes were collected from different parts of the state and maintained at the farm. The genotypes under study has been enlisted in Table 3.1.

Table 3.1 List of genotypes and their source of collection

S.No.	Genotypes	Source
1.	LGCOHF-1	Department of Vegetable Science, COH&F, Neri, Hamirpur
2.	LGCOHF-2	Department of Vegetable Science, COH&F, Neri, Hamirpur
3.	LGCOHF-3	Department of Vegetable Science, COH&F, Neri, Hamirpur
4.	LGCOHF-4	Department of Vegetable Science, COH&F, Neri, Hamirpur
5.	LGCOHF-5	Department of Vegetable Science, COH&F, Neri, Hamirpur
6.	LGCOHF-6	Department of Vegetable Science, COH&F, Neri, Hamirpur
7.	LGCOHF-7	Department of Vegetable Science, COH&F, Neri, Hamirpur
8.	LGCOHF-8	Department of Vegetable Science, COH&F, Neri, Hamirpur
9.	LGCOHF-9	Department of Vegetable Science, COH&F, Neri, Hamirpur
10.	LGCOHF-10	Department of Vegetable Science, COH&F, Neri, Hamirpur
11.	LGCOHF-11	Department of Vegetable Science, COH&F, Neri, Hamirpur
12.	LGCOHF-12	Department of Vegetable Science, COH&F, Neri, Hamirpur
13.	LGCOHF-13	Department of Vegetable Science, COH&F, Neri, Hamirpur
14.	LGCOHF-14	Department of Vegetable Science, COH&F, Neri, Hamirpur
15.	LGCOHF-15	Department of Vegetable Science, COH&F, Neri, Hamirpur
16.	LGCOHF-16	Department of Vegetable Science, COH&F, Neri, Hamirpur
17.	LGCOHF-17	Department of Vegetable Science, COH&F, Neri, Hamirpur
18.	LGCOHF-18	Department of Vegetable Science, COH&F, Neri, Hamirpur
19.	LGCOHF-19	Department of Vegetable Science, COH&F, Neri, Hamirpur
20.	LGCOHF-20	Department of Vegetable Science, COH&F, Neri, Hamirpur

21.	LGCOHF-21	Department of Vegetable Science, COH&F, Neri, Hamirpur
22.	LGCOHF-22	Department of Vegetable Science, COH&F, Neri, Hamirpur
23.	LGCOHF-23	Department of Vegetable Science, COH&F, Neri, Hamirpur
24.	LGCOHF-24	Department of Vegetable Science, COH&F, Neri, Hamirpur
25.	LGCOHF-25	Department of Vegetable Science, COH&F, Neri, Hamirpur
26.	LGCOHF-26	Department of Vegetable Science, COH&F, Neri, Hamirpur
27.	LGCOHF-27	Department of Vegetable Science, COH&F, Neri, Hamirpur
28.	LGCOHF-28	Department of Vegetable Science, COH&F, Neri, Hamirpur
29.	LGCOHF-29	Department of Vegetable Science, COH&F, Neri, Hamirpur
30.	LGCOHF-30	Department of Vegetable Science, COH&F, Neri, Hamirpur
31.	LGCOHF-31	Department of Vegetable Science, COH&F, Neri, Hamirpur
32.	LGCOHF-32	Department of Vegetable Science, COH&F, Neri, Hamirpur
33.	LGCOHF-33	Department of Vegetable Science, COH&F, Neri, Hamirpur
34.	LGCOHF-34	Department of Vegetable Science, COH&F, Neri, Hamirpur
35.	LGCOHF-35	Department of Vegetable Science, COH&F, Neri, Hamirpur
36.	LGCOHF-36	Department of Vegetable Science, COH&F, Neri, Hamirpur
37.	LGCOHF-37	Department of Vegetable Science, COH&F, Neri, Hamirpur
38.	Kandaghat Selection heck variety)	KVK, Kandaghat (UHF, Nauni)

Source: Department of Vegetable Science, COH&F, Neri, Hamirpur

3.2.1 FIELD PREPARATION AND INTERCULTURAL OPERATIONS

The field was ploughed three times at an interval of four days. The last ploughing was followed by planking. The crop was grown as per recommended package of practices for garlic crop.

3.2.2 EXPERIMENTAL DESIGN

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The Plots was randomly selected for planting of each genotype with 3 replications.

Cloves of different genotypes were sown at a spacing of 20×10 cm in a plot size of 1×1 m, accommodating 50 plants/plot.

3.3 Observations recorded

The observations were recorded from ten randomly selected plants from each plot in each replication for distinct morphological characters. The observations of different quantitative and qualitative characters were recorded as follows:

3.3.1 Plant height (cm)

Plant height of ten randomly selected plants was measured from crown portion of the plant to the tip of upper most leaf with the help of a meter scale and then average was worked out.

3.3.2 Number of leaves per plant

From ten randomly selected plants number of leaves per plant were counted and then averaged.

3.3.3 Days to maturity

Days to maturity were recorded when leaves dry completely and 80% neck fall appears.

3.3.4 Neck thickness (cm)

From randomly selected plants, neck thickness was measured with Digital Vernier Caliper and mean was calculated.

3.3.5 Bulb length (cm)

Length was measured with digital Vernier Calliper from the polar side of the ten randomly selected bulbs and average was calculated.

3.3.6 Bulb breadth (cm)

Equatorial diameter of ten randomly selected bulbs was measured with Digital Vernier Calliper and average was worked out.

3.3.7 Bulb weight (g)

Ten bulbs were selected randomly, weighed and average was worked out in grams.

3.3.8 Clove length (cm)

Clove length of ten randomly selected cloves from bulbs was measured with Digital Vernier Calliper and average was calculated.

3.3.9 Clove weight (g)

Ten cloves were selected randomly, weighed and average was worked out.

3.3.10 Number of cloves per bulb

Number of cloves were counted from randomly selected ten bulbs and mean was taken.

3.3.11 Bulb yield per plot (kg)

The bulbs from each plot were harvested. Dried leaves were separated and the bulbs were cured for 2 weeks and weighed. Yield was expressed in kilograms.

3.3.12 Total soluble solids (°Brix)

Garlic cloves were grounded in pestle and mortar. The extract was then squeezed with muslin cloth and a drop of juice was placed on the refractometer. The numbers on the scale were visible when the refractometer was pointed towards a light source which represented the concentration of soluble solids in the garlic extract in °Brix.

3.3.13 Drying percentage (%)

Garlic cloves were peeled and weighed 100 g for each treatment and its replications. Samples were dried at 60 ± 5 °C in a hot air sterilized blower type oven. Cloves were dried until constant weight was obtained. The dry samples were then weighed.

$$\text{Drying percentage(\%)} = \frac{\text{weight after drying}}{\text{weight before drying}} \times 100$$

3.3.14 Disease intensity (if any)

Disease scoring was done after 150, 170, 190 days of planting on ten randomly selected diseased leaves. Further, the genotypes were placed in different categories of resistance and susceptibility. Stemphylium blight intensity was estimated on the basis of leaf area covered by the disease using 0-9 disease-rating scale (Mayee and Datar, 1986).

Table 3.2 Disease rating scale for stemphylium blight intensity

Grade	Leaf area infected (%)
0	Nil
1	< 1%
2	2 - 5 %
3	6 - 10 %
4	11 - 15 %
5	16 - 25 %
6	26 - 40 %
7	41 - 60 %
8	61 - 75 %
9	> 75%

Per cent disease intensity (PDI) was calculated on the basis of rating scale and the total number of leaves observed as given below:

$$\text{PDI (\%)} = \frac{\text{Sum of all disease ratings}}{\text{Total number of leaves observed in all grade} \times \text{Maximum disease grade}}$$

Table 3.3 Categorization of the genotypes for their reaction on the basis of PDI

Disease intensity	Reaction
0 - 10 %	Resistant
11 - 25 %	Moderately Resistant
26 - 50 %	Moderately Susceptible
51 - 75 %	Susceptible
> 75 %	Highly Susceptible

3.4 STATISTICAL ANALYSIS

Analysis of variance was done as suggested by Gomez and Gomez (1983).

3.4.1 ANOVA for RCBD

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F _{cal}
Genotypes	(g-1)	S _g	M _g = S _g / (g-1)	M _g /M _e
Replications	(r-1)	S _r	M _r = S _r /(r-1)	M _r /M _e
Error	(r-1)(g-1)	S _e	M _e = S _e /(r-1)(g-1)	
Total	(rg-1)	S _T		

Where,

R	=	Number of replications
G	=	Number of genotypes
S _r	=	Sum of squares due to replications
S _g	=	Sum of squares due to genotypes
S _e	=	Sum of squares due to error
S _T	=	Total sum of squares
M _r	=	Mean sum of squares due to replications
M _g	=	Mean sum of squares due to genotypes
M _e	=	Mean sum of squares due to error

The replication and entries mean sum of squares was tested against error mean squares by 'F' test at (r-1), (r-1) (g-1) and (g-1), (r-1) (g-1) degree of freedom for RCBD at 5% level of significance.

The calculated F-values were compared with tabulated F- value. When F- test found significant, critical differences were calculated to find out the superiority of one genotype over the others.

Critical difference (CD) was calculated as follows:

$$\begin{aligned} CD_{0.05} &= S.E. (d) \times t_{(0.05) (r-1) (g-1) df} \\ SE (d) \pm &= \sqrt{2 Me/r} \\ SE (m) \pm &= Me/r \end{aligned}$$

Where,

SE (m) ±	=	Standard error of mean
SE (d) ±	=	Standard error of difference
CD _{0.05}	=	Critical difference at 5 per cent level of significance

3.4.2 Parameters of variability

Parameters of variability were estimated as per formula given by Burton and De vane (1953).

3.4.2.1 Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{\text{Phenotypic variance (V}_p)}}{\text{General mean of population (GM)}} \times 100$$

3.4.2.2 Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{\text{Genotypic variance (V}_g)}}{\text{General mean of population (GM)}} \times 100$$

Where:

$$V_e = M_e$$

$$V_g = \text{Genotypic variance } (M_g - M_e) / r$$

$$V_p = \text{Phenotypic variance } (V_g + V_e)$$

3.4.2.3 Heritability

Heritability in broad sense was calculated as per formula given by Burton and Devane (1953) and Allard (1960).

$$H (\%) = \frac{V_g}{V_p} \times 100$$

Where,

$$H = \text{Heritability (\%)}$$

$$V_g = \text{Genotypic variance } [V_g = (M_g - M_e) / r]$$

$$V_p = \text{Phenotypic variance } (V_g + V_e)$$

3.4.2.4 Genetic advance

The expected genetic advance resulting from selection of five percent superior individuals was calculated as per Allard (1960):

$$GA = H \times \sigma_p \times K$$

Where,

$$H = \text{Heritability (\%)}$$

$$\sigma_p = \text{Phenotypic standard deviation}$$

K = Selection differential at 5% selection index (K = 2.06)

3.4.2.5 Genetic gain

Genetic advance expressed as per cent of population mean was calculated by the method given by Johnson *et al.* (1955).

$$GG = \frac{GA}{GM} \times 100$$

Where,

GG = Genetic gain

GA = Genetic advance

GM = Population mean

For categorization of magnitude of different parameters, suggested the following limits:

PCV and GCV > 30% - High
 15-30% - Moderate
 <15% - Low

Heritability >80% - High
 50-80% - Moderate
 < 50% - Low

Genetic gain
 >50% - High
 25-50% - Moderate
 < 25% - Low

3.5 CORRELATION ANALYSIS

The correlations between all characters under study, at genotypic, phenotypic and environmental level were estimated as per the method described by Al-Jibouri *et al.* (1958).

Source of variation	Degree of freedom	Mean sum of square		Mean sum of square	Variation ratio (F- value)
		X	Y		
Replication (r)	r-1				
Genotypes (t)	g-1	$M_g X$	$M_g Y$	$M_g XY = MP_1$	MP_1 / MP_2
Error (r)	(r-1)(g-1)	$M_e X$	$M_e Y$	$M_e XY = MP_2$	

Genotypic, Phenotypic and environmental co-variance between X and Y characters worked out as under:

$$\begin{aligned} \text{Environmental covariance (V}_e \text{XY)} &= \text{MP}_2 \\ \text{Genotypic covariance (V}_g \text{XY)} &= (\text{MP}_1 - \text{MP}_2)/r \\ \text{Phenotypic covariance (V}_p \text{XY)} &= \text{V}_g \text{XY} + \text{V}_e \text{XY} \end{aligned}$$

Where,

$$\begin{aligned} \text{V}_e \text{XY} &= \text{Environmental covariance between X and Y} \\ \text{V}_g \text{XY} &= \text{Genotypic covariance between X and Y} \\ \text{V}_p \text{XY} &= \text{Phenotypic covariance between X and Y} \end{aligned}$$

Coefficients of correlation:

3.5.1 Phenotypic correlation between characters X and Y:

$$r_p = \frac{\text{V}_p \text{XY}}{\sqrt{\text{V}_p \text{X} \times \text{V}_p \text{Y}}}$$

3.5.2 Genotypic correlation between characters X and Y:

$$r_g = \frac{\text{V}_g \text{XY}}{\sqrt{\text{V}_g \text{X} \times \text{V}_g \text{Y}}}$$

3.5.3 Environmental correlation between characters X and Y:

$$r_e = \frac{\text{V}_e \text{XY}}{\sqrt{\text{V}_e \text{X} \times \text{V}_e \text{Y}}}$$

Where,

$\text{V}_p \text{XY}$, $\text{V}_g \text{XY}$, $\text{V}_e \text{XY}$ denotes phenotypic, genotypic and environmental covariances between characters X and Y, respectively.

$\text{V}_p \text{X}$, $\text{V}_g \text{X}$, $\text{V}_e \text{X}$ denotes phenotypic, genotypic and environmental variances between characters X, whereas, $\text{V}_p \text{Y}$, $\text{V}_g \text{Y}$, $\text{V}_e \text{Y}$ denotes phenotypic, genotypic and environmental variances between characters Y.

3.6 PATH COEFFICIENT ANALYSIS

The following formula was used for calculating path coefficient analysis suggested by Dewey and Lu (1959). The path coefficient was obtained by the simultaneous selection of following equations, which express the basic relationship between genotypic correction (r) and path coefficient (P)

$$r_{14} = P_{14} + r_{12} P_{24} + r_{13} P_{34}$$

$$r_{24} = r_{21} P_{14} + P_{24} + r_{23} P_{34}$$

$$r_{34} = r_{31} P_{14} + P_{34} + r_{24} P_{34}$$

where r_{14} , r_{24} and r_{34} are genotypic correlation of components characters with yield (dependent variable) and r_{13} , r_{23} and r_{24} are genotypic correlations among the component characters (independent variable) and $r_{12} P_{24}$, $r_{13} P_{34}$, $r_{21} P_{14}$, $r_{23} P_{34}$, $r_{31} P_{14}$ and $r_{24} P_{34}$ indirect effects.

The direct effects were calculated by the following set of equations:

$$P_{14} = C_{11} r_{14} + C_{12} r_{24} + C_{13} r_{34}$$

$$P_{24} = C_{21} r_{14} + C_{22} r_{24} + C_{23} r_{34}$$

$$P_{34} = C_{31} r_{14} + C_{32} r_{32} + C_{24} r_{34}$$

Where C_{11} , C_{12} , C_{23} and C_{33} are constants and P_{14} , P_{24} and P_{34} are the estimates of direct effects.

3.6.1 Residual effect:

It measures the role of other possible independent variables which were not included in the study on dependent variable. The residual effect was estimated with the help of direct effect and simple correction coefficient as given below:

$$I = P^2_{x4} + P^2_{14} + P^2_{24} + P^2_{34} + 2P_{14}r_{12}P_{24} + 2P_{14}r_{13}P_{34} + 2P_{24}r_{22}P_{34}$$



Plate 1: Field view of experimental garlic crop.

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled “**Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hill conditions of Himachal Pradesh.**” was carried out at Experimental Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (HP) during *Rabi* season of 2020-21. Thirty eight diverse genotypes of garlic including check Kandaghat selection were evaluated for yield and yield contributing characters. The experimental results so obtained are presented under the following sub-heads:

- 4.1 General performance of the genotypes**
- 4.2 Genetic variability**
- 4.3 Phenotypic and genotypic coefficient of variation**
 - 4.3.1 Heritability**
 - 4.3.2 Genetic advance**
 - 4.3.3 Genetic gain**
- 4.4 Correlation coefficient analysis**
- 4.5 Path coefficient analysis**

4.1 GENERAL PERFORMANCE OF THE GENOTYPES

The results of analysis of variance revealed significant differences among genotypes for all the characters under study indicating the presence of sufficient genetic variability in the material (Appendix-II). The mean performances of thirty eight genotypes for various characters studied are described and discussed below:

4.1.1 Plant height (cm)

The analysis of variance indicated significant variation among the genotypes for plant height (Appendix-II) with values ranging from 54.09 cm to 76.48. cm (Table 4.1). Maximum plant height was recorded in the genotype LGCOHF-3 which was statistically at par with LGCOHF-11 (76.26 cm) and LGCOHF-8 (75.76 cm), while minimum plant height was recorded in LGCOHF-21 which was found statistically at par with LGCOHF- 29 (54.31 cm).

Table4.1 Mean performance of garlic genotypes for plant height (cm), number of leaves and neck thickness.

Genotypes	Plant height (cm)	Number of leaves per plant	Neck thickness(cm)
LGCOHF-1	64.03	7.38	0.69
LGCOHF-2	69.06	7.51	0.75
LGCOHF-3	76.48	7.57	0.51
LGCOHF-4	62.04	6.77	1.20
LGCOHF-5	63.70	7.61	0.95
LGCOHF-6	59.21	7.08	0.59
LGCOHF-7	62.28	6.30	0.86
LGCOHF-8	75.76	6.72	1.09
LGCOHF-9	57.70	7.35	0.95
LGCOHF-10	73.06	7.47	1.12
LGCOHF-11	76.26	7.70	0.88
LGCOHF-12	67.19	7.47	0.72
LGCOHF-13	68.06	6.64	0.63
LGCOHF-14	55.78	7.71	1.19
LGCOHF-15	64.95	6.62	0.91
LGCOHF-16	71.41	7.83	0.99
LGCOHF-17	58.15	7.71	1.06
LGCOHF-18	57.21	7.62	0.95
LGCOHF-19	66.01	7.35	0.61
LGCOHF-20	70.78	7.18	0.77
LGCOHF-21	54.08	7.49	0.81

LGCOHF-22	73.79	7.29	0.91
LGCOHF-23	55.68	6.37	0.91
LGCOHF-24	59.15	7.04	1.03
LGCOHF-25	60.70	7.30	1.09
LGCOHF-26	63.94	7.01	0.64
LGCOHF-27	55.50	7.62	0.95
LGCOHF-28	63.34	7.09	0.89
LGCOHF-29	54.31	7.71	0.85
LGCOHF-30	56.10	6.92	0.76
LGCOHF-31	58.67	8.21	0.71
LGCOHF-32	58.92	7.94	0.76
LGCOHF-33	67.25	7.33	0.65
LGCOHF-34	60.92	6.57	0.63
LGCOHF-35	60.47	8.25	0.72
LGCOHF-36	51.08	7.70	1.32
LGCOHF-37	60.72	8.03	0.67
Kandaghat Selection (Check)	65.96	7.82	0.86
Mean	63.15	7.35	0.86
Range	54.09-76.48	6.30-8.25	0.51-1.32
SE(m)	0.36	0.27	0.04
C.V.%	0.98	6.34	7.72
C.D.(0.05)	1.01	0.76	0.11

Twelve genotypes recorded more plant height than the check variety Kandaghat Selection.

Variability in plant height was due to the inherent genetic makeup of the different genotypes. Similar trends for the observations on plant height were reported by Figliuolo *et al.* (2001), Singh and Chand (2003), Alam *et al.* (2010), Panse *et al.* (2013) and Singh *et al.* (2015).

4.1.2 Numbers of leaves per plant

Significant differences were observed among the genotypes for number of leaves per plant, indicating the presence of variability (Appendix-II). Maximum number of leaves per plant was recorded in LGCOHF-35 (8.25) which was found statistically at par with LGCOHF-31, LGCOHF-37, LGCOHF-32, LGCOHF-16, Kandaghat Selection, LGCOHF-29, LGCOHF-14, LGCOHF-36, LGCOHF-18, LGCOHF-27, LGCOHF-5, LGCOHF-3, LGCOHF-2 and LGCOHF-21. Minimum numbers of leaves were recorded in LGCOHF-7. Five genotypes recorded more number of leaves per plant than Kandaghat Selection, check variety. These results are in agreement with the findings of Yadav *et al.* (2012), Pervin *et al.* (2014), Khar *et al.* (2015), Singh *et al.* (2015) and Bhatt *et al.* (2017).

4.1.3 Neck Thickness (cm)

The analysis of variance indicated significant variation among the genotypes for neck thickness (Appendix-II) with values ranging from 0.51-1.32cm. Mean performance of different genotypes has been presented in the (Table 4.1) which depicted that minimum neck thickness was observed in LGCOHF-3 (0.51 cm) which was statistically at par with LGCOHF-6 (0.59 cm) and LGCOHF-19 (0.61 cm) while maximum neck thickness was recorded in LGCOHF-36 (1.32 cm). The perusal of data indicates the mean neck thickness was (0.86 cm). The check variety, Kandaghat Selection recorded 0.86 cm neck thickness. 17 genotypes observed less neck thickness than check variety. The findings of Yadav *et al.* (2012), Panse *et al.* (2013) and Singh *et al.* (2015) are in close harmony with the results of present study.

Table4.2: Mean performance of garlic genotypes for bulb length (cm), bulb breadth (cm) and bulb weight (g).

Genotypes	Bulb length (cm)	Bulb breadth (cm)	Bulb weight (g)
LGCOHF-1	3.83	3.80	34.26
LGCOHF-2	3.50	5.09	27.41
LGCOHF-3	2.82	3.46	31.56
LGCOHF-4	3.71	3.72	20.71
LGCOHF-5	3.17	4.47	34.00
LGCOHF-6	2.89	3.81	22.73
LGCOHF-7	3.78	4.76	25.26
LGCOHF-8	3.66	5.19	26.11
LGCOHF-9	4.34	4.55	37.40
LGCOHF-10	2.96	5.39	36.62
LGCOHF-11	4.35	5.16	28.43
LGCOHF-12	2.89	4.23	27.57
LGCOHF-13	2.79	3.34	27.22
LGCOHF-14	4.40	6.34	33.16
LGCOHF-15	3.54	4.27	27.71
LGCOHF-16	4.60	4.86	24.06
LGCOHF-17	4.40	5.16	34.89
LGCOHF-18	4.59	4.54	35.41
LGCOHF-19	3.58	3.77	30.77

LGCOHF-20	3.55	4.42	22.81
LGCOHF-21	3.96	5.13	35.63
LGCOHF-22	3.67	3.62	30.70
LGCOHF-23	2.92	3.37	22.19
LGCOHF-24	3.25	3.61	28.45
LGCOHF-25	3.63	4.28	22.73
LGCOHF-26	2.78	4.37	26.48
LGCOHF-27	4.40	5.40	34.30
LGCOHF-28	3.62	4.99	36.41
LGCOHF-29	4.54	4.56	34.20
LGCOHF-30	3.80	4.38	32.64
LGCOHF-31	3.70	5.26	34.24
LGCOHF-32	3.35	4.28	36.31
LGCOHF-33	3.53	4.27	18.31
LGCOHF-34	3.38	4.25	36.44
LGCOHF-35	4.43	6.08	38.86
LGCOHF-36	4.60	5.98	37.87
LGCOHF-37	3.27	4.48	24.44
Kandaghat Selection (Check)	3.45	4.92	39.63
Mean	3.68	3.68	30.47
Range	2.78-4.60	3.34-6.34	18.31-39.63
SE(m)	0.17	0.10	0.74
C.V.%	8.07	3.95	4.20
C.D.(0.05)	0.48	0.29	2.09

4.1.4 Bulb length (cm)

Bulb length revealed significant variation among the genotypes. The mean performance of different genotype for bulb length is presented in table 4.2. Mean bulb length of 3.68cm was observed. Maximum bulb length was recorded in LGCOHF-36 and LGCOHF-16 (4.60 cm each) which was found statistically at par with LGCOHF-18, LGCOHF-29, LGCOHF-35, LGCOHF-14, LGCOHF-17, LGCOHF-27, LGCOHF-11 and LGCOHF-9. Minimum bulb length was observed in LGCOHF-26 followed by LGCOHF-13, LGCOHF-3, LGCOHF-6, LGCOHF-12, LGCOHF-23, LGCOHF-10 and LGCOHF-5. Twenty four genotypes recorded more bulb length than check variety Kandaghat Selection. These findings are in accordance with the work of Alam *et al.* (2010), Tsega *et al.* (2011), Panse *et al.* (2013) and Vatsyayan *et al.* (2013) who reported significant variation among the genotypes for bulb length in garlic. Yadav *et al.* (2012) and Kumar *et al.* (2017) reported mean bulb length of 3.69 cm and 4.24 cm, respectively in garlic.

4.1.5 Bulb breadth (cm)

Significant variation was recorded for bulb breadth among the genotypes. The average bulb breadth for different genotypes is presented in table 4.2, being maximum in LGCOHF-14 which was found statistically at par with LGCOHF-35 (6.08 cm) and minimum in LGCOHF-13 followed by LGCOHF-24 (3.61) and with LGCOHF-22 (3.62). The population mean for bulb breadth was 3.68 cm. Twelve genotypes were observed to have more bulb breadth than Kandaghat selection. These findings are in agreement with the results of Osman and Moustafa (2009), Alam *et al.* (2010), Tsega *et al.* (2011), Yadav *et al.* (2012), Panse *et al.* (2013), Khar *et al.* (2015), Sandhu *et al.* (2015), Singh *et al.* (2015) and Vatsyayan *et al.* (2013) reported mean bulb breadth in garlic.

4.1.6 Bulb weight (g)

The bulb weight exhibited significant variation among the genotypes ranging from 18.31 to 39.63 g (Table 4.2). The perusal of data indicated that the mean bulb weight for all the genotypes was 30.47 g. Bulb weight was maximum (39.63 g) in Kandaghat Selection and was observed statistically at par with LGCOHF-35 (38.86), LGCOHF-36 (37.87),

LGCOHF-9 (37.40) and LGCOHF-10 (36.62). Minimum bulb weight was recorded in LGCOHF-33 (18.31g) which was statistically different from other genotypes. Present results were confirmed by the findings of Gupta *et al.* (2007), Osman and Moustafa (2009), Tsega *et al.* (2011), Sandhu *et al.* (2015) and Singh *et al.* (2015) who also reported that different garlic genotypes differed significantly for average bulb weight.

4.1.7 Clove length (cm)

The analysis of variance indicated significant variation among genotypes for the clove length, which varied from 1.12 to 3.36 cm (Table 4.3). Clove length was found maximum in LGCOHF-8 which was found statistically at par with LGCOHF-9, Kandaghat Selection, LGCOHF-17, LGCOHF-32, LGCOHF-31, LGCOHF -35 and LGCOHF-2 while minimum in LGCOHF-19 (1.12 cm). Two genotypes recorded more clove length than check variety Kandaghat Selection. The results are in close conformity with Tsega *et al.* (2011) and Yadav *et al.* (2012), Vatsyayan *et al.* (2013), Singh *et al.* (2015) and Kumar *et al.* (2017), who reported that different garlic genotypes differed significantly for clove length.

Table 4.3: Mean performance of garlic genotypes for clove length (cm), clove weight (g) and number of cloves per bulb.

Genotypes	Clove length (cm)	Clove weight (g)	Number of cloves per bulb
LGCOHF-1	2.80	3.04	11.37
LGCOHF-2	3.12	2.35	13.44
LGCOHF-3	2.78	1.78	24.18
LGCOHF-4	2.64	1.83	29.82
LGCOHF-5	2.78	3.37	11.27
LGCOHF-6	2.66	1.48	14.93
LGCOHF-7	2.36	3.08	18.49

LGCOHF-8	3.36	2.23	19.23
LGCOHF-9	3.34	4.13	8.54
LGCOHF-10	2.91	3.41	13.43
LGCOHF-11	2.90	2.47	12.52
LGCOHF-12	2.37	2.37	14.19
LGCOHF-13	1.93	1.39	19.34
LGCOHF-14	2.95	3.21	8.92
LGCOHF-15	2.67	2.35	17.59
LGCOHF-16	2.29	1.92	11.99
LGCOHF-17	3.14	2.95	12.32
LGCOHF-18	2.89	3.24	10.03
LGCOHF-19	1.12	2.17	22.74
LGCOHF-20	2.80	2.35	14.43
LGCOHF-21	3.09	3.62	12.71
LGCOHF-22	2.67	2.20	14.32
LGCOHF-23	2.50	1.64	8.77
LGCOHF-24	2.66	2.28	17.38
LGCOHF-25	3.09	2.50	15.45
LGCOHF-26	2.63	1.76	23.11
LGCOHF-27	3.03	3.02	12.42
LGCOHF-28	3.11	3.39	9.98
LGCOHF-29	3.10	2.13	15.32
LGCOHF-30	2.98	2.37	13.59
LGCOHF-31	3.13	3.28	10.82

LGCOHF-32	3.14	3.42	10.05
LGCOHF-33	2.89	2.23	11.29
LGCOHF-34	3.01	3.32	14.16
LGCOHF-35	3.13	3.28	13.76
LGCOHF-36	2.80	3.44	9.58
LGCOHF-37	1.38	2.43	22.15
Kandaghat Selection (Check)	3.22	4.27	12.15
Mean	2.77	2.68	14.63
Range	1.12-3.36	1.39-4.27	8.54-29.82
SE(m)	0.08	0.17	0.47
C.V.%	5.28	11.16	5.58
C.D.(0.05)	0.24	0.49	1.33

4.1.8 Clove weight (g)

The clove weight is an important trait which effects the production and productivity directly. The clove weight exhibited significant variation among the genotypes varied from 1.39 to 4.27 g (Table 4.3). The population mean was 2.68 g. Maximum clove weight of 4.27 g was recorded in Kandaghat Selection which was observed statistically at par with LGCOHF-9 (4.13) whereas, minimum was in LGCOHF-13 (1.39) followed by LGCOHF-6 (1.49 g), LGCOHF-23 (1.64), LGCOHF-26 (1.76), LGCOHF-3 (1.78) and LGCOHF-4 (1.83). The variability for clove weight in garlic has also been reported by Tsega *et al.* (2011), Singh *et al.* (2012), Panse *et al.* (2013), Sandhu *et al.* (2015) and Singh *et al.* (2015).

4.1.9 Number of cloves per bulb

Significant differences among the genotypes were observed for number of cloves per bulb which ranged from 8.54 to 29.82 (Table 4.3). Maximum number of cloves per bulb was

found in LGCOHF-4 (29.82) which was statistically different for other genotypes. Minimum number of cloves per bulb was found in LGCOHF-9 (8.54) followed by LGCOHF-23 (8.77), LGCOHF-14 (8.92) and LGCOHF-36 (9.58). Twelve genotypes recorded less number of cloves per bulb than check variety Kandaghat Selection. Twenty five genotypes recorded more number of cloves per bulb than check variety Kandaghat Selection. Significant amount of variability for number of cloves per bulb is also reported by Tsega *et al.* (2011), Singh *et al.* (2012), Yadav *et al.* (2012), Panse *et al.* (2013), Vatsyayan *et al.* (2013), Pervin *et al.* (2014), Singh *et al.* (2015) and Kumar *et al.* (2017).

4.1.10 Total soluble solids (°B)

Significant amount of variability was recorded for total soluble solids which varied from 18.19 - 33.30 °B (Table 4.4). It was found maximum in LGCOHF-10 (33.30 °B) which was statistically different for other genotypes. While, total soluble solids was minimum in LGCOHF-4 (18.19°B). Nine genotypes were observed to have more total soluble solids than Kandaghat Selection, the check variety. Variations for total soluble solids has also been reported by Vatsyayan *et al.* (2013), Singh *et al.* (2015), Kumar *et al.* (2017) and Bhatt *et al.* (2017).

4.1.11 Drying percentage (%)

Significant variation was recorded for drying percentage among the genotypes. The average bulb breadth for different genotypes is presented in table 4.4. The population mean for drying percentage was 39.75 %. Maximum drying percentage of 44.47% was found in Kandaghat Selection, the check variety, while minimum (36.53%) was recorded in LGCOHF- 12 followed by LGCOHF-20 (36.54%), LGCOHF-15 (37.18%), LGCOHF-1 (37.39%) and LGCOHF-24 (37.68%). Similar results for drying percentage has also been reported by Singh and Chand (2003), Verma *et al.* (2004), Vatsyayan *et al.* (2013), Khar *et al.* (2015) and Sandhu *et al.* (2015).

4.1.12 Days to Maturity

The values ranged between 195.44 to 230.73 days for days to maturity (Table 4.5) depicting significant variations. Mean value for days to maturity was 217.25 days. Minimum days were

Table4.4: Mean performance of garlic genotypes for TSS (°B) and drying percentage (%).

Genotypes	TSS (°Brix)	Drying percentage (%)
LGCOHF-1	31.36	37.39
LGCOHF-2	25.03	38.98
LGCOHF-3	25.29	40.58
LGCOHF-4	18.19	42.18
LGCOHF-5	27.14	39.11
LGCOHF-6	24.16	40.95
LGCOHF-7	31.14	42.65
LGCOHF-8	26.08	39.56
LGCOHF-9	25.32	39.09
LGCOHF-10	33.30	38.73
LGCOHF-11	25.21	39.43
LGCOHF-12	27.15	36.53
LGCOHF-13	23.04	42.17
LGCOHF-14	29.29	38.93
LGCOHF-15	27.66	37.18
LGCOHF-16	26.17	41.06
LGCOHF-17	28.13	39.94
LGCOHF-18	25.57	39.37
LGCOHF-19	24.17	40.21
LGCOHF-20	23.08	36.54
LGCOHF-21	21.62	38.25

LGCOHF-22	26.31	41.02
LGCOHF-23	25.20	40.44
LGCOHF-24	28.14	37.68
LGCOHF-25	22.35	38.41
LGCOHF-26	25.37	39.39
LGCOHF-27	27.29	42.21
LGCOHF-28	20.17	38.85
LGCOHF-29	30.62	38.35
LGCOHF-30	25.69	39.96
LGCOHF-31	23.64	37.74
LGCOHF-32	30.47	42.71
LGCOHF-33	21.85	38.78
LGCOHF-34	24.24	40.05
LGCOHF-35	23.21	40.66
LGCOHF-36	28.96	39.84
LGCOHF-37	26.17	40.96
Kandaghat Selection (Check)	27.88	44.47
Mean	25.94	39.75
Range	18.19-33.30	36.53-44.47
SE(m)	0.08	0.41
C.V.%	0.55	1.78
C.D.(0.05)	0.23	1.15

taken by the LGCOHF-3(195.44) which was observed statistically at par with LGCOHF-33 (195.50) and LGCOHF-25 (195.89). Maximum days (230.73) were taken by LGCOHF-37. Kandaghat Selection took 227.51 days to maturity. Thirty six genotypes recorded less number of days to maturity than check variety. Similar findings have also been reported by Gowda *et al.* (2007), Gupta *et al.* (2007), Tsega *et al.* (2011), Yadav *et al.* (2012) and Panse *et al.* (2013).

4.1.13 Bulb yield per plot

The analysis of variance indicated significant differences among the genotypes for bulb yield per plot which ranged from 0.92 - 1.98 kg per plot (Table 4.5). Maximum yield was obtained from Kandaghat Selection (1.98 kg) which was found statistically at par with LGCOHF-35 (1.94 kg), LGCOHF-32 (1.93kg), LGCOHF-36 (1.89kg), LGCOHF-9 (1.88kg) and LGCOHF-18 (1.85kg). The lowest bulb yield was recorded in LGCOHF-33 (0.92 kg) followed by LGCOHF-4 (1.04kg). Similar results for bulb yield per plot is reported by Kadu *et al.* (2005), Shashidhar *et al.* (2005), Vashisht and Singh (2005), Yadav *et al.* (2012), Panse *et al.* (2013) and Vatsyayan *et al.* (2013).

Table4.5: Mean performance of garlic genotypes for days to maturity, bulb yield per plot (kg) and diseases intensity.

Genotypes	Days to maturity	Bulb yield per plot (Kg)	Disease intensity (%)
LGCOHF-1	222.52	1.71	29.78 (33.06)
LGCOHF-2	225.34	1.37	16.21 (23.73)
LGCOHF-3	195.44	1.58	36.02 (36.87)
LGCOHF-4	226.26	1.04	16.50 (23.95)
LGCOHF-5	223.47	1.70	40.49 (39.50)
LGCOHF-6	198.37	1.14	36.74 (37.29)
LGCOHF-7	220.25	1.26	27.84 (31.83)

LGCOHF-8	218.35	1.31	23.67 (29.10)
LGCOHF-9	217.48	1.89	16.59 (24.03)
LGCOHF-10	222.45	1.83	19.57 (26.24)
LGCOHF-11	212.44	1.42	33.68 (35.46)
LGCOHF-12	216.32	1.38	28.65 (32.35)
LGCOHF-13	222.89	1.36	40.07 (39.26)
LGCOHF-14	216.51	1.76	18.62 (25.55)
LGCOHF-15	200.37	1.39	29.57 (32.93)
LGCOHF-16	201.37	1.20	36.43 (37.11)
LGCOHF-17	217.63	1.81	12.14 (20.38)
LGCOHF-18	223.41	1.85	7.47 (15.86)
LGCOHF-19	215.38	1.54	39.86 (39.13)
LGCOHF-20	198.51	1.14	17.23 (24.51)
LGCOHF-21	224.52	1.78	11.81 (20.09)
LGCOHF-22	225.59	1.54	17.75 (24.91)
LGCOHF-23	222.55	1.11	36.84 (37.36)
LGCOHF-24	222.77	1.42	23.79 (29.18)
LGCOHF-25	195.89	1.14	23.98 (29.31)
LGCOHF-26	224.65	1.32	33.74 (35.50)
LGCOHF-27	226.71	1.72	9.16 (17.60)
LGCOHF-28	223.97	1.82	13.80 (21.80)
LGCOHF-29	222.33	1.71	16.48 (23.93)
LGCOHF-30	220.80	1.63	26.75 (31.13)
LGCOHF-31	218.75	1.71	7.54 (15.90)

LGCOHF-32	216.55	1.93	7.35 (15.72)
LGCOHF-33	195.50	0.92	39.75 (39.07)
LGCOHF-34	212.81	1.82	37.99 (38.03)
LGCOHF-35	226.00	1.94	10.21 (18.62)
LGCOHF-36	223.11	1.89	9.95 (18.37)
LGCOHF-37	230.73	1.22	40.62 (39.58)
Kandaghat Selection (Check)	227.51	1.98	7.55 (15.95)
Mean	217.25	1.534	23.74
Range	195.44-230.73	0.92-1.98	7.35-40.62
SE(m)	0.36	0.05	0.40
C.V.%	0.29	5.12	2.91
C.D.(0.05)	1.01	0.13	1.12

(Figures in parentheses are angular transformed values)

4.1.14 Intensity of stemphylium blight

Percent disease intensity (PDI) for stemphylium blight ranged between 7.35 to 40.62 % (Table 4.5) and mean PDI was 23.74 %. Minimum PDI (7.35 %) was recorded in the LGCOHF-32 which was statistically at par with LGCOHF-18 (7.47 %), LGCOHF-31 (7.54%), Kandaghat Selection (7.55%), while maximum PDI (40.62 %) was recorded in LGCOHF-37 which was found statistically at par with LGCOHF-5 (40.49 %), LGCOHF-13(40.07) and LGCOHF-19 (39.86). Three genotypes were observed to have less PDI than Kandaghat Selection. The severity of stemphylium blight are reported by Mishra *et al.* (2009) and Singh *et al.* (2012). LGCOHF-2, LGCOHF-4, LGCOHF-8, LGCOHF-9, LGCOHF-10, LGCOHF-14, LGCOHF-17, LGCOHF-20, LGCOHF-21, LGCOHF-22, LGCOHF-24, LGCOHF-25, LGCOHF-27, LGCOHF-28, LGCOHF-29, LGCOHF-35 and LGCOHF-36 were moderately resistant to the disease. None of the genotypes was found to be susceptible for stemphylium blight.

Table4.6: Diseases reaction of garlic genotypes against stemphylium blight:

DISEASE REACTION	GENOTYPES
RESISTANT	LGCOHF-32, LGCOHF-18, LGCOHF-31 and Kandaghat selection.
MODERATELY RESISTANT	LGCOHF-2, LGCOHF-4, LGCOHF-8, LGCOHF-9, LGCOHF-10, LGCOHF-14, LGCOHF-17, LGCOHF-20, LGCOHF-21, LGCOHF-22, LGCOHF-24, LGCOHF-25, LGCOHF-27, LGCOHF-28, LGCOHF-29, LGCOHF-35 and LGCOHF-36.
MODERATELY SUSCEPTIBLE	LGCOHF-1, LGCOHF-3, LGCOHF-5, LGCOHF-6, LGCOHF-7, LGCOHF-11, LGCOHF-12, LGCOHF-13, LGCOHF-15, LGCOHF-16, LGCOHF-19, LGCOHF-23, LGCOHF-26, LGCOHF-30, LGCOHF-33, LGCOHF-34 and LGCOHF-37.
SUSCEPTIBLE	NONE
HIGHLY SUSCEPTIBLE	NONE

4.2 GENETIC VARIABILITY

The estimates of variability *viz.*, coefficients of variability (phenotypic and genotypic), heritability (in broad sense) and genetic advance as per cent of mean (genetic gain) were worked out to facilitate selection for various characters. The results pertaining to different parameters of variability are presented in Table 4.7.

Coefficients of variation

The estimates of coefficients of variability (phenotypic and genotypic) depicted a clear picture of extent of variability present in the available germplasm. For all the characters studied, phenotypic coefficients of variability were higher in magnitude than the corresponding genotypic coefficients of variability, though the difference was less in majority of cases thus, indicating that environmental factors have played less influence on the expression of these characters. Coefficients of variability varied in magnitude *i.e.* either low or moderate or high, indicating that there was a substantial variation in the experimental material used.

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) have been tabulated in Table 4.7. The investigation showed considerable extent of variability for all the characters studied. The phenotypic and genotypic coefficients of variation were higher for stemphylium blight incidence (48.33% and 48.42%) and number of cloves per bulb (32.62 % and 33.46%) respectively, indicating further scope of improvement and facilitating the selection for these characters. The results are in line with the finding of Tsega *et al.* (2011), Vatsyayan *et al.* (2013) and Khar *et al.* (2015), Singh *et al.* (2012) who recorded high estimates of phenotypic and genotypic coefficients of variation for characters like stemphylium blight and number of cloves per bulb.

Moderate phenotypic and genotypic coefficients of variation were observed for clove weight (26.34% and 28.61%), neck thickness (21.92% and 23.24%), bulb yield per plot (19.18% and 19.85%), bulb weight (18.75% and 19.21%), clove length (16.79% and 17.60%), bulb length (15.83% and 16.88%) and bulb breadth (16.18% and 16.66%) respectively. Singh *et al.* (2012), Yadav *et al.* (2012) and Panse *et al.* (2013) have also reported moderate estimates of phenotypic and genotypic coefficients of variation for clove length, bulb weight and clove weight. Moderate estimates of phenotypic and genotypic coefficients of variation for characters like bulb breadth, clove length and neck thickness have been observed by Vatsayayan *et al.* (2013). Yadav *et al.* (2012) and Panse *et al.* (2013).

Low estimates of phenotypic and genotypic coefficients of variation were recorded for total soluble solids (12.32% and 12.34%), plant height (10.62% and 10.67%), number of leaves per plant (5.55% and 8.43%), days to maturity (4.68% and 4.69%) and drying percentage (4.38% and 4.73%) respectively. Similar findings are also observed by Tsega *et al.* (2011), Singh *et al.* (2012), Panse *et al.* (2013), Pervin *et al.* (2014) and Sandhu *et al.* (2015). Gupta *et al.* (2007), Yadav *et al.* (2012) and Panse *et al.* (2013) reported low amount of variability for days to maturity. Low phenotypic and genotypic coefficients of variation are also reported by Vatsyayan *et al.* (2013) for drying percentage, Khar *et al.* (2015) and Sandhu *et al.* (2015) for total soluble solids.

4.2.2 Heritability

The estimate of genotypic coefficient of variation does not offer full scope to judge the inheritance of a particular trait. Therefore, estimation of heritability for different traits becomes imperative for genetic improvement. Burton and De-Vane (1953) has suggested that genetic coefficient of variability along with heritability estimates would give a reliable indication of expected amount of improvement through selection. High heritability (>80 %) indicates that a large proportion of phenotypic variance is attributed to genotypic variance, and reliable selection could be made for the characters on the basis of phenotypic variation.

In the present investigation, estimates of heritability (broad sense) varied from 43.43-99.16% (Table 4.7). High heritability was recorded for the characters *viz.* plant height (99.16%), total soluble solids (97.80%), bulb weight (97.22%), diseases intensity (95.64%), bulb weight (95.21%), bulb breadth (94.38%), bulb yield per plot (93.34%) clove length (91.00%), days to maturity (89.63), neck thickness (88.97%), drying percentage (85.81%) and clove weight (84.79%). Moderate heritability was recorded for bulb length (77.17%). Low heritability was recorded for number of leaves per plant (43.43%).

High heritability for plant height, bulb weight, bulb yield per plot, number of cloves per bulb are also reported by Gupta *et al.* (2007), Dhall and Brar (2013). Further Pervin *et al.* (2014), Sharma *et al.* (2016) and Singh *et al.* (2018), have reported high heritability for total soluble solids, length of clove, weight of clove, neck thickness, days to maturity and bulb breadth. High heritability for these characters indicates that these traits are least influenced by the environment and selection could be the important elements for crop improvement.

4.2.3 Genetic advance and genetic gain

Genetic advance is defined as genetic improvement of a particular trait achieved through selection annually. Genetic gain is the percentage of population mean. The estimates of heritability alone are not sufficient for predicting the effect of selection and therefore the genetic advance/gain is also equally important. Genetic gain pertaining to different traits is presented in

table 4.7. High genetic gain was observed for diseases intensity (99.38%), number of cloves per bulb (67.01%) and clove weight (50.97%). These result are similar to the findings of Sable *et al.* (2020), Choudhary *et al.* (2017), Vatsyayan *et al.* (2013) and Singh *et al.* (2012).

Moderate genetic gain was recorded for characters viz. neck thickness (42.60%), bulb yield per plot (38.17%), bulb weight (37.68%), clove length (32.99%), bulb breadth (32.38%), bulb length (26.83%) and total soluble solids (25.36%). These results are similar to the finding of Divya *et al.* (2021), Kumari (2021) have reported moderate genetic gain for nick thickness, bulb breadth and clove length. Bekis (2020) and Sharma *et al.* (2016) have observed moderate genetic gain for bulb yield per plot, bulb length and bulb weight.

Low genetic gain was recorded for plant height (21.79%), days to maturity (9.62%), drying percentage (8.36%) and number of leaves per plant (7.54%) which points toward the existence of non-additive gene action. Bhatt *et al.* (2017), Khar *et al.* (2015) and Vatsyayan *et al.* (2013) have also reported low genetic gain for plant height, days to maturity, drying percentage and number of leaves per plant.

4.3 CORRELATION COEFFICIENT ANALYSIS

Correlation coefficient is estimated between yield and other characters at genotypic and phenotypic levels to know the inter relationship among the characters. It provides information about the nature, extent and direction of selection pressure to be applied. Yield is a complex character controlled by several yield contributing components and is highly influenced by environmental factors. Hence, knowledge of association of characters with yield is important for making selection.

In the present study, the estimates of phenotypic and genotypic correlation coefficients were observed for different characters and same have been presented in table 4.8. In general the estimates of genotypic correlations are higher than their respective phenotypic correlations for all the traits, indicating inherent relationship. Genotypic correlation provides measure of genetic association between traits and is more reliable than phenotypic correlation.

Table 4.7: Estimates of Range, Phenotypic and Genotypic coefficients of variation, heritability, genetic advance and genetic gain (%).

Character	Range	Mean Range \pm SE(d)	Coefficients of variability (%)		Heritability (%)	Genetic Advance	Genetic Gain (%)
			Genotypic	Phenotypic			
Plant height (cm)	54.09-76.48	63.15 \pm 0.51	10.62	10.67	99.16	13.76	21.79
Number of leaves per plant	6.30-8.25	7.35 \pm 0.38	5.55	8.43	43.43	0.55	7.54
Bulb length (cm)	2.78-4.60	3.68 \pm 0.24	15.83	16.88	77.17	0.986	26.83
Bulb breadth (cm)	3.34-6.34	4.57 \pm 0.15	16.18	16.66	94.38	1.48	32.38
Neck thickness (cm)	0.51-1.32	0.86 \pm 0.06	21.92	23.24	88.97	0.37	42.60
Bulb weight (gm)	18.31-39.63	30.47 \pm 1.05	18.75	19.21	95.21	11.48	37.68
Number of cloves per bulb	8.54-29.82	14.63 \pm 0.67	32.62	33.46	97.22	9.80	67.01
Clove weight (gm)	1.39-4.27	2.68 \pm 0.24	26.34	28.61	84.79	1.34	50.97
Clove length (cm)	1.12-3.36	2.77 \pm 0.12	16.79	17.60	91.00	0.92	32.99
Total Soluble Solids (B)	18.19-33.30	25.94 \pm 0.12	12.32	12.34	97.80	6.58	25.36
Drying percentage (%)	36.53-44.47	39.75 \pm 0.58	4.38	4.73	85.81	3.32	8.36
Days to maturity	195.44-23.73	217.25 \pm 0.56	4.68	4.69	89.63	20.90	9.62
Disease intensity	7.35-40.62	23.72 \pm 0.51	48.33	48.42	95.64	23.59	99.38
Bulb yield per plot (kg)	0.92-1.98	1.534 \pm 0.06	19.18	19.85	93.34	0.59	38.17

4.3.1 Bulb yield per plot

Bulb yield per plot has positive and significant correlation with plant height (0.327 and 0.319), number of leaves per plant (0.571 and 0.341), bulb length (0.396 and 0.321), bulb breadth (0.475 and 0.442), bulb weight (1.000 and 0.987), clove weight (0.809 and 0.720), clove length (0.421 and 0.393) and days to maturity (0.442 and 0.429). Negatively significant correlation with number of cloves per bulb (-0.467 and -0.443) at both genotypic and phenotypic levels respectively. Khar *et al.* (2005), Baghalian *et al.* (2006) and Singh *et al.* (2006) have reported similar findings.

4.3.2 Plant height

Plant height has positive and significant association with bulb length (0.365 and 0.315), bulb breadth (0.210 and 0.203), bulb weight (0.308 and 0.300), number of clove per bulb (0.321 and 0.315), clove weight (0.339 and 0.303), bulb yield per plot (0.327 and 0.319). Negatively significant correlation was obtained for neck thickness (-0.217 and -0.203), days to maturity (-0.315 and -0.313) at both genotypic and phenotypic levels, respectively. Similar findings have been observed by Agrawal and Tiwari (2009), Singh *et al.* (2011) and Barad *et al.* (2012).

4.3.3 Number of leaves per plant

Number of leaves per plant has positive and significant association with bulb length (0.511 and 0.285), bulb breadth (0.610 and 0.389), bulb weight (0.558 and 0.326), clove weight (0.463 and 0.331) and bulb yield per plot (0.571 and 0.341). Negatively significant correlation was obtained for number of cloves per bulb (-0.392 and -0.238) at both genotypic and phenotypic levels, respectively. These observations are similar to the findings of Singh *et al.* (2006) and Patil *et al.* (2012).

4.3.4 Bulb length

Bulb length has positive and significant association with bulb weight (0.635 and 0.544), neck thickness (0.503 and 0.420), bulb weight (0.377 and 0.311), clove weight (0.409 and

0.366), clove length (0.316 and 0.303) and bulb yield per plot (0.396 and 0.321). Negatively significant correlation was obtained for number of cloves per bulb (-0.409 and -0.354) at both genotypic and phenotypic levels, respectively and are similar to the findings of Panse et al. (2013), Singh et al. (2013), and Ijaz *et al.* (2015).

4.3.5 Bulb breadth

Bulb breadth has positive and significant association with neck thickness (0.456 and 0.398), bulb weight (0.467 and 0.437), clove weight (0.602 and 0.548), clove length (0.437 and 0.404), days to maturity (0.223 and 0.217) and bulb yield per plot (0.475 and 0.442). Negatively significant correlation was obtained for number of cloves per bulb (-0.432 and -0.420) at both genotypic and phenotypic levels, respectively. Similar findings of Figliuolo *et al.* (2001) and Singh *et al.* (2013) have been reported.

4.3.6 Neck thickness

Neck thickness has positive and significant association with clove weight (0.278 and 0.268), clove length (0.321 and 0.259) and days to maturity (0.203 and 0.193). Negatively significant correlation was obtained for number of cloves per bulb (-0.212 and -0.201) at both genotypic and phenotypic levels, respectively and are similar to the findings of Singh *et al.* (2006) and Patil *et al.* (2012).

4.3.7 Bulb weight

Bulb weight has positive and significant association with clove weight (0.802 and 0.722), clove length (0.410 and 0.392), days to maturity (0.453 and 0.441) and bulb yield per plot (1.000 and 0.987). Negatively significant correlation was obtained for number of cloves per bulb (-0.447 and -0.427) at both genotypic and phenotypic levels, respectively. Similar findings of Agarwal and Tiwari (2009), Panse et al. (2013), Singh et al. (2013), and Ijaz *et al.* (2015) have been reported.

4.3.8 Number of cloves per bulb

Number of cloves per bulb has positive and significant association with drying percentage (0.209) at genotypic level only. Negatively significant correlation was obtained

for clove weight (-0.588 and -0.519), clove length (-0.504 and -0.473) and bulb yield per plot (-0.467 and -0.443) at both genotypic and phenotypic levels, respectively are similar to the findings of Khar *et al.* (2005) and Ijaz *et al.* (2015).

4.3.9 Clove weight

Cloves weight has positive and significant association with clove length (0.491 and 0.441), days to maturity (0.344 and 0.318) and bulb yield per plot (0.809 and 0.720) at both genotypic and phenotypic levels, respectively was found similar to the findings of Yadav *et al.* (2007), Dubey *et al.* (2010) and Singh *et al.* (2013).

4.3.10 Clove length

Clove length has positive and significant association with bulb yield per plot (0.421 and 0.393) at both genotypic and phenotypic levels, respectively. Similar findings of Sonkiya *et al.* (2012) and Singh *et al.* (2013) have also been reported.

4.3.11 Total Soluble Solids

Total Soluble Solids has positive and significant association with days to maturity (0.214 and 0.213) at both genotypic and phenotypic levels, respectively. Panse *et al.* (2013), Singh *et al.* (2013), and Ijaz *et al.* (2015) have also reported similar findings.

4.3.12 Drying percentage

Drying percentage has positive and significant association with days to maturity (0.270 and 0.249) at both genotypic and phenotypic levels, respectively. Similar findings of Dubey *et al.* (2010) and Bhatt *et al.* (2017) have also been reported.

4.3.13 Days to maturity

Days to maturity has positive and significant association with bulb yield per plot (0.442 and 0.429) at both genotypic and phenotypic levels, respectively. Singh *et al.* (2006) and Patil *et al.* (2012) have reported similar findings.

Table 4.8: Genotypic coefficients of correlation among different traits in garlic.

	PH	NLPP	BL	BB	NT	BWT	NCPB	CW	CL	TSS	DP	DTM	BYPP
PH	1	0.113	0.365**	0.210*	-0.217*	0.308**	0.321**	0.339**	0.143	0.095	-0.015	-0.315**	0.327**
NLPP		1	0.511**	0.610**	0.001	0.558**	-0.392**	0.463**	0.174	-0.024	-0.043	0.131	0.571**
BL			1	0.635**	0.503**	0.377**	-0.409**	0.409**	0.316**	-0.053	-0.015	0.122	0.396**
BB				1	0.456**	0.467**	-0.432**	0.602**	0.437**	-0.076	-0.062	0.223*	0.475**
NT					1	0.114	-0.212*	0.278**	0.321**	0.157	-0.008	0.203*	0.13
BWT						1	-0.447**	0.802**	0.410**	0.082	0.071	0.453**	1.000**
NCPB							1	-0.588**	-0.504**	0.12	0.209*	-0.029	-0.467**
CW								1	0.491**	0.066	0.027	0.344**	0.809**
CL									1	0.012	-0.162	-0.022 ^{NS}	0.421**
TSS										1	0.134	0.214*	0.107
DP											1	0.270**	0.08
DTM												1	0.442**
BYPP													1

PH= Plant height, NLPP= Number of leaves per plant, BL= Bulb length, BB= Bulb breadth, NT= Neck thickness, BWT= Bulb weight, NCPB= Number of cloves per bulb, CW= Clove weight, CL= Clove length, TSS= Total soluble solids, DP= Drying percentage, DTM= Days to maturity, BYPP= Bulb yield per plot.

Residual effect: -0.00456

* significant at 5 % level of significance

** significant at 1 % level of significance

Table 4.8: Phenotypic coefficients of correlation among different traits in garlic.

	PH	NLPP	BL	BB	NT	BWT	NCPB	CW	CL	TSS	DP	DTM	BYPP
PH	1	0.057	0.315**	0.203*	-0.203*	0.300**	0.315**	0.303**	0.134	0.094	-0.010	-0.313**	0.319**
NLPP		1	0.285**	0.389**	0.012	0.326**	-0.238*	0.331**	0.118	-0.012	0.012	0.088	0.341**
BL			1	0.544**	0.420**	0.311**	-0.354**	0.366**	0.303**	-0.039	-0.005	0.109	0.321**
BB				1	0.398**	0.437**	-0.420**	0.548**	0.404**	-0.072	-0.046	0.217*	0.442**
NT					1	0.096	-0.201*	0.268**	0.259**	0.145	-0.039	0.193*	0.119
BWT						1	-0.427**	0.722**	0.392**	0.078	0.063	0.441**	0.987**
NCPB							1	-0.519**	-0.473**	0.119	0.181	-0.028	-0.443**
CW								1	0.441**	0.061	0.027	0.318**	0.720**
CL									1	0.016	-0.131	-0.019	0.393**
TSS										1	0.124	0.213*	0.102
DP											1	0.249**	0.074
DTM												1	0.429**
BYPP													1

PH= Plant height, NLPP= Number of leaves per plant, BL= Bulb length, BB= Bulb breadth, NT= Neck thickness, BWT= Bulb weight, NCPB= Number of cloves per bulb, CW= Clove weight, CL= Clove length, TSS= Total soluble solids, DP= Drying percentage, DTM= Days to maturity, BYPP= Bulb yield per plot.

* significant at 5 % level of significance

** significant at 1 % level of significance

4.4 PATH COEFFICIENT ANALYSIS

Path coefficient analysis depicts the effects of different independent characters individually and in combination with other characters on the expression of dependent character. It is an important tool for partitioning the correlation coefficients into direct and indirect effects of independent variables on a dependent variable. It provides an effective means of a critical examination of specific force action to produce a given correlation and measure the relative importance of each factor. In this analysis, bulb yield per plot was taken as dependent variable and rest of the characters were considered as independent variables.

Path coefficient analysis (Table 4.9) revealed positive and direct effect of bulb weight (0.993) followed by total soluble solids (0.039), drying percentage (0.016) and bulb breadth (0.011) on bulb yield per plot. Whereas, negative direct effect was observed of days to maturity (-0.038) followed by number of cloves per bulb (-0.034), clove length (-0.025), clove weight (-0.022), plant height (-0.020), neck thickness (-0.013), number of leaves per plant (-0.004) and bulb length (0.003) on bulb yield per plot.

Regarding indirect effects, it was found that highest indirect positive effect of clove weight was observed via. bulb weight (0.796). Plant height and number of leaves per plant showed maximum positive indirect effect via. days to maturity (0.012) and bulb weight (0.554) respectively. Bulb length and bulb weight showed maximum positive indirect effect via. bulb weight (0.374 and 0.463) respectively. Neck thickness and bulb weight showed maximum positive indirect effect via. bulb weight (0.114) and number of cloves per bulb (0.015) respectively. Number of cloves per bulb showed maximum positive indirect effect via. clove weight (0.013). Clove weight, clove length, total soluble solids, drying percentage and days to maturity showed positive indirect effect via. bulb weight (0.796, 0.407, 0.081, 0.071 and 0.449) respectively.

On the other hand, the highest indirect negative effect was of number of clove per plant via. bulb weight (-0.444). Plant height showed maximum negative indirect effect via. bulb weigh(-0.306).

Table 4.9: Path coefficient analysis showing direct and indirect effect of different traits on bulb yield per plot.

	PH	NLPP	BL	BW	NT	BWT	NCPB	CW	CL	TSS	DP	DTM	BYPP
PH	-0.021	0.001	0.001	-0.002	0.001	-0.306	-0.011	0.007	0.004	0.004	0.000	0.012	-0.327
NLPP	0.002	-0.004	-0.002	0.007	0.000	0.554	0.013	-0.010	-0.004	-0.001	-0.001	-0.005	0.571
BL	0.008	-0.002	-0.003	0.007	-0.001	0.374	0.014	-0.009	-0.008	-0.002	0.000	-0.005	0.396
BW	0.004	-0.003	-0.002	0.011	-0.001	0.463	0.014	-0.013	-0.011	-0.003	-0.001	-0.008	0.475
NT	0.005	0.010	-0.002	0.005	-0.013	0.114	0.007	-0.006	-0.008	0.006	0.000	-0.008	0.13
BWT	0.006	-0.002	-0.001	0.005	0.000	0.993	0.015	-0.018	-0.010	0.003	0.001	-0.017	1.000
NCPW	-0.007	0.002	0.001	-0.005	0.001	-0.444	-0.034	0.013	0.012	0.005	0.003	0.001	-0.467
CW	0.007	-0.002	-0.001	0.007	-0.001	0.796	0.020	-0.022	-0.012	0.003	0.000	-0.013	0.809
CL	0.003	-0.001	-0.001	0.005	-0.001	0.407	0.017	-0.011	-0.025	0.000	-0.003	0.001	0.421
TSS	-0.002	0.000	0.000	-0.001	0.000	0.081	-0.004	-0.001	0.000	0.039	0.002	-0.008	0.107
DP	0.000	0.000	0.000	-0.001	0.000	0.071	-0.007	-0.001	0.004	0.005	0.016	-0.010	0.08
DTM	0.007	-0.001	0.000	0.002	-0.001	0.449	0.001	-0.008	0.001	0.008	0.004	-0.038	0.442

PH= Plant height, NLPP= Number of leaves per plant, BL= Bulb length, BB= Bulb breadth, NT= Neck thickness, BWT= Bulb weight, NCPB= Number of cloves per bulb, CW= Clove weight, CL= Clove length, TSS= Total soluble solids, DP= Drying percentage, DTM= Days to maturity, BYPP= Bulb yield per plot.

Number of leaves per plant, bulb length, bulb weight showed maximum negative indirect effect via. clove weight (-0.010, -0.009 and -0.013) respectively. Neck thickness showed maximum negative indirect effect via. clove length and days to maturity (-0.008 each). Bulb weight and number of cloves per bulb showed highest negative indirect effect via. clove weight (-0.018) and bulb weight (-0.444) respectively. Clove weight and clove length showed maximum negative indirect effect via. days to maturity (-0.013) and clove weight (-0.011) respectively. Total soluble solids and drying percentage maximum negative indirect effect via. days to maturity (-0.008 and -0.010 each). Days to maturity showed maximum negative indirect effect via. clove weight (-0.008).

Dubey *et al.* (2010) and Singh *et al.* (2013) are in accordance with present work who reported that bulb weight had highest positive direct effect on bulb yield per plot. Mishra and Gautam (2000) and Singh *et al.* (2006) found direct positive effect of dry matter content towards bulb yield. Singh *et al.* (2008) observed negative and direct effect of bulb length as well as number of cloves per bulb on bulb yield. Yadav *et al.* (2007) reported negative direct effect of bulb length and clove length on bulb yield. Negative direct effect of bulb length and number of cloves per bulb on total bulb yield was observed by Singh *et al.* (2013). Dhall and Brar (2013) reported negative and direct effect of clove length and number of cloves per bulb on bulb yield.

In the present investigation, bulb weight exhibited high positive and direct effect and had significant positive correlation with bulb yield per plot. Therefore, this character should be considered while improving the garlic yield.



Kandaghat Selection



LGCOHF-18



LGCOHF-35



LGCOHF-9

Plate 2: Promising Genotypes of Garlic

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled “**Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hill conditions of Himachal Pradesh.**” was carried out with thirty eight diverse genotypes of garlic, including Kandaghat Selection as check variety to ascertain the variability, heritability, correlations and path coefficient analysis. The experiment was laid out in Randomized Complete Block Design at Experimental Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (HP). The seed sowing was done on 14 October 2020 at a spacing of 20 x 10 cm in a plot size of 1 x 1 m. The observations were recorded on various characters *viz.*, plant height (cm), number of leaves per plant, days to maturity, neck thickness (cm), bulb length (cm), bulb breadth (cm), bulb weight (g), clove length (cm), clove weight (g), number of cloves per bulb, bulb yield per plot (kg), total soluble solids (^oBrix), drying percentage (%) and disease intensity. The results obtained from the present studies are summarized as under:

Parameters of variability and correlation were estimated for different characters and path coefficient analysis was carried out for bulb yield per plot with other horticultural traits. Analysis of variance revealed highly significant differences among genotypes for all the horticultural characters. Maximum plant height was recorded in LGCOHF-3, while minimum in LGCOHF-21. Maximum number of leaves per plant was recorded in LGCOHF-35, whereas LGCOHF-7 had minimum number of leaves per plant. Neck thickness was maximum in LGCOHF-36 and minimum in LGCOHF-3. Maximum bulb length was observed in LGCOHF-36, while it was minimum in LGCOHF-26. Bulb breadth was maximum in LGCOHF-14. Kandaghat Selection and LGCOHF-33 recorded maximum and minimum bulb weight, respectively. Maximum clove length was found for LGCOHF-8, while minimum in LGCOHF-19. Clove weight was maximum for Kandaghat Selection, while minimum in LGCOHF-13. Highest number of cloves per bulb were observed in LGCOHF-4, while minimum in LGCOHF-9. Total soluble solids were found maximum in LGCOHF-10, while minimum in LGCOHF-12. Maximum extent of drying percentage was found in Kandaghat Selection whereas, minimum in LGCOHF-12

Maximum days to maturity was taken by LGCOHF-37 and was minimum in LGCOHF-3. Kandaghat Selection recorded maximum bulb yield per plot, while LGCOHF-33 recorded minimum bulb yield per plot. Stemphylium blight intensity was minimum in LGCOHF-37, while maximum for LGCOHF-32.

Parameters of variability

High estimates of phenotypic and genotypic coefficients of variation were obtained for stemphylium blight incidence and number of cloves per bulb, indicating further scope of improvement of these characters through selection. Moderate phenotypic and genotypic coefficients of variation were observed for clove weight, neck thickness, bulb yield per plot, bulb weight, clove length, bulb length and bulb breadth. Low estimates of phenotypic and genotypic coefficients of variation were recorded for total soluble solids, plant height, number of leaves per plant, days to maturity and drying percentage.

High heritability coupled with high genetic gain was recorded for number of cloves per bulb, clove weight and stemphylium blight intensity. High heritability with moderate genetic gain was recorded for bulb breadth, neck thickness, bulb weight, clove length, TSS and bulb yield per plot. High heritability with low genetic gain was recorded for plant height, number of leaves per plant, drying percentage and days to maturity. High heritability coupled with high genetic gain indicates the preponderance of additive gene action thereby showing the importance of selection for further improvement for these traits.

Correlation studies

The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. The results showed that genotypic correlations in general, were higher in magnitude than phenotypic ones. Bulb yield per plot was positively and significantly associated with plant height, number of leaves per plant, bulb length, bulb breadth, bulb weight, clove weight, clove length and days to maturity whereas, negatively and significantly associated with number of cloves per bulb.

Path coefficient analysis

Path coefficient analysis revealed positive and direct effect of bulb yield per plot via. bulb weight followed by total soluble solids, drying percentage and bulb breadth. Whereas, negative direct effects were observed for days to maturity followed by number of cloves per

bulb, clove length, clove weight, plant height, neck thickness, number of leaves per plant and bulb length on bulb yield per plot. Maximum positive indirect effect on yield was observed through clove weight. Number of cloves per bulb had maximum negative indirect effect on yield followed by bulb breadth, bulb length, clove length, number of cloves per bulb and total soluble solids.

Table 5.1 Best three genotypes with respect to different characters in garlic

Character	Genotypes	Mean
Plant height	LGCOHF-3	76.48
	LGCOHF-11	76.26
	LGCOHF-8	75.76
Number of leaves per plant	LGCOHF-35	8.25
	LGCOHF-31	8.21
	LGCOHF-37	8.03
Neck thickness	LGCOHF-36	1.32
	LGCOHF-4	1.20
	LGCOHF-14	1.19
Bulb length	LGCOHF-36	4.60
	LGCOHF-16	4.60
	LGCOHF-18	4.59
Bulb breadth	LGCOHF-14	6.34
	LGCOHF-35	6.08
	LGCOHF-36	5.98
Bulb weight	Kandaghat Selection	39.63
	LGCOHF-35	38.86
	LGCOHF-36	37.87
Clove length	LGCOHF-8	3.36
	LGCOHF-9	3.34
	Kandaghat Selection	3.22
Clove weight	Kandaghat Selection	4.27
	LGCOHF-9	4.13
	LGCOHF-21	3.62
Number of cloves per bulb	LGCOHF-9	8.54
	LGCOHF-23	8.77
	LGCOHF-14	8.92

Total soluble solids	LGCOHF-10	33.30
	LGCOHF-1	31.36
	LGCOHF-29	30.62
Drying percentage	Kandaghat Selection	44.47
	LGCOHF-32	42.71
	LGCOHF-7	42.65
Days to maturity	LGCOHF-37	230.73
	Kandaghat Selection	227.51
	LGCOHF-27	226.71
Bulb yield per plot	Kandaghat Selection	1.98
	LGCOHF-35	1.94
	LGCOHF-32	1.93
Disease intensity	LGCOHF-32	7.35
	LGCOHF-18	7.47
	LGCOHF-31	7.54

Conclusion

From the present study, it can be concluded that adequate variability was present among the genotypes for growth, yield and quality characters. LGCOHF-35, LGCOHF-32, LGCOHF-9 and LGCOHF-18 genotypes performed better than the check variety Kandaghat Selection for number of leaves per plant, bulb breadth, bulb length, clove length and days to maturity. These genotypes were also statistically at par with check variety Kandaghat Selection for bulb weight, drying percentage, clove weight and bulb yield per plot. The LGCOHF-32, LGCOHF-18, LGCOHF-31 and Kandaghat Selection showed field resistance against stemphylium blight.

High heritability coupled with high to moderate genetic gain for most of the characters, indicating the effect of additive gene effect for the expression of different characters. Bulb yield per plot was positively and significantly associated with majority of the yield contributing characters whereas, negatively and significantly associated with number of cloves per bulb. Positive and direct effect of bulb yield per plot was observed through bulb weight followed by total soluble solids, drying percentage and bulb breadth.

Therefore, on the basis of the present investigation, four genotyped *viz.* LGCOHF-35, LGCOHF-32, LGCOHF-9 and LGCOHF-18 can be released as variety/varieties after further evaluation or can be used as a source of resistance against Stemphylium blight.

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APPENDIX- I
Mean metrological data during the study period (2020-21)

Month	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	Rainfall (mm)
October	28.60	58.00	34.60
November	23.80	57.00	7.60
December	19.40	62.00	18.80
January	19.40	56.00	4.00
February	21.00	56.00	35.60
March	24.2	55.00	88.50
April	29.4	45.00	30.60
May	30.5	46.00	115.00

**Source: Meteorological Observatory, Department of Soil Science and Water
Management, College of Horticulture and Forestry, Neri, Hamirpur HP
177 001**

APPENDIX- II

Analysis of variance (ANOVA) for various horticultural traits in garlic

Source	Mean sum of squares		
Character	Replications	Genotype	Errors
Df	2	37	74
Plant height (cm)	1.183	36.219	0.384
Number of leaves per plant	0.055	0.912	0.089
Bulb length (cm)	0.101	0.645	0.005
Bulb breadth (cm)	0.064	0.701	0.101
Neck thickness (cm)	0.003	0.435	0.012
Bulb weight (gm)	1.012	87.023	0.834
Number of cloves per bulb	0.098	0.603	0.278
Clove weight (gm)	0.012	1.642	0.022
Clove length (cm)	0.004	0.123	0.002
Total Soluble Solids (B)	0.364	20.032	0.435
Drying percentage (%)	0.203	2.012	0.237
Days to maturity	2.52	48.231	0.936
Disease intensity	0.024	30.294	0.312
Bulb yield per plot (kg)	0.004	0.273	0.004

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Title of Thesis : “Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hills conditions of Himachal Pradesh”

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Abstract

The present investigation entitled “Genetic evaluation of local genotypes of Garlic (*Allium sativum* L.) under low hills conditions of Himachal Pradesh” was conducted at the experimental farm” was carried out at Vegetable Research Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (H.P) during season, 2021. Thirty eight diverse genotypes of garlic comprising of local collections along with standard checks Kandaghat Selection were evaluated in Randomized Complete Block Design with three replications to ascertain extent of variability, heritability, genetic advance and gain, correlation and path coefficient analysis for yield and other horticultural traits among the genotypes. Analysis of variance revealed significant differences among all the genotypes for all the characters under study. Genotypes viz., LGCOHF-LGCOHF-35, LGCOHF-32, LGCOHF-9 and LGCOHF-18 genotypes performed better than the check variety Kandaghat Selection for number of leaves per plant, bulb breadth, bulb length, clove length and days to maturity. LGCOHF-32, LGCOHF-18, LGCOHF-31 and Kandaghat Selection exhibited field resistance against the stemphylium blight. High heritability coupled with high to moderate genetic gain for most of the characters, indicating the effect of additive gene effect for the expression of different characters. Bulb yield per plot was positively and significantly associated with majority of the yield contributing characters whereas, negatively and significantly associated with number of cloves per bulb. Positive and direct effect of bulb yield per plot was observed through bulb weight followed by total soluble solids, drying percentage and bulb breadth

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Certificate/ degree	Year	University/ Board	Marks (%)	Division
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Graduation	2019	Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P)	80.4	FIRST

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