# ASSESSMENT OF GENETIC VARABILITY, CORRELATION AND PATH ANALYSIS STUDIES IN RADISH (*Raphanus sativus* L.)

*Thesis*

**by**

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**(NH-2018-39-M)**

**submitted to**

**Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY SOLAN (NAUNI) HP - 173 230 INDIA**

**in**

**partial fulfilment of the requirements for the degree**

**of**

**MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE**

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## CERTIFICATE-I

This is to certify that the thesis entitled, **"Assessment of genetic variability, correlation and path analysis studies in radish (*Raphanus sativus* L.)"** 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) – 173 230 is a bonafide research work carried out by **Mr Ajay Singh** (NH-2018-39-M) son of Sh. Shamsher Singh under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

**Place: Neri, Hamirpur**
**Date: 26th August, 2020**

**Dr Shiv Pratap Singh**
**Chairman**
**Advisory Committee**

## CERTIFICATE-II

This is to certify that the thesis entitled, **"Assessment of genetic variability, correlation and path analysis studies in radish (*Raphanus sativus* L.)"**,submitted by **Mr Ajay Singh** (NH-2018-39-M) son of Sh Shamsher Singh to the Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 India in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE** in the discipline of **HORTICULTURAL SCIENCE** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an Internal Examiner.

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**Dated: 26th August, 2020** **(Ajay Singh)**

# CONTENTS

# ABBREVIATIONS

| | | |
|---|---|---|
| % | : | Percent |
| = | : | Equal to |
| × | : | Multiplication |
| $^0$C | : | Degree Celsius |
| ANNOVA | : | Analysis of Variance |
| C.V. | : | Coefficient of Variation |
| CD | : | Critical Difference |
| *et al.* | : | co–workers |
| etc. | : | *etcetera* |
| g | : | Gram |
| HP | : | Himachal Pradesh |
| m$^2$ | : | Meter square |
| mg | : | Milligram |
| mm | : | Millimeter |
| NHB | : | National Horticulture Board |
| SE | : | Standard error |
| UHF | : | University of Horticulture and Forestry |
| CoH&F | : | College of Horticulture and Forestry |
| *viz.* | : | 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 |
| cv | : | Cultivar |
| pH | : | Power of hydrogen |
| i.e | : | That is |

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# *Chapter-1*

# INTRODUCTION

Radish (*Raphanus sativus* L.) is a diploid plant (2n=2x=18) belongs to family *Brassicaceae* or *Cruciferae* originated from the Central and Western China and India. It is one of the most ancient vegetables. It was cultivated about 2700 B.C. Radish is a major root vegetable grown worldwide in both tropical and temperate regions of the world. It is an ancient domesticated vegetable, originally grown in China and Korea (Kaneko & Matsuzawa, 1993). It is grown for its young fleshy tuberous roots and hypocotyls, consumed mainly as a salted vegetable, eaten as grated radish, garnish and salad. Radish roots have many shapes ranging from round to oval, icicle, half long and long (conical, cylindrical or spindle shape with blunt or semi-blunt end). They also vary in terms of size, time of root formation, length of time they remain suitable for making salad. The skin colour of radish may vary from white to pink, red, black and various other shades. Besides the roots and green leaves, the pods called as *Moongra* is usually eaten raw and cooked as a vegetable.

Radish forms an important dietary component in day to day human food. Radish is low in calories and good source of vitamin C, protein, fat, minerals, fiber and carbohydrates (Singh and Nath, 2012). Radish leaves are more nutritious than their roots. Pink skinned varieties of radish in comparison to white skinned varieties generally contain high ascorbic acid. The pink colour of radish roots is due to the presence of anthocyanin pigment. The high nutritional value of radish is considered quite useful for patients with piles, hepatic disorders, increased spleen and jaundice (Brar and Nandpuri, 1972). Black radish juice contains tonic and has laxative action on intestine and indirectly stimulates the flow of bile.

The characteristic pungent flavor and taste of radish roots is due to the high volatile isothiocyanate alkaloid content (trans-4methyl thiobutenyl isothiocyanate), which is more synthesized at high temperatures. Radish's black to red color is due to anthocyanins, the most versatile polyphenols. They possess neutraceutical, coloring and anti-oxidant properties (Horbowicz *et al.*, 2008, Jing *et al.*, 2014).

Radish is mainly a cool season vegetable crop and is divided into two groups: Asian or tropical and European or temperate. Asian types can tolerate high temperatures in comparison to temperate types. Asian types are sown from August-January in the low hills of Himachal Pradesh and North Indian plains. The Asian type yields roots and seeds under both tropical and temperate climates. In India radish is grown over an area of 2,02,000 hectare with an annual production of 31,45,000 MT (Anonymous, 2019). The major states where radish is grown on a large scale are West Bengal, Bihar, Uttar Pradesh, Karnataka, Punjab, Maharashtra and Assam. In Himachal Pradesh, radish is grown in an area of 1,950 hectare with a production of 39,760 MT (Anonymous, 2018).

Four species of Alternaria *viz. A. raphanin, A. brassiciciola, A. brassicae* and *A. alternata* have been reported to be associated with radish crop from different parts of the world (Rashid and Hossain, 2011). This pathogen attacks all the above ground parts of the plant producing severe spotting and blighting on leaves, shoots and pods. Islam *et al.* (2007) described that infection of *Alternaria brassicae* was optimum at 25 C on older leaves. Ghimimire *et al*. (2016) reported that the severe infection of Alternaria was associated with low temperature with high relative humidity (more than 90%) with an average rainfall of 0.3mm. The chemical control is very costly and ineffective. Therefore, identification of some genotypes which are resistant to this disease can help to develop some new improved Alternaria resistant varieties in radish.

The genetic improvement of the crop depends on the amount of genetic variability present in the population and the germplasm serves as a valuable source of base population and provides the possibility for wide variability (Vavilov, 1951). The role of genetic variation in a crop is of paramount importance in selecting the best genotypes for rapidly improving yield and desirable horticultural characteristics, as well as in selecting the most suitable parents for further breeding programme. Genetic variability study helps in understanding the nature of variation in different horticultural traits both quantitative and qualitative respectively. Variations may be caused by environmental factors, genetic factors, mutations or by attacks by any biological agents. Genetic variation is important in a given germplasm and is a fundamental necessity for crop improvement, as it provides more opportunities for selection to implement an efficient and productive breeding programme. It is therefore essential to know the amount of genetic variability available and the efficacy of the selection depends on the magnitude of genetic variability present in the given set of germplasm collected from indigenous and exotic sources. Further the extent of heritability helps the breeder to identify the traits which can be easily selected. Genetic advance explains the degree of gain obtained in a given character under a particular selection pressure. Estimates of heritability with genetic advance are more reliable and meaningful. The correlation studies help the breeder to know about the type of association between the various traits in a given set of germplasm. The path coefficient analysis helps to work out the direct and indirect effect of the various horticultural traits on the dependent character like yield.

Therefore, there is a necessity to conduct genetic studies for the computation of various genetic parameters and characterization of the superior genotypes of radish for different horticultural traits including yield and disease resistance to Alternaria blight under low hill conditions of Himachal Pradesh. Hence, the present investigation entitled **"Assessment of genetic variability, correlation and path analysis studies in radish (*Raphanus sativus* L.)"** was carried out at experimental farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri Hamirpur with the following objectives:

1. To study the performance and extent of genetic variability in the radish genotypes.
2. To estimate heritability and genetic advance.
3. To study the character association and path analysis for different traits in various radish genotypes.
4. To identify the best genotype with desirable horticultural traits.

# *Chapter-2*

# REVIEW OF LITERATURE

The review of literature pertaining to the present investigation with title **"Assessment of genetic variability, Correlation and path analysis studies in Radish (*Raphanus sativus* L.)"** under appropriate heading is as follows:

i. Genetic variability
ii. Heritability and Genetic Advance
iii. Correlation
iv. Path analysis

## i.) Genetic variability

Genetic variability is the basis of all plant improvement programs, and if present, it can be exploited for the development of superior varieties of crops. Vavilov (1951) first realized that a wider range of variation in any crop provides better opportunities to pick desirable types. The various parameters like range and coefficients of variation are the measures of variability. The higher values of GCV in comparison to PCV indicate that there is little influence of environment on the expression of character and selection is effective for such traits. However, higher values of PCV reflect the role of environment in controlling a particular trait.

Nijjar *et al*. (1996) evaluated 30 radish cultivars for genetic variation in terms of ascorbic acid and isothiocyanate content. The studies indicated highly significant variations for both the characters among different genotypes. The high amount of ascorbic acid was found in radish cultivars *viz.* Punjab Safed (349.10 µg/100g), Pusa Chetki (332.80 µg/100g), Pusa Himani (400.70 µg/100g) and Selection 4 (345.10 µg/100g).

Anjanappa *et al*. (1998) studied 5 radish cultivars and found that the plant height was greatest for the cultivars Local (51.84 cm) and Arka Nishant (50.80 cm). While it was least for Pusa Chetki (39.19 cm). Root shape also varied from tapering (Local) to conical (Arka Nishant); however, most of the varieties were cylindrical. Flesh colour of Chinese Pink was pink whereas that of Arka Nishant was white. The highest root to leaf ratio was found in the cultivar Arka Nishant and the lowest was observed in cultivar Chinese Pink.

In an investigation carried out at Assam by Langthasa and Baruah (2000) in nine radish cultivars it was found that the cultivar Bombay Red (339.7 q/ha) recorded the highest root yield. The duration of crop maturity was longest for the cultivar Japanese White (54.3 days) and shortest for the Crimson French Breakfast (28.3 days). However, the highest root width was recorded in Pusa Chetki (5.65 cm) and lowest root width in Long White Icicle (3.23 cm).

Badiger *et al*. (2001) studied yield and quality characters in radish cv. KSSC-01, KSSC-02 and KSSC-03 under Bangalore, Karnataka conditions. They found the highest number of leaves (11.94), root weight (161.67 g), root yield (69.40 t/ha) and root length (15.12 cm) in KSSC-03 while lowest root cracking (15.35 %) incidence was observed in KSSC-01.

The study on the performance of seven cultivars of radish by Ahmad *et al*. (2003) suggested that the significant variation was found in different traits while the differences in root diameter were non-significant.

Singh *et al.* (2005) conducted study on the genetic variability and character association in 21diverse genotypes of radish under temperate conditions of Kashmir and recorded high value of GCV and PCV for root yield, average root weight, average leaf weight, root length and root diameter.

The research findings of Singh and Taj (2005) on the performance of 20 radish cultivars under rainfed conditions of Nagaland suggested significant variations for all the growth and yield parameters due to variations found in different cultivars.

Obiadalla *et al.* (2006) evaluated 15 radish cultivars for various horticultural characters including yield. The observations were recorded for character number of root leaves, whole plant flesh weight, root/whole plant percentage, net root weight and total plant weight. Cultivar New White Chinese had the highest root weight (129.9g), leaf (216.4g) and whole plant fresh weight (391.2g). White Icicle recorded the highest value (80.12%) for root/whole plant percentage; while, Crimson Giant had the lowest value for root/whole plant percentage (24.52%).

Mukhdoomi *et al*. (2007) estimated parameters for genetic variability in twenty-three cultivars of radish and revealed highly significant variances among genotypes for all the horticultural traits and found that both phenotypic and genotypic coefficient of variability were high for all the characters except for days to maturity, dry matter content and ascorbic acid content of roots.

In a study conducted by Mapari *et al*. (2009) on genetic variability among 24 genotypes of radish for different traits the highest genotypic coefficient of variation as well as phenotypic coefficient of variation were recorded in fresh weight of leaves.

Khan *et al*. (2011) assessed 20 genotypes of radish to study the genetic variability, heritability and genetic advance in radish and reported that both genotypic as well as phenotypic coefficient of variation were high for number of leaves, leaf weight, total plant weight, root yield/plant, acidity and ascorbic acid.

Ullah *et al.* (2010) conducted an experiment on genetic variability in 21 varieties of radish and reported that root length, leaf length and root yield showed high genotypic coefficients of variation and heritability. However, the highest value of genetic advance was observed in the horticultural trait root yield.

Jatoi *et al.* (2011) evaluated 49 local and exotic radish genotypes including two check cultivars. The genetic variation was apparent for most of the characters like plant biomass, root weight, leaf length, root length and root diameter. While higher variation was observed in root shape, root length, root colour, flesh texture and root type.

Kumar *et al.* (2012) studied the variability and divergence for horticultural traits in 35 genotypes of temperate radish during the months of September–January in 2009–2010 and reported that CGN-17290 had 51% more yield over the check 'White Icicle' and performed better for plant emergence (19.28 %), days to marketable maturity (26.00 days), leaf length (24.05 cm), leaf width (11.09), root/top ratio (4.03), root length (22.73 cm), dry matter (5.50 %), average root weight (36.09), and fiber content (0.12 %). The genotypes CGN-23811, CGN-11997, and CGN-11994 performed better than the check for total soluble solids, ascorbic acid, and total sugar. Whereas, high coefficients of variability (phenotypic and genotypic) were found for root length, average root weight, total soluble solids, root/top ratio, fiber content, and total sugar, indicating close association between phenotype and genotypes.

In an investigation conducted by Sivathanu *et al.* (2014) to check the seasonal effect on variability and trait relationship in radish on 10 genotypes for 14 characters during the rabi, summer and kharif seasons the various parameters like mean performance, variability and character association were worked out. They found that various traits like number of leaves, root diameter, fresh weight of the plant, dry weight of the plant and fresh weight of root per plant had high genetic variability.

Mallikarjunarao *et al.* (2015) evaluated twenty-four genotypes of radish during Rabi season 2011-12 at the Research Farm Division of Vegetable Science SKUAST-Kashmir and reported that the genotypic as well as phenotypic coefficients of variation were high for number of leaves, leaf weight, total plant weight, root yield/plant, acidity, and ascorbic acid.

Nagar *et al.* (2016) conducted a study on genetic variability in temperate radish at Garhwal Hills with 21 genotypes of radish during Rabi season of 2014-15 for different horticultural traits. They recorded moderate phenotypic and genotypic coefficients of variation for the traits *viz*. root weight without leaves, leaf weight, root weight with leaves, root diameter and root length.

A study was carried out by Dongarwar *et al.* (2017) on 7 varieties of radish i.e. Pusa Desi, Pusa Chetki, Pusa Reshmi, Pusa Himani, Japanese White, Arka Nishant and IHR-1-1. They found that maximum plant height (28.29 cm) and chlorophyll content of leaves (3.10 mg/g) were there in cultivar Arka Nishant. Total fresh weight of plant (190.06 g to 226.60 g) were again observed maximum in variety Arka Nishant; while, minimum values of these traits were reported in variety Pusa Desi. The fresh weight of root ranged from 122.76 g to 161.74 g. The maximum root to shoot ratio (1.37) was observed in variety Arka Nishant. The maximum value of root diameter (3.69 cm) was found in variety Arka Nishant. The maximum root yield per plot (32.34 kg $plot^{-1}$) and $hectare^{-1}$ (53.91 t $ha^{-1}$) was observed in variety Arka Nishant. The maximum moisture content of root (97.75%) was recorded in Arka Nishant variety. The maximum ascorbic acid content (18.36 mg 100 $g^{-1}$) and TSS (4.00 °B) was recorded in the variety Arka Nishant.

Roopa *et al.* (2018) evaluated 35 genotypes of radish for different horticultural characters and reported the highest genotypic co-efficient of variation as well as phenotypic co-efficient of variation for the character root to leaf ratio among various yield attributing traits and calcium content among various biochemical parameters. Almost all the traits exhibited high heritability ranging from 73.85-99.96%.

An experiment was conducted by Singh *et al.* (2019) during Rabi season of 2014-15 on nine genotypes of radish and reported that minimum leaf weight was observed in Hong Kong-11 (10.4 g) and maximum in the genotype Pusa Himani (17.56 g). The maximum leaf length was recorded in the cultivar Pusa Reshmi (18.80 cm) and minimum in Suneha (11.63 cm). However, the maximum root length was recorded in genotype Pusa Himani (24.40 cm) and minimum was in Suneha (19.00 cm). The maximum root thickness was recorded in Pusa Himani (5.26 cm) and minimum in Snow White (3.40 cm). Maximum fresh root weight was recorded in Pusa Himani (85.53 g) and minimum in Suneha (63.80 g). Whereas, the maximum yield was recorded in Pusa Himani (34.14 t/ha) followed by Pusa Reshmi (32.65 t/ha) and Japanese White (32.28 t/ha) while minimum in Suneha (26.27 t/ha).

Semba *et al.* (2019) carried a study on the performance of six different varieties of radish under foot hill region of Dehradun and revealed that maximum plant height (60.53 cm), leaf length (32.55 cm), fresh weight of leaves (97.61 g), fresh weight per plant (242.25 g) and total dry weight content (21.05 g) were observed in Menu Early, while the maximum length of roots (34.63 cm), fresh weight of root (160.16 g), total yield of radish root (46.91 t/ha) and the dry weight of radish root (10.96 g) were found in genotype Korean Cross. The maximum width of root (4.44 cm) was recorded in the cultivar Scarlet Red Globe. Among all genotypes for different traits, seed germination (65.47 %), yield of leaves (25.13 t/ha), total yield (69.47 t/ha) and dry weight of leaves (10.17 g) were found maximum in the cultivar Snow White, while maximum number of leaves per plant (18.55) was observed in Local Check.

### ii.) Heritability and Genetic Advance

Heritability is the ratio of genotypic variance or total variance to the phenotypic variance. According to Fisher (1918), the heritable and non-heritable components form the continuous variability displayed by a quantitative individual. Heritable component is there due to the effect of genotype, whereas non-heritable components are caused by environmental factors. Wright (1921) stated that heritability component comprised of additive and non-additive portion and it was the former which responds to the selection. While, under selection, improvement in the mean genotypic value of selected plants over the parental population is known as genetic gain. Genetic advancement success under selection depends on three main factors (Allard, 1960): genetic variability, heritability and intensity of selection. Genetic advance estimates aid in understanding the kind of gene action involved in the expression of various polygenic characters. High genetic benefit values are indicative of the effect of additive and low values are indicative of non-additive gene action.

It is not appropriate that a character showing high heritability will also exhibit high genetic advance (Johnson *et al*. 1955). High heritability along with high genetic advance indicates that the heritability might be due to additive gene effects (Panse, 1957) whereas, the high heritability linked with low genetic advance might be due to non-additive gene action which includes dominance and epistasis (Liang and Walter, 1969). Low heritability along with high genetic advance reveals that the character is governed by additive gene effects. The low heritability is being showed due to high environmental effect.

Iwata *et al.* (2000) studied Japanese radish varieties and found that the root size showed high broad sense heritability but low narrow sense heritability and over dominance. The alleles constructing larger root sizes were mostly dominant. Thus, symmetrical and asymmetrical variations exhibited different mode of inheritance.

Sirohi and Narayanan (2000) estimated genetic analysis of yield and its components in radish and found that additive component of variance was greater than dominance component of variance for most of the traits. They also reported the presence of additive gene actions for five characters *viz*. root weight, shoot weight, leaf length, leaf width and yield per plant which create the possibility to utilize these traits by selection methods in later generations of the hybrid progeny.

A study was conducted by Singh *et al*. (2005) on genetic variability and characters association in 21diverse genotypes of radish under temperate conditions of Kashmir. They reported the high level of heritability coupled with high genetic gain in root yield followed by average root weight, average leaf weight, top: root ratio, root length, root diameter, number of leaves per plant and leaf length which indicates that these characters had additive gene effect and therefore these are more reliable for effective selection.

Kobayashi *et al*. (2007) conducted a trial on diallel analysis of radish to estimate genetic parameters in 13 floral traits and reported broad sense heritability in 12 traits which ranged from 93-99 % and suggested that the character floral morphology was highly heritable. But narrow sense heritability ranged from 34.00-89.00 per cent in the various characters studied.

Mapari *et al*. (2009) evaluated genetic variability in 24 genotypes of radish and reported higher heritability for all the characters (31.42-99.58 %). While, highest genetic advance was found in case of root diameter. However, the value of genetic advance ranged from 3.04 % - 91.12% for all the characters.

An investigation was conducted by Mukhdoomi *et al*. (2010) on twenty-three genotypes of radish and found that the broad sense heritability was high for all the characters while genetic gain was maximum for root length followed by root to shoot ratio.

Ullah *et al.* (2010) studied genetic variability in twenty-one varieties of radish and reported high heritability for characters viz. root length, leaf length, and root yield. However, the highest genetic advance was observed in root yield.

An experiment was conducted by Naseeruddin *et al.* (2011) on twenty genotypes of radish and reported high heritability in broad sense for leaf weight, number of leaves, total plant weight, root weight, total soluble solid and ascorbic acid. Whereas, genetic advance in per cent of mean was maximum for root yield per plant followed by leaf weight.

Tanaka *et al*. (2011) conducted a diallel analysis involving inbred lines of the Japanese radish 'Sakurajima daikon' and found that the root weight showed high broad-sense heritability. However, hollow root occurrence expressed by hollow area ratio exhibited a low broad-sense and narrow-sense heritability.

Tanaka *et al*. (2012) studied diallel analysis of root shape in Japanese radish and reported that the root length exhibited high broad–sense heritability. However, root diameter showed low narrow sense heritability. They reported that the dominant genes for the root length, root diameter, ratio of root diameter to root length and degree of root top width and root bottom roundness had effects to elongate the root length, enlarge root diameter, increase the ratio of the root diameter to root length and increase tapering of the root bottom respectively.

Kumar *et al.* (2012) conducted study on 35 temperate genotypes of radish during the months of September–January in 2009–2010. The observations were made on the characters plant emergence, days to marketable maturity, number of leaves, leaf length, leaf width, root color, root shape, root/top ratio, root length, root diameter, average root weight, crown diameter, dry matter, and contents of total soluble solids, ascorbic acid, total sugar, and fiber and it was found that high heritability, with moderate to high coefficients of variability and high genetic gain were recorded for all characters except plant emergence and days to marketable maturity, indicating the role of additive gene action for the control of inheritance of these characters.

Sivathanu *et al.* (2014) evaluated 10 genotypes for 14 characters during the rabi, summer and kharif seasons to determine mean performance during 2012-2013. They reported that the characters *viz*. number of leaves, root diameter, fresh weight of the plant, dry weight of the plant and fresh weight of root per plant had high heritability and genetic advance in all seasons, indicating the possibility of improvement of these traits through simple selection.

Mallikarjunarao *et al.* (2015) evaluated 24 cultivars of radish during Rabi season (2011-12). They observed high broad sense heritability for root weight, total dry matter of roots, leaf weight, root diameter, vitamin C, shoot to root ratio, total soluble solids, leaf length, root length and leaf number. However, genetic advance in per cent of mean was maximum for the trait leaf weight followed by root weight while minimum genetic advance in percent of mean was observed for the character total soluble solids.

Nagar *et al.* (2016) investigated 21 genotypes of radish under temperate conditions at Uttarakhand during Rabi seasons of 2014-15 for different horticultural traits and recorded high heritability coupled with moderate genetic gain for root length, root weight with leaves, root weight without leaves, leaf weight and root diameter.

Roopa *et al.* (2018) carried out study on 30 genotypes of radish for all the characters. They observed high heritability ranging from 73.85-99.96%. However, high amount of genetic advance as percent of mean, for all the characters ranging from 15.13-238.10%.

### iii.) Correlation

Correlation is used to determine the degree (strength) and direction of the relationship between two variables and more. This is a measure of the relationship between two traits, which worked at the same time (Hayes *et al*. 1955). Yield is an important parameter which is polygenically controlled and its expression depends on the performance of traits. Consequently, the selection of superior genotypes based on yield performance as such is usually not effective. The breeder has to choose the planting material based on phenotypic expression for the selection of superior genotypes. So, it is very important to know the correlation between these traits (Robinson *et al*. 1951).

The relationship between two variables which can be directly observed is termed as phenotypic correlation but it does not give the true picture of the relationship between two characters because along with genetic value the environmental impact also involved. That's why the genetic correlation is important for the study of real genetic variation in different characters. The genetic improvement is dependent trait and can be accomplished by applying strong selection to a character which is genetically correlated with the dependent character. That is known as correlated response. Correlation studies bring better understanding of components which help the plant breeder to improve yield during selection (Johnson *et al*. 1955).

Sharma *et al*. (2002) conducted an experiment on Asiatic radish with regard to correlation studies and found that the character root weight was positively and significantly correlated with the characters plant height, leaf length, leaf width, leaf size, leaf weight per plant, root length, root thickness, root size and leaf per root weight ratio, while negative and significant correlations were observed with the root shape at both phenotypic and genotypic levels.

Panwar *et al*. (2003) studied inter-relationship amongst 11 characters in radish and found that fresh weight of shoot and roots were positively correlated with all the characters, except ascorbic acid content which showed significant negative correlation.

Zhao *et al*. (2008) assessed nutritional quality of 42 Chinese radish cultivars and they observed that dry matter content was positively correlated with the TSS, vitamin C content and protein. While, vitamin C content of radish exhibited a positive correlation with the protein content.

Kumar *et al.* (2009) conducted correlation study in European radish genotypes and found positive correlation of average root weight with seed germination, number of leaves, leaf length, leaf width, root top ratio, root length, root diameter and dry matter. All these characters were mainly contributed towards yield and thus selection on the basis of these characters will be effective.

A correlation study was carried out by Mapari *et al*. (2009) in 24 genotypes of radish and reported that root yield per plant was positively correlated with number of leaves per plant at harvest, fresh weight of leaves, root length, total plant weight, chlorophyll content of leaves and days required to harvest.

Ridhima *et al.* (2009) estimated the correlation in European radish genotypes and found that highly significant and positive correlation was observed for average root weight with seed germination, number of leaves, leaf length, leaf width, root top ratio, root length, root diameter and dry matter which suggested that these are the major yield contributing characters.

Ullah *et al.* (2010) conducted a study on genetic variability, correlation and path coefficient analysis of yield and yield contributing traits involving 21 varieties of radish. Root yield had significant and positive correlation with days to harvest, root length and root diameter, and showed only positive correlation with the characters plant height and leaf width.

Sivathanu *et al.* (2014) carried out study on 10 genotypes of radish during the rabi, summer and kharif seasons of 2012-2013. Correlation and direct effect of component traits on root yield were influenced by season in direction and magnitude. Root length, root diameter, root/leaves ratio and dry weight of root per plant exhibited direct and positive correlation on root yield in all seasons and thus they could be used as appropriate selection parameters for improvement of root yield in radish.

Jabal *et al*. (2015) estimated phenotypic variances and correlation of yield components of six local genotypes of radish. The correlation analysis showed that root weight was positively and significantly correlated with both yield and root diameter. And the yield was positively and significantly correlated with root diameter. While, root length was also positively and significantly correlated with the characters plant height and number of leaves per plant.

Mallikarjunarao *et al*. (2015) investigated yield and its components in radish. Correlation studies revealed that root weight was positively and significantly correlated with leaf number, leaf length, leaf width, leaf weight, root length, root diameter, yield per plant, total dry matter and vitamin-C. While, root weight was negatively and significantly correlated with shoot to root ratio and total soluble solids at both phenotypic and genotypic levels.

Chakraborty *et al.* (2016) investigated 15 germplasm lines of radish from different parts of Meghalaya on the basis of 23 horticultural traits during winter season from October to January (2014-15). Correlation analysis was carried out to study the character association and contribution of ten quantitative characters, namely leaf length, leaf width, number of leaves, petiole length, crown head diameter, root length, root diameter, days to root harvest, root weight and yield. Phenotypic and Genotypic correlation coefficient analysis revealed that root weight, days to root harvest, number of leaves, root length, leaf width, and root diameter had significant positive correlation, while petiole length, leaf length and crown head diameter had significant negative correlation with marketable yield.

Nagar *et al.* (2016) carried out study on 21 genotypes of radish during Rabi season for different horticultural traits. The phenotypic and genotypic correlation coefficients among different characters showed that marketable root yield per hectare had positive and significant association with root weight without leaf, root weight with leaf, root length, number of leaves and length of whole plant.

Kaur *et al.* (2017) evaluated 17 radish genotypes and observations were recorded on 18 parameters related to plant growth, root yield and root quality. Character association analysis revealed highly significant and positive correlation between root yield and marketable yield, root weight, plant weight, root diameter, root length and root plant ratio. Increase in root mass also lead to increase in vitamin C and isothiocyanate content in the roots.

Roopa *et al.* (2018) conducted an experiment on 30 genotypes of radish and found that root yield per hectare had significant and positive correlations with leaf area, root diameter, root length, root to leaf ratio and root weight both at genotypic and phenotypic levels during kharif season of 2017-2018. Positive and significant correlation was observed for root to leaf ratio with root weight and root yield per hectare at both genotypic and phenotypic level.

### iv.) Path Analysis

Wright (1921) originally developed the concept of path analysis but Dewey and Lu (1959) first used that technique for plant selection. Path coefficient analysis is a powerful source and efficient selection technique, because the correlation coefficient alone can provide misleading information when considered as the criteria for selecting high yield, as such a character may not be directly correlated with yield but may exert its influence through other characters. Path coefficient splits the coefficient of correlation into the direct and indirect effect measurements. In other words, it tests the direct and indirect contribution of various dependent characters.

If correlation between yield and character is due to a character's direct effect, it reveals a true relationship between them and direct selection for this character is rewarding for improving yield. In plant breeding, it is very tough to have complete knowledge of all component traits of yield. The residual effect measures the role of other probable independent variables which were not included in the study involving dependent and independent variables.

Singh *et al.* (2005) studied 21 diverse genotypes of radish under temperate conditions of Kashmir and found that root yield could be successfully improved by making selection for greater average root weight, root diameter and root length. The characters like root diameter, root length and average gross weight were identified to have direct positive effect on root yield. Whereas, the characters *viz*. number of leaves per plant, leaf length and top/root ratio had negative direct effect on root yield.

Mapari *et al*. (2009) studied path analysis in 24 genotypes of radish and reported positive direct effect on root yield through the characters total plant weight, root length, days to harvest, number of leaves per plant at harvest and chlorophyll content of leaves.

Kumar *et al.* (2009) conducted a study pertaining to path analysis in European radish using 35 diverse genotypes of radish, introduced from the Crop Genetic Resources, Netherland. They reported that average root weight had highly significant and positive correlation with seed germination, number of leaves, leaf length, leaf width, root top ratio, root length, root diameter and dry matter.

Ullah *et al.* (2010) conducted genetic variability, character association and path coefficient analysis of radish with 21 varieties. Path coefficient analysis revealed that plant height had the maximum positive direct effect on root yield followed by root diameter, leaf width and days to harvest.

Jamatia *et al.* (2015) evaluated 20 radish genotypes for 15 traits. The path coefficient analysis revealed that number of flowers per plant had maximum positive direct effect on pod yield per plant followed by number of seeds per pod and secondary branches per plant.

Mallikarjunarao *et al*. (2015) estimated path coefficient analysis of radish and found that the leaf weight, leaf number, leaf length, root length and root diameter showed maximum direct effects towards average root weight. Hence these traits should be given more importance while selecting genotypes for root yield improvement.

Nagar *et al.* (2016) carried out study on 21 genotypes of radish during Rabi season for different horticultural traits. They observed that maximum positive direct effect towards root yield per plant was contributed by root weight without leaf, length of whole plant, root weight with leaf and number of leaves.

Kaur *et al.,* (2017) evaluated 17 cultivars of radish for 18 characters related to plant growth, root yield and root quality. Path coefficient analysis both at phenotypic and genotypic levels revealed strongly positive direct effect of characters marketable yield, root weight and foliage weight on the total root yield.

# *Chapter-3*

# MATERIALS AND METHODS

The present investigation entitled, "**Assessment of genetic variability, correlation and path analysis studies in radish (*Raphanus sativus* L.)"** was undertaken to access the extent of genetic variability, heritability and genetic advance, correlation coefficient and path coefficient analysis during the autumn-winter season of 2019 at Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur, H.P. The details of the materials used and experimental methods followedduring the course of present investigation are described below as follows:

## 3.1 Geographical features

### 3.1.1 Location

Experimental Farm Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur, H.P. is located in the Sub montane low hills zone (Zone-I) of Himachal Pradesh. Geographically, it is situated at an altitude 650 m above mean sea level between 31$^{o}$41'47.6" N & 72$^{o}$28'6.3" E.

### 3.1.2 Climatic and weatherconditions

The climate of the region is characterized as sub-tropical with hot summers and mild to cool winters. The monthly data pertaining to the average temperature, totalrainfall and average relative humidity during the period of current investigation has been tabulated as under:

**Table 3.1 Agro-meterological data during cropping period.**

| Month | Average Monthly Temperature ($^{o}$ C) | Average Relative Humidity (%) | Total monthly Rainfall (mm) |
|---|---|---|---|
| **September, 2019** | 23.36 | 88.60 | 291.6 |
| **October, 2019** | 19.11 | 74.25 | 11.4 |
| **November, 2019** | 14.79 | 78.33 | 20.0 |

### 3.1.3 Soil

The soil structure of the experimental site was sandy clay loamy soil with pH ranging from 7.02 -7.28.

### 3.1.4 Experimentalmaterial

The experimental material used for present investigation comprised of 18genotypes (17 local accessions and 1 commercial variety) of radish. The cultivar Japanese White was used as standard check. The genotypes were diverse with respect to morphological and important economical horticultural traits. List of various genotypes used in the present investigation is as follows:

**Table 3.2:List of various genotypes of radish included in current study along with their source.**

| Sr. No. | Genotype | Source |
|---|---|---|
| 1 | R-COHF-NERI-1 | Department of Vegetable Science COHF, Neri Hamirpur |
| 2 | R-COHF-NERI-2 | Department of Vegetable Science COHF, Neri Hamirpur |
| 3 | R-COHF-NERI-3 | Department of Vegetable Science COHF, Neri Hamirpur |
| 4 | R-COHF-NERI-4 | Department of Vegetable Science COHF, Neri Hamirpur |
| 5 | R-COHF-NERI-5 | Department of Vegetable Science COHF, Neri Hamirpur |
| 6 | R-COHF-NERI-6 | Department of Vegetable Science COHF, Neri Hamirpur |
| 7 | R-COHF-NERI-7 | Department of Vegetable Science COHF, Neri Hamirpur |
| 8 | R-COHF-NERI-8 | Department of Vegetable Science COHF, Neri Hamirpur |
| 9 | R-COHF-NERI-9 | Department of Vegetable Science COHF, Neri Hamirpur |
| 10 | R-COHF-NERI-10 | Department of Vegetable Science COHF, Neri Hamirpur |
| 11 | R-COHF-NERI-11 | Department of Vegetable Science COHF, Neri Hamirpur |
| 12 | R-COHF-NERI-12 | Department of Vegetable Science COHF, Neri Hamirpur |
| 13 | R-COHF-NERI-13 | Department of Vegetable Science COHF, Neri Hamirpur |
| 14 | R-COHF-NERI-14 | Department of Vegetable Science COHF, Neri Hamirpur |
| 15 | R-COHF-NERI-15 | Department of Vegetable Science COHF, Neri Hamirpur |
| 16 | R-COHF-NERI-16 | Department of Vegetable Science COHF, Neri Hamirpur |
| 17 | R-COHF-NERI-17 | Department of Vegetable Science COHF, Neri Hamirpur |
| 18 | Japanese White (Check) | IARI Regional Station, Katrain, Kullu, HP |

## 3.2 Experimentaldesign and layout

The experiment was laid out in randomized complete block design (RCBD) on 17th September, 2019. The details of the design, number of replications, plot size, spacing etc. are given below:

| | | |
|---|---|---|
| Number of genotypes | : | 18 (including check) |
| Design | : | Randomized Complete Block Design |
| Replications | : | 3 |
| Plot Size | : | 1.2 m × 1 m |
| Spacing | : | 30 cm × 7.5 cm |
| Number of plants/plot | : | 53 |
| No. of plots | : | 54 |

The standard cultural practices were followed as per recommendation in the package of practices for vegetable crops (Anonymous, 2017).

### 3.2.1 Land preparation

The experimental field was thoroughly ploughed 1-2 times. Deep ploughing was done to bring the soil to a fine tilth and all the clods of the soil were thoroughly broken. All the weeds and stubble were removed from the soil. The ridges were built in the plots at a distance of 30 cm and sowing of radish seeds was done on ridges.

**Intercultural Operations**

### 3.2.2 Thinning of seedlings

Seedling emerged within 10-12 days of sowing. The thinning operation of seedling was done twice to remove the sick and overcrowded seedlings. First thinning was carried out after 15 days of sowing mainly to remove unhealthy and lanky seedlings. The second thinning was performed 10 days after the first thinning to maintain the optimum space of 7.5 cm between the two radish seedlings.

### 3.2.3 Weeding

Weeding was done on a regular basis to keep the plot free from weeds and to keep the soil loose and airy.

Plate 1. Sowing of radish seeds on ridges

Plate 2. Experimental farm showing various genotypes of radish

### 3.2.4 Irrigation

The irrigation was done immediately after sowing and subsequent irrigations were given intermittently to keep the optimum soil moisture as and when required depending upon the weather conditions.

## 3.3 Observations recorded

The observations were recorded in each replication on five competitive plants picked at random from each plot. The plants were tagged to easily identify them and record various observations. The method followed for recording various observations with respect to different horticultural traits is described as follows:

### 3.3.1 Days to 50% germination

Days to 50 per centgermination was recorded by counting the number of days taken from date of sowing to 50 per cent seedling emergence in each plot separately.

### 3.3.2 Plant height (cm)

Five randomly chosen plants were selected in each plot to observe plant height. The average of five plants was worked out. The height was recorded from the top root end to the extreme tip of the foliage at the time of uprooting of radish with the help of meter scale.

### 3.3.3 Number of leaves per plant

Randomly five plants were selected and tagged. Number of leaves of each plant were counted separately at the time of uprooting radish for the final harvest and the average of five plants was worked out.

### 3.3.4 Leaf length (cm)

It was measured in centimeters by taking average from the five randomly selected leaves from the radish plants. The length of the leave was recorded with the help of the meter scale from the base of petiole to the highest point of leaf at the time of uprooting of radish for final harvest.

### 3.5.5 Leaf width (cm)

It was measured in centimeters from the widest portion of the leaf, using meter scale. The average of five leaves was worked out at the time of uprooting of the radish for final harvest.

### 3.3.6 Crown diameter (mm)

Crown diameter was recorded with the help of digital Vernier Calliper at the crown end in mm at the time of the final harvest of the radish.

### 3.3.7 Root length (cm)

The length of five randomly selected roots was measured from crown to distal end in cm. at the time of final harvest of radish.

### 3.3.8 Root diameter (mm)

Root diameter was measured in millimeters just below the crown, using digital Vernier Calliper at the time of final harvest of radish. The average of five randomly selected roots was worked out for recording the above observation.

### 3.3.9 Days taken to marketable maturity

Days taken to marketable maturity was recorded by counting the number of days taken from seed sowing to the attainment of full marketable size of the roots i.e. final harvesting of the radish roots.

### 3.3.10 Average root weight with leaves (g)

In order to record the average root weight with leaves the radish roots were thoroughly washed to clear the soil and keeping the leaves intact. The weight of these five radish roots was taken with the help of the top pan balance in grams and average was worked out.

### 3.3.11 Average root weight without leaves (g)

Five randomly selected radish roots without leaves were taken from the produce of each plot and their weights were recorded in grams and then average root weight was calculated.

### 3.3.12 Total soluble solids (°B)

Radish juice was obtained after crushing and filtering the juice with the help of the muslin cloth. Total soluble solids were recorded by placing small amount of juice on Hand Refractometer prism.The results were translated as ° Brix (Ranganna,1986).

### 3.3.13 Root yield per plot (kg)

Root yield per plot was recorded at every uprooting of the marketable radish roots from each plot separately and added to get the yield per plot in kilograms.

### 3.3.14 Root colour and shape

Colour (external only) and shape of the roots was recorded on the basis of visual observation at the time of final harvest of the radish root.

### 3.3.15 Ascorbic acid (mg/100g)

The ascorbic acid content was determined according to the procedure given in Association of Official Agricultural Chemists (AOAC,1980) by using 2, 6-dichlorophenol indophenols dye. The sample was extracted by homogenizing and extracted solution was titrated against the metaphosphoric acid till the light pink colour end point was obtained. The Vitamin C content was calculated through the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Dye factor} \times \text{Titer value} \times \text{Volume made up}}{\text{Aliquot taken for estimation} \times \text{Weight of sample taken for estimation}} \times 100$$

### 3.3.16 Prevalence of Alternaria blight

**a) Disease incidence (%)**

The disease incidence (%) was calculated by using the following formula under natural epiphytotic conditions on five tagged plants which were not given any fungicide spray:

$$\text{Disease incidence (\%)} = \frac{\text{Total number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

**b) Disease severity (%)**

The severity of Alternaria blight was recorded by following 0-5 scale with slight modifications under natural epiphytotic conditions on the plants showing disease incidence and the severity was calculated using the formula given by Townsend and Heuberger, (1943). The details are as follows:

| Disease grade | Infected leaf area (%) | Disease reaction |
|---|---|---|
| 0 | No visible infection | Immune (I) |
| 1 | 1.0-5.0 | Resistance (R) |
| 2 | 5.1-15.0 | Moderately resistant (MR) |
| 3 | 15.1-30.0 | Moderately susceptible (MS) |
| 4 | 30.1-50.0 | Susceptible (S) |
| 5 | >50 | Highly susceptible (HS) |

Per cent disease index (PDI) = $\frac{\text{Total sum of numerical ratings}}{\text{Total number of ratings} \times \text{Maximum disease grade}} \times 100$

## 3.4 Statistical analysis:

The data obtained from the present investigation was subjected to statistical analysis as per the methods suggested by Gomez and Gomez (1984) for Randomized Complete Block Design (RCBD). The statistical analysis was carried out for each observed character by using MS-Excel, OPSTAT and SPAR 1.0 packages.

### 3.4.1 Analysis of Variance

| Source of variation | Degree offreedom | Sum of squares | Mean sum of squares | $F_{cal}$ |
|---|---|---|---|---|
| Replication | (r-1) | $S_r$ | $M_r = S_r/(r-1)$ | $M_r/M_e$ |
| Genotypes | (g-1) | $S_g$ | $M_g = S_g/(g-1)$ | $M_g/M_e$ |
| 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 genotype mean sum of squares were 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 respectively at 5% level of significance.

The calculated F-values were compared with tabulated F-values. When F calculated values were >= F tabulated values, the critical differences were calculated to find out the superiority of one genotype over the others for a given character.

**Critical difference (CD) was calculated as follows**

$CD_{0.05}$ = S.E. (d) $\times t_{(0.05)}$(r-1) (g-1) df

SE (d) ± = $\sqrt{2\,Me/r}$

SE (m) ± = $\sqrt{Me/r}$

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

## 3.5 PARAMETERS OF VARIABILITY

All the quantitative characters excluding prevalence of *Alternaria* blight, which differed significantly in terms of genotypes, were utilized further for the estimation of following genetic parameters:

- Mean performance and geneticvariability
- Heritability (in broadsense)
- Genetic advance(GA)
- Genetic gain (GG)

### 3.5.1 Mean performance and geneticvariability

The Genotypic and Phenotypic Coefficients of variability were calculated as per formulae given by Burton and De-Vane (1953).

#### 3.5.1.1 Phenotypic coefficient of variation (PCV)

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

#### 3.5.1.2 Genotypic coefficient of variation (GCV)

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

### 3.5.2 Heritability

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

$$\text{H (\%)} = \frac{\text{Vg}}{\text{Vp}} \times 100$$

Where,

H= Heritability (%)

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

$V_p$= Phenotypic variance $(V_g + V_e)$

### 3.5.3 Genetic advance

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

$$\text{GA} = \text{H} \times \sigma\text{p} \times \text{K}$$

Where,

H = Heritability (%)

$\sigma_p$ = Phenotypic standard deviation

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

### 3.5.4 Genetic gain

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

$$\text{GG} = \frac{GA}{GM} \text{ x } 100$$

Where,

GG = Genetic gain

GA = Genetic advance

GM = Population mean

PCV and GCV were classified as shown below (Cherian, 2000)

PCV

| | |
|---|---|
| <10% | Low |
| 10-20% | Moderate |
| >20% | High |

GCV

| | |
|---|---|
| <10% | Low |
| 10-20% | Moderate |
| >20% | High |

Heritability

The heritability was categorized as suggested by Johnson *et al.* (1955):

| | |
|---|---|
| <50% | Low |
| 50-70% | Moderate |
| >70% | High |

Genetic gain

| | |
|---|---|
| <25% | Low |
| 25-50% | Moderate |
| >50% | High |

### 3.6 Correlation analysis

The genotypic and phenotypic correlations were calculated by using analysis of variance and covariance matrix in which total variability was split into replications, genotypes and errors.The correlations between all characters under study, at genotypic and phenotypic 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:

Environmental covariance ($V_e$ XY) = $MP_2$

Genotypic covariance ($V_g$ XY) = $(MP_1 - MP_2)/r$

Phenotypic covariance ($V_p$XY) = $V_g$ XY + $V_e$ XY

Where,

$V_e$ XY = Environmental covariance between X and Y

$V_g$ XY = Genotypic covariance between X and Y

$V_p$XY = Phenotypic covariance between X and Y

**Coefficients of correlation:**

**3.6.1 Phenotypic correlation between characters X and Y:**

$$r_p = \frac{\text{Vp XY}}{\sqrt{\text{Vp X x Vp Y}}}$$

Where,

Vp XY = Phenotypic covariance between X and Y

Vp X = Phenotypic variance of X

Vp Y = Phenotypic variance of Y

### 3.6.2 Genotypic correlation between characters X and Y:

$$r_g = \frac{\text{Vg XY}}{\sqrt{\text{Vg X x Vg Y}}}$$

Where,

Vg XY = Genotypic covariance between X and Y

VgX = Genotypic variance ofX
VgY = Genotypic variance ofY

$V_p$X and $V_g$ Xdenote phenotypic and genotypic variances respectively between characters X, whereas, $V_p$Y and $V_g$ Ydenote phenotypic and genotypic variances respectively between characters Y.

Genotypic variance (Vg) = (Mg-Me) / r

Phenotypic variance (Vp) = (Vg+Ve)

The calculated correlation coefficients (r) values were compared with 'r'($t_r$) (for tabulated between r and $t_r$) tabulated values as given by Fisher and Yates (1963) at (n-2) degrees of freedom to test their significance, where 'n' denotes number of genotypes. If calculated 'r' value at 5 per cent level of significance was greater than tabulated value of 'r' ($t_r$), then the correlation was said to be significant.

### 3.7 Path coefficient analysis

The genotypic correlation coefficients were used in finding out their direct and indirect contributions towards the dependent character i.e. root yield per plot.

The following formula was used for calculating path coefficient analysis suggested by Deweyand 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)

$$r_{14}= P_{14}+ r_{12} P_{24}+ r_{13} P_{34}$$
$$r_{24}= r_{21} P_{14} + P_{24} + r_{23} P_{34}$$
$$r_{34}= r_{31} P_{14} + P_{32} + r_{24} P_{34}$$

where $r_{14}$,$r_{24}$ and $r_{34}$ are genotypic correlation of components characters with root 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:

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

$$P_{24}= C_{21}\ r_{14} + C_{22}\ r24+ C_{23}\ r_{34}$$

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

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.

### 3.7.1 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:

$$1 = P^2x_4 + P^2{}_{14} + P^2{}_{24} + P^2{}_{34} + 2P_{14}r_{12}P_{24} + 2P_{14}r_{13}P_{34} + 2P_{24}r_{22}P_{34}$$

# *Chapter – 4*

# RESULTS AND DISCUSSION

The present investigation entitled "**Assessment of genetic variability, correlation and path analysis studies in radish (*Raphanus sativus* L.)**" was undertaken using eighteen diverse genotypes of radish including one check cultivar Japanese White, to study variability, heritability, genetic advance, correlation coefficient analysis and path coefficient analysis.

The results obtained after the evaluation of genotypes are discussed and supported with relevant or appropriate references under the following headings:

**4.1 Analysis of variance**

**4.2 Variability studies**

**4.2.1. Mean performance**

**4.2.2. Parameters of variability**

**4.3 Heritability and genetic advance**

**4.4 Correlation coefficient analysis**

**4.5 Path coefficient analysis**

## 4.1 Analysis of variance

Analysis of variance indicated significant mean sum of squares due to genotypes for all traits *viz*. days to 50% germination (11.11), plant height (54.50), number of leaves per plant (13.38), leaf length (21.48), leaf width (8.84), crown diameter (17.92), root length (24.90), root diameter (35.35), days taken to marketable maturity (53.14), average root weight with leaves (224.86), average root weight without leaves (182.18), total soluble solids (5.05),ascorbic acid (20.01), root yield per plot (4.75) and prevalence of *Alternaria* blight *viz*. disease incidence (54.31) and disease severity (47.34) (Appendix-II) under study suggesting sufficient differences among various genotypes for these traits. Therefore, further variability analysis was done for all the quantitative traits. However, only mean performance was recorded for prevalence of *Alternaria* blight (disease severity and disease incidence). The replication sum of squares was significant for characters *viz.* root diameter, days taken to marketable maturity, total soluble solid and root yield per plot suggesting significant differences among the replications for these traits respectively.

## 4.2 Variability studies

### 4.2.1 Mean performance of genotypes

The variability studies were conducted in radish involving 18 genotypes collected from various sources. Observations with respect to 15 quantitative characters *viz*. days to 50% germination, plant height, number of leaves per plant, leaf length, leaf width, crown diameter, root length, root diameter, days taken to marketable maturity, average root weight with leaves, average root weight without leaves, total soluble solids,ascorbic acid, root yield per plot and prevalence of *Alternaria* blight (disease incidence and disease severity) were recorded. Further observations pertaining to qualitative character i.e. root shape and colour were also tabulated for the 18 genotypes of radish studied under present investigation. The parameters of variability i.e. PCV and GCV were only recorded for 14 quantitative traits excluding the character Prevalence of *Alternaria* blight (disease incidence and disease severity) for which only the mean values were tabulated.

The observations pertaining to mean performance of 18 genotypes of radish with respect to various quantitative and qualitative traits is discussed as below:

#### 4.2.1.1 Days to 50% germination

Days to 50% germination is determined by seed genetic composition, morphological features and environmental factors. Less number of days to 50% germination is desirable (Ranal and Santana, 2006) to obtain early maturity of the crop. The values for the character Days to 50% germination ranged from 07.00–13.00 days (Table 4.1). However, the value of overall mean was found to be11.11 days. Minimum number of days to 50% germination was observed in genotype Japanese White (07.00 days) suggesting the superiority of the variety for the given trait. The genotype Japanese White was followed by R-COHF-NERI-6 (8.67 days) in terms of superiority for days to 50% germination. Whereas, the maximum number of days to 50% germination was observed in genotype R-COHF-NERI-9 (13.00 days), which was statistically at par with two other genotypes viz. R-COHF-NERI-12 (12.67 days) andR-COHF-NERI-13 (12.33 days). Nagar (2016) also reported similar findings for days to 50% germination in radish with respect to range (7-13.33 days) and the mean performance of genotype Japanese White (7.00 days).

#### 4.2.1.2 Plant height (cm)

The perusal of data (Table 4.1) for plant height revealed that the range for the character varied from 51.00–59.87 and the mean value exhibited by this trait was 54.50 cm. Less plant height is a desirable trait as it prevents the lodging of the plants with wind

**Plate 3. Germination of radish seeds**

etc. The least plant height was observed in check variety Japanese White (51.00 cm), which was found statistically at par with genotype R-COHF-NERI-9 (51.33 cm), R-COHF-NERI-1 (51.80 cm), R-COHF-NERI-17 (52.33 cm), R-COHF-NERI-16 (53.13 cm), R-COHF-NERI-5 (53.80 cm), R-COHF-NERI-14 (53.93 cm), R-COHF-NERI-7 (54.60 cm), R-COHF-NERI-10 (54.87 cm) and R-COHF-NERI-11 (55.13 cm). However, the maximum plant height was recorded in the genotype R-COHF-NERI-8 (59.87cm) suggesting the undesirable characteristic of the genotype. These findings are in line with those of Ola *et al*. (2018) and Singh *et al*. (2019).

#### 4.2.1.3 Number of leaves

More number of leaves is a desirable trait in radish as greater number of leaves help in manufacturing ample photosynthates thereby increasing the root yield. Further, the radish leaves are rich source of nutrients and can be consumed as vegetable. Maximum number of leaves were observed in genotype R-COHF-NERI-3 (17.07), which was found statistically at par with the genotype R-COHF-NERI-2 (16.03). The overall mean value (Table 4.1) for the character was 13.38 and the number of leaves in various genotypes ranged from 6.93-17.07. While, the minimum number of leaves were found in genotype R-COHF-NERI-9 (6.93) followed by R-COHF-NERI-8 (9.6) and R-COHF-NERI-4 (9.73). These findings were in accordance to those observed by Mallikarjunarao *et al*. (2015), Ola *et al*. (2018) and Singh *et al*. (2019).

#### 4.2.1.4 Leaf length (cm)

The data presented in Table 4.2 showed the mean leaf length as 29.45 cm. However, the leaf length for the given 18 genotypes of radish varied from 21.48-39.97 cm. The radish genotype COHF-NERI-12 (39.97 cm) recorded the maximum leaf length followed by R-COHF-NERI-16 (37.13 cm) and R-COHF-NERI-7 (35.27 cm). While the minimum leaf length was found in genotype R-COHF-NERI- 17 (23.77 cm), which was found statistically at par with two genotypes viz. R-COHF-NERI- 11 (25.73 cm) and R-COHF-NERI-9 (25.57 cm). The results are in conformity with the observations of Jatoi *et al*. (2011), Mallikarjunarao *et al*. (2015) and Singh *et al*. (2019).

#### 4.2.1.5 Leaf width (cm)

The perusal of Table 4.2. revealed that the range of leaf width varied from 7.42– 10.27 cm. Maximum leaf width was observed in genotype R-COHF-NERI-2 (10.27 cm) which was found statistically at par with genotypes viz. R-COHF-NERI-12 (9.97 cm), R-COHF-NERI-3 (9.60 cm), R-COHF-NERI-10 (9.50 cm), R-COHF-NERI-9 (9.47 cm), R-COHF-NERI-4 (9.33 cm) and R-COHF-NERI-6 (9.10 cm). While, the least leaf width was reported in genotype R-COHF-NERI-11 (7.63 cm) which was found statistically at par with genotypes R-COHF-NERI-1 (7.80 cm), R-COHF-NERI-7 (8.17 cm), R-COHF-NERI-8 (8.17 cm), R-COHF-NERI-14 (8.27 cm), COHF-NERI-15 (8.37 cm), R-COHF-NERI-5 (8.37 cm), R-COHF-NERI-13 (8.40 cm), Japanese White (8.42 cm) and R-COHF-NERI-6 (9.10 cm).Similar results were observed by Mallikarjunarao *et al*. (2015) and Singh *et al*. (2019) in radish.

**Table 4.1 Mean performance of radish genotypes for the horticultural traits days to 50% germination, plant height (cm) and number of leaves per plant.**

| Genotype | Days to 50% germination | Plant height (cm) | Number of leaves per plant |
|---|---|---|---|
| R-COHF-NERI-1 | 11.67 | 51.80 | 15.53 |
| R-COHF-NERI-2 | 11.33 | 57.80 | 16.03 |
| R-COHF-NERI-3 | 11.00 | 57.60 | 17.07 |
| R-COHF-NERI-4 | 11.00 | 57.73 | 9.73 |
| R-COHF-NERI-5 | 11.67 | 53.80 | 15.67 |
| R-COHF-NERI-6 | 8.67 | 56.73 | 14.33 |
| R-COHF-NERI-7 | 9.67 | 54.60 | 15.33 |
| R-COHF-NERI-8 | 10.00 | 59.87 | 9.60 |
| R-COHF-NERI-9 | 13.00 | 51.33 | 6.93 |
| R-COHF-NERI-10 | 12.33 | 54.87 | 10.93 |
| R-COHF-NERI-11 | 10.67 | 55.13 | 11.13 |
| R-COHF-NERI-12 | 12.67 | 58.62 | 11.07 |
| R-COHF-NERI-13 | 12.33 | 57.27 | 14.00 |
| R-COHF-NERI-14 | 12.00 | 53.93 | 15.33 |
| R-COHF-NERI-15 | 11.00 | 55.47 | 14.13 |
| R-COHF-NERI-16 | 12.00 | 53.13 | 17.03 |
| R-COHF-NERI-17 | 12.00 | 52.33 | 13.00 |
| Japanese White (Check) | 7.00 | 51.00 | 13.97 |
| **Mean** | **11.11** | **54.50** | **13.38** |
| **Range** | **7-13** | **51.00-59.87** | **6.93-17.07** |
| **SE(m)** | **0.27** | **1.53** | **0.39** |
| **CV (%)** | **4.27** | **4.88** | **5.02** |
| **C.D. (0.05)** | **0.79** | **4.44** | **1.12** |

#### 4.2.1.6 Crown diameter (mm)

Crown diameter mean observations for various genotypes of radish ranged from 14.24–23.67 mm (Table 4.2). Over all mean for this horticultural trait was found out to be 19.92 mm. Larger crown diameter is desirable in case of radish as it helps in increasing the radish root yield. Highest value for crown diameter was recorded in genotype R-COHF-NERI-17 (23.67 mm) which was found statistically at par with R-COHF-NERI-12 (21.88 mm). While minimum crown diameter was exhibited by the genotype R-COHF-NERI-11 (14.24 mm) which was found to be statistically at par with the genotypes R-COHF-NERI-6 (15.65 mm), R-COHF-NERI-14 (16.01 mm), R-COHF-NERI-5 (16.48 mm), R-COHF-NERI-13 (16.52 mm), R-COHF-NERI-16 (16.85 mm), Japanese White (16.96 mm), R-COHF-NERI-4 (17.11 mm), R-COHF-NERI-7 (17.16 mm), R-COHF-NERI-8 (17.20 mm), R-COHF-NERI-9 (17.27 mm) and R-COHF-NERI-15 (17.30 mm).Identical observations with regard to crown diameter in radish have been reported by Kumar *et al*. (2012) and Guleria (2016).

#### 4.2.1.7 Root length (cm)

The data recorded on root length showed wide range (15.03-29.50 cm) among various genotypes of radish (Table 4.3). Root length is an important character contributing to root yield since the economic part in radish is a root; however, the consumer preference for specific length sometimes affects the popularity of a particular genotype.

Grand mean for this trait was found to be 24.90 cm. It is evident from the Table 4.3 that the highest root length was found in the genotype R-COHF-NERI-3 (29.50 cm) and this genotype was found statistically at par with other genotypes namely R-COHF-NERI-12 (29.43 cm), R-COHF-NERI-2 (28.80 cm), R-COHF-NERI-13 (28.07 cm), R-COHF-NERI-14 (27.80 cm), R-COHF-NERI-5 (26.97 cm), R-COHF-NERI-4 (26.73 cm), R-COHF-NERI-10 (26.17 cm), R-COHF-NERI-11 (26.13 cm), R-COHF-NERI-6 (25.80 cm) and R-COHF-NERI-1 (25.60 cm). The genotype R-COHF-NERI-9 (15.03 cm) was found to be the shortest in terms of root length among all the genotypes and it was found statistically at par with another radish genotype i.e. R-COHF-NERI-16 (15.80 cm). These findings were in line to those obtained by Mallikarjunarao *et al*. (2015), Roopa *et al*. (2018) and Singh *et al*. (2019) in radish.

**Table 4.2 Mean performance of radish genotypes for the horticultural traits leaf length (cm), leaf width (cm) and crown diameter (mm).**

| Genotypes | Leaf length (cm) | Leaf width (cm) | Crown diameter (mm) |
|---|---|---|---|
| R-COHF-NERI-1 | 27.83 | 7.80 | 19.87 |
| R-COHF-NERI-2 | 27.60 | 10.27 | 19.60 |
| R-COHF-NERI-3 | 27.23 | 9.60 | 19.74 |
| R-COHF-NERI-4 | 28.33 | 9.33 | 17.11 |
| R-COHF-NERI-5 | 28.23 | 8.37 | 16.48 |
| R-COHF-NERI-6 | 28.33 | 9.10 | 15.65 |
| R-COHF-NERI-7 | 30.03 | 8.17 | 17.16 |
| R-COHF-NERI-8 | 35.27 | 8.17 | 17.20 |
| R-COHF-NERI-9 | 25.57 | 9.47 | 17.27 |
| R-COHF-NERI-10 | 33.27 | 9.50 | 19.05 |
| R-COHF-NERI-11 | 25.73 | 7.63 | 14.24 |
| R-COHF-NERI-12 | 39.97 | 9.97 | 21.88 |
| R-COHF-NERI-13 | 27.33 | 8.40 | 16.52 |
| R-COHF-NERI-14 | 27.83 | 8.27 | 16.01 |
| R-COHF-NERI-15 | 29.30 | 8.37 | 17.30 |
| R-COHF-NERI-16 | 37.13 | 10.23 | 16.85 |
| R-COHF-NERI-17 | 23.77 | 8.10 | 23.67 |
| Japanese White (Check) | 27.33 | 8.42 | 16.96 |
| **Mean** | **29.45** | **8.84** | **17.92** |
| **Range** | **23.77–39.97** | **7.63–10.27** | **14.24–23.67** |
| **SE(m)** | **0.74** | **0.51** | **1.19** |
| **CV (%)** | **4.33** | **9.99** | **11.53** |
| **C.D. (0.05)** | **2.13** | **1.47** | **3.44** |

### 4.2.1.8 Root diameter (mm)

The data pertaining to the character root diameter has been presented in Table 4.3. Grand mean for this trait was found to be 35.35 mm. The values of root diameter in various genotypes of radish ranged from 15.60–42.70 mm. The maximum value of root diameter (42.70 mm) was reported in the genotype R-COHF-NERI-9, which was found statistically at par with genotypes R-COHF-NERI-6 (42.10 mm), R-COHF-NERI-3

(40.37 mm), R-COHF-NERI-2 (39.36 mm), R-COHF-NERI-12 (39.28 mm) and Japanese White (38.30 cm). While, the least root diameter was seen in the genotype R-COHF-NERI-16 (22.56 mm) amongst all the genotypes under study. These findings for root diameter were in confirmation to those recorded by Mallikarjunarao *et al*. (2015), Roopa *et al*. (2018) and Singh *et al*. (2019) in radish.

#### 4.2.1.9 Days taken to marketable maturity

The character days taken to marketable maturity plays a very important role in identifying the early genotypes and it is one of the important characters for breeding a new variety (Singh, 2001). The early genotype, if shows high heritability can be used for developing future early varieties. The above horticultural trait under study ranged from 46.33 –58.67 days (Table 4.3). The genotype R-COHF-NERI-6 was earliest in terms of marketable maturity (46.33 days) and was found statistically at par with genotype viz. R-COHF-NERI-7 (47.67 days). However, on the other hand the maximum days to marketable maturity were taken by the genotype R-COHF-NERI-10 (58.67 days), which was found statistically at par with genotypes viz. R-COHF-NERI-12 (58.24 days) and R-COHF-NERI-13 (57.86 days). These results were in accordance to those obtained by Dongarwar *et al.* (2017).

#### 4.2.1.10 Average root weight with leaves (g)

The higher average root weight with leaves is a desirable trait in case of radish as it directly contributes to the higher yields and helps the farmer to increase his/her income. Radish is generally sold in the market with leaves and these leaves are very nutritious hence, they are often used to make vegetable. The mean values corresponding to average root weight with leaves of various radish genotypes ranged from 135.40–339.07g. While the Grand mean for this trait was found to be 224.86 g. The highest average root weight with leaves was recorded by the genotype R-COHF-NERI-12(339.07 kg); which was found statistically at par with genotype R-COHF-NERI-6 (275.85 g), R-COHF-NERI-10 (272.40 g), R-COHF-NERI-2 (260.47 g), R-COHF-NERI-14 (247.13 g) and R-COHF-NERI-7 (243.27 g). Whereas, the minimum average root weight was recorded by the genotype R-COHF-NERI-9 (135.40 g) and it was statistically at par with the radish genotype R-COHF-NERI-8 (168.33 g). Semba *et al*. (2019), Dongarwar *et al.* (2017) and Ola *et al.* (2018) conducted similar studies in radish and their findings were in line with observation of the current study.

#### 4.2.1.11 Average root weight without leaves (g)

Average root weight without leaves is again the horticultural trait which directly contributes to the yield. The mean values observed by 18 genotypes of radish (Table 4.4), ranged from 89.53–241.56 g. Grand mean for this horticultural character was found to be 182.18 g. Maximum average root weight with leaves was observed in the radish genotype R-COHF-NERI-12 (251.56 g) showing its superiority over rest of the radish genotypes, However, this genotype was found statistically at par with the genotypes R-COHF-NERI-6 (241.56 g), R-COHF-NERI-3 (240.60 g), R-COHF-NERI-2 (234.40 g) and R-COHF-NERI-10 (225.47 g). Whereas, the minimum average root weight without leaves was found in the radish genotype R-COHF-NERI-9 (89.53 g). These results were in confirmation to those obtained by Semba *et al*. (2019), Dongarwar *et al.* (2017) and Roopa *et al.* (2018) in radish.

**Table 4.3 Mean performance of radish genotypes for the horticultural traits root length (cm), root diameter (mm), days taken to marketable maturity and average root weight with leaves (g).**

| Genotypes | Root length (cm) | Root diameter (mm) | Days taken to marketable maturity | Average root weight with leaves (g) |
|---|---|---|---|---|
| R-COHF-NERI-1 | 25.60 | 33.57 | 56.67 | 220.40 |
| R-COHF-NERI-2 | 28.80 | 39.36 | 56.67 | 260.47 |
| R-COHF-NERI-3 | 29.50 | 40.37 | 52.00 | 279.40 |
| R-COHF-NERI-4 | 26.73 | 37.56 | 50.00 | 217.13 |
| R-COHF-NERI-5 | 26.97 | 34.78 | 53.67 | 199.87 |
| R-COHF-NERI-6 | 25.80 | 42.10 | 46.33 | 336.00 |
| R-COHF-NERI-7 | 24.70 | 35.97 | 47.67 | 243.27 |
| R-COHF-NERI-8 | 24.33 | 32.06 | 49.00 | 168.33 |
| R-COHF-NERI-9 | 15.03 | 42.70 | 56.00 | 135.40 |
| R-COHF-NERI-10 | 26.17 | 35.49 | 58.67 | 272.40 |
| R-COHF-NERI-11 | 26.13 | 29.78 | 55.33 | 220.00 |
| R-COHF-NERI-12 | 29.43 | 39.28 | 58.24 | 339.07 |
| R-COHF-NERI-13 | 28.07 | 33.64 | 57.86 | 186.53 |
| R-COHF-NERI-14 | 27.80 | 34.40 | 54.67 | 247.13 |
| R-COHF-NERI-15 | 23.40 | 33.75 | 51.67 | 207.20 |
| R-COHF-NERI-16 | 15.80 | 22.56 | 54.00 | 227.07 |
| R-COHF-NERI-17 | 20.47 | 30.60 | 49.00 | 197.20 |
| Japanese White (Check) | 23.43 | 38.30 | 49.00 | 221.36 |
| **Mean** | **24.90** | **35.35** | **53.14** | **232.12** |
| **Range** | **15.03–29.50** | **22.56–42.70** | **46.33–58.67** | **135.40-339.07** |
| **SE(m)** | **1.36** | **1.68** | **0.57** | **17.39** |
| **CV (%)** | **9.50** | **8.18** | **1.86** | **12.97** |
| **C.D. (0.05)** | **3.94** | **4.83** | **1.64** | **49.32** |

#### 4.2.1.12 Root yield per plot (kg)

Higher yield is the principal objective in all the crop improvement programmes and thus the root yield per plot is a very important horticultural trait as it directly influences the root yield of radish produced in a unit area. High amount of variation in terms of range (3.59 –7.18 kg) was recorded in the 18 genotypes of radish under study. Maximum root yield of 7.18 kg was observed in the radish genotype R-COHF-NERI-12 (7.18 kg) which was found statistically at par with genotype R-COHF-NERI-6 (7.12 kg). While, minimum value of root yield per plot was observed in genotype R-COHF-NERI-8 (3.59 kg) of radish, which was statistically at par with genotypes R-COHF-NERI-9 (3.68 kg), R-COHF-NERI-17 (3.79 kg), R-COHF-NERI-16 (3.82 kg), R-COHF-NERI-13 (3.95 kg).These findings for root yield per plot (kg) were similar to those reported by Singh *et al.* (2019), Roopa *et al.*(2018) and Ola *et al.*(2018).

#### 4.2.1.13 Total soluble solid (ºB)

High amount of TSS is desirable in radish roots. The perusal of Table 4.5 revealed that the values of the genotypes for the character total soluble solids ranged from 3.03–5.93 °B. The comparison of mean values of all the genotypes under study showed that highest total soluble solids content was found in genotype R-COHF-NERI-15 (5.93 °B), which was found statistically at par with genotypes R-COHF-NERI-1 (5.90 °B) and R-COHF-NERI-9 (5.83 °B). Whereas, minimum value for this trait was recorded in genotype R-COHF-NERI-4 (3.03 °B) followed by R-COHF-NERI-6 (4.63°B) and R-COHF-NERI-5 (4.77°B). Similar values for the trait total soluble solid were also recorded by Kumar *et al.* (2012), Mallikarjunarao *et al*. (2015) and Ola *et al*. (2015) in case of radish.

#### 4.2.1.14 Ascorbic acid (mg/100g)

Ascorbic acid or Vitamin-C is an important constituent of radish roots. It is required for the growth and the repair of the tissues of human body and also acts as an antioxidant and prevents us from various diseases. Therefore, high content of Ascorbic acid is desirable trait in radish roots. In the present investigation the value of ascorbic acid in radish roots of the various genotypes ranged from 14.51–29.92 mg/100g (Table 4.5). The mean values depicted that the genotype R-COHF-NERI-14 had maximum (29.92 mg/100g) ascorbic acid content which was statistically at par with genotype R-COHF-NERI-6 (29.47 mg/100g). While, minimum ascorbic acid content was seen in the genotype R-COHF-NERI-3 (14.51 mg/100g) which was statistically at par with the genotypes R-COHF-NERI-17 (14.96 mg/100g), R-COHF-NERI-15 (15.87 mg/100g), Japanese White (15.98 mg/100g) and R-

COHF-NERI-1 (16.32 mg/100g). Dongarwar *et al*. (2017), Kumar *et al*. (2012), Mallikarjunarao *et al*. (2015) and Ola *et al*. (2015) obtained similar values for the ascorbic acid in radish roots.

**Table 4.4 Mean performance of radish genotypes for the horticultural traits, average root weight without leaves (g), marketable root yield per plot (kg), TSS (°B) and ascorbic acid (mg/100 g).**

| Genotypes | Average root weight without leaves (g) | Root yield per plot (kg) | TSS (°B) | Ascorbic acid (mg/100g) |
|---|---|---|---|---|
| R-COHF-NERI-1 | 180.73 | 4.67 | 5.90 | 16.32 |
| R-COHF-NERI-2 | 234.40 | 5.52 | 5.20 | 19.49 |
| R-COHF-NERI-3 | 240.60 | 5.92 | 4.83 | 14.51 |
| R-COHF-NERI-4 | 181.67 | 4.60 | 3.03 | 16.77 |
| R-COHF-NERI-5 | 162.53 | 4.40 | 4.77 | 22.21 |
| R-COHF-NERI-6 | 241.56 | 7.12 | 4.63 | 29.47 |
| R-COHF-NERI-7 | 196.73 | 5.16 | 4.97 | 25.39 |
| R-COHF-NERI-8 | 145.67 | 3.59 | 4.97 | 22.67 |
| R-COHF-NERI-9 | 89.53 | 3.68 | 5.83 | 25.39 |
| R-COHF-NERI-10 | 225.47 | 5.77 | 5.37 | 24.48 |
| R-COHF-NERI-11 | 174.87 | 4.66 | 5.17 | 27.20 |
| R-COHF-NERI-12 | 251.87 | 7.18 | 5.00 | 18.59 |
| R-COHF-NERI-13 | 137.80 | 3.95 | 5.30 | 21.31 |
| R-COHF-NERI-14 | 198.00 | 5.24 | 4.97 | 29.92 |
| R-COHF-NERI-15 | 165.00 | 4.39 | 5.93 | 15.87 |
| R-COHF-NERI-16 | 141.33 | 3.82 | 5.13 | 17.68 |
| R-COHF-NERI-17 | 156.93 | 3.79 | 4.93 | 14.96 |
| Japanese White (Check) | 154.48 | 4.71 | 4.97 | 15.98 |
| **Mean** | **182.18** | **4.90** | **5.05** | **20.01** |
| **Range** | **89.53 - 251.87** | **3.59 -7.18** | **3.03 -5.93** | **14.51–29.92** |
| **SE(m)** | **14.23** | **0.18** | **0.18** | **0.70** |
| **CV (%)** | **13.34** | **6.23** | **6.22** | **5.70** |
| **C.D. (0.05)** | **40.35** | **0.51** | **0.52** | **2.00** |

#### 4.2.1.15 Prevalence of *Alternaria* blight

The *Alternaria* blight causes considerable damage in radish under low hill conditions of Himachal Pradesh and lowers the production of radish root and seed yield. The pathogen of *Alternaria* blight attacks all the above ground parts of the plant producing severe spotting and blighting on leaves, shoots and pods. The blight is a serious destroyer and disease development is so fast that whole crop is lost in a few days. Therefore, the problem deserves immediate and effective measures of control (Verma and Verma, 2010) but control measures enhance the cost of production. So, identification of genotypes which are resistant to *Alternaria* blight is quite essential. In the present study the prevalence of *Alternaria* blight was studied under the two subheads i.e. disease incidence (%) and disease severity (%). The description of which, with respect, to various radish genotypes is given below as under:

##### 4.2.1.15.1 Disease incidence (%)

The percentage of number of plants infected from total number of plants on which the observations are taken is referred to as disease incidence. Disease incidence of *Alternaria* blight was recorded immediately after appearance of disease on the crop (Ghimire *et al*., 2016). The higher disease incidence can destroy the crop as well as increase the cost of production. So, genotypes which are less susceptible to *Alternaria* are desirable. The range of disease incidence varied from 50.67-84.34 % while the overall mean value was found to be 54.31 %. Lowest percentage for disease incidence was recorded by the genotype R-COHF-NERI-17 (84.34 %) of radish which was found statistically at par to the genotype R-COHF-NERI-16 (82.26 %). However, the minimum percentage for disease incidence was found in R-COHF-NERI-3 (50.67 %) which was statistically at par with the radish genotype R-COHF-NERI-9 (53.96%). These findings are in line with those of Islam *et al*. (2007).

##### 4.2.1.15.2 Disease severity (%)

Disease severity is the percentage of relevant host tissue covered by symptom or lesion or damage by disease. The disease severity estimation was based on a modified 0 to 5 scale given by Townsend and Heuberger (1943) and the disease scoring was started 10 days after disease appearance (Ghimire *et al.*, 2016). The high value of disease severity can cause significant damage to the crop and increase the cost of production for disease control which is not desirable. The best genotype in terms of disease severity having minimum percentage for disease severity was R-COHF-NERI-9 (39.87 %) which was statistically at par with genotypes R-COHF-NERI-8 (44.83 %), R-COHF-NERI-10 (43.33 %) and R-COHF-NERI-

**Table: 4.5 Prevalence of *Alternaria* blight in various radish (*Raphanus sativus* L.) genotypes.**

| Genotypes | Prevalence of *Alternaria* blight | |
|---|---|---|
| | **Disease incidence (%)** | **Disease severity (%)** |
| R-COHF-NERI-1 | 56.12 (48.50) | 45.93 (42.62) |
| R-COHF-NERI-2 | 64.42 (53.36) | 50.27 (45.14) |
| R-COHF-NERI-3 | 50.67 (45.37) | 49.40 (44.60) |
| R-COHF-NERI-4 | 69.74 (56.62) | 57.63 (49.45) |
| R-COHF-NERI-5 | 72.36 (58.27) | 61.10 (51.54) |
| R-COHF-NERI-6 | 70.98 (57.39) | 59.80 (50.83) |
| R-COHF-NERI-7 | 69.35 (56.41) | 61.10 (51.40) |
| R-COHF-NERI-8 | 60.86 (51.26) | 44.83 (41.96) |
| R-COHF-NERI-9 | 53.96 (47.26) | 39.87 (39.12) |
| R-COHF-NERI-10 | 55.39 (48.08) | 43.33 (41.03) |
| R-COHF-NERI-11 | 56.54 (48.74) | 45.50 (42.25) |
| R-COHF-NERI-12 | 64.62 (53.48) | 51.13 (45.62) |
| R-COHF-NERI-13 | 66.35 (54.55) | 51.13 (45.63) |
| R-COHF-NERI-14 | 70.65 (57.21) | 58.07 (49.64) |
| R-COHF-NERI-15 | 65.82 (54.21) | 54.17 (47.37) |
| R-COHF-NERI-16 | 82.26 (65.09) | 70.63 (57.25) |
| R-COHF-NERI-17 | 84.34 (66.77) | 71.93 (58.10) |
| Japanese White (Check) | 67.21 (55.05) | 56.33 (48.63) |
| **Mean** | 54.31 | 47.34 |
| **CD (0.05)** | 3.16 | 8.89 |
| **$SE_m$** | 1.09 | 3.08 |
| **CV** | 3.49 | 11.26 |

*Values in the parenthesis are the Arcsine (angular) transformed values.

11 (45.50 %). Range of disease severity varied from 39.87 to 71.93 %. The overall mean of all the 18 genotypes under study was 45.93 %. Highest percentage for disease severity was found in the radish genotype R-COHF-NERI-17 (71.93 %) which was found statistically at par with R-COHF-NERI-16. These results were in confirmation to those obtained by Suhag *et al*. (1993) and Ghimire *et al.* (2016).

#### 4.2.1.16 Root shape and root color

Root shape and color are the qualitative characters and there is lot of variability in terms of root shape and color in radish. The liking for a particular root shape and color depends upon the consumer's preference. However, the colored roots are more nutritious due to the presence of coloring pigments in them.

**Table 4.6 Root shape and root color of different genotypes in radish.**

| Genotypes | Root shape | Root color |
|---|---|---|
| R-COHF-NERI-1 | Conical | White |
| R-COHF-NERI-2 | Conical | White |
| R-COHF-NERI-3 | Conical | White |
| R-COHF-NERI-4 | Cylindrical | White |
| R-COHF-NERI-5 | Conical | White |
| R-COHF-NERI-6 | Cylindrical | White |
| R-COHF-NERI-7 | Conical | White |
| R-COHF-NERI-8 | Conical | Red |
| R-COHF-NERI-9 | Conical | Red |
| R-COHF-NERI-10 | Cylindrical | White |
| R-COHF-NERI-11 | Conical | White |
| R-COHF-NERI-12 | Conical | Red |
| R-COHF-NERI-13 | Conical | White |
| R-COHF-NERI-14 | Conical | White |
| R-COHF-NERI-15 | Conical | White |
| R-COHF-NERI-16 | Conical | White |
| R-COHF-NERI-17 | Conical | White |
| Japanese White (Check) | Cylindrical | White |

The majority of genotypes of radish studied had conical root shape (13 genotypes) whereas only 5 genotypes viz. R-COHF-NERI-4, R-COHF-NERI-6, R-COHF-NERI-9, R-

COHF-NERI-10 and Japanese White exhibited cylindrical type of root shape on the basis of visual observation.

On the basis of visual inspection three genotypes *viz*. R-COHF-NERI-8, R-COHF-NERI-9 and R-COHF-NERI-12 had red colored roots and hence showed the presence of coloring pigments in them. While, majority of genotypes (15 in number) including check (Japanese White) had white colored roots. Anjanappa *et al*. (1998) and Jatoi *et al*. (2011) reported similar observations for root shape and root color in radish.

### 4.2.2 Parameters of variability

Vavilov (1951) first realized that a wider range of variation in any crop provides better opportunities to pick desirable types. For calculating variability; range and coefficients of variation are used in plant breeding. If the value of GCV is higher than that of PCV, it shows that there is more contribution of genetic component towards the expression of the character and selection for such traits will be effective. But in the opposite scenario when the value of PCV is higher than that of GCV, it is an indicator that the variation is not only due to genetic makeup of the plant but also due to environmental influence. In such cases, where the influence of environment is more, the selection for the individual horticultural character is ineffective.

The analysis of genetic variability, among the radish genotypes undertaken, in the present study was done only for 14 quantitative horticultural traits of radish excluding prevalence of *Alternaria* blight. The data recorded by characterization was used to work out the estimates of variability viz. Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV). Further Heritability in broad sense ($h^2_{bs}$%) and Genetic Advance were also worked out to find the efficacy of selection for a particular trait. The estimates of genetic parameters for different traits are presented in Table 4.8 and the results pertaining to these parameters are briefly presented and discussed as below:

#### 4.2.2.1 Coefficients of variability

The Table 4.8 showed that the phenotypic coefficient of variation was higher in magnitude in comparison to genotypic coefficient of variation for all the characters under study. However, the differences between PCV and GCV values for all the characters was lower in magnitude which indicated that the contribution of environment was quite less in governing the various traits. The observations recorded with respect to Phenotypic and Genotypic coefficient have been discussed under the following headings:

R-COHF-NERI-1

R-COHF-NERI-2

R-COHF-NERI-3

R-COHF-NERI-4

R-COHF-NERI-5

R-COHF-NERI-6

R-COHF-NERI-7

R-COHF-NERI-8

**Plate 4.a Variability in leaves of various radish genotypes**

R-COHF-NERI-9

R-COHF-NERI-10

R-COHF-NERI-11

R-COHF-NERI-12

R-COHF-NERI-14

R-COHF-NERI-15

R-COHF-NERI-17

Japanese White

**Plate 4.b Variability in leaves of various radish genotypes**

#### 4.2.2.1.1 Phenotypic coefficient of variation

The data presented in table 4.8 indicates that wide range of phenotypic variability exists in experimental material. The phenotypic coefficient of variation (PCV) ranged from7.65 to 27.60%. High phenotypic coefficient of variation existed for the traits viz. root yield per plot (27.60%), root diameter (27.42%), average root weight without leaves (26.08%), average root weight with leaves (25.23%), ascorbic acid (24.85%) and number of leaves per plant (21.95%). Sivathanu *et al.* (2014), Ullah *et al*. (2010) and Kumar *et al* (2012) also observed high PCV values for identical traits in radish. Moderate phenotypic coefficient of variation (PCV) were exhibited for root length (18.33%), crown diameter (16.10%), leaf length (14.85%), days to 50% germination (13.86%), TSS (13.02%), leaf width (12.62%) and plant height (10.10%). Moderate values of PCV for the traits discussed above have also been reported by Mallikarjunarao *et al.* (2015) and Kumar *et al*. (2012). While, days taken to marketable maturity (7.65%) exhibited low phenotypic coefficient of variation (PCV). The findings were in line to those obtained by Ullah *et al*. (2010).

#### 4.2.2.1.2 Genotypic coefficient of variation

Genotypic coefficient of variation tells us about the amount of variation present in the population which is there due to the genetic component. In the experimental material, wide range of genotypic coefficient of variation was observed for characters under study ranging from 7.23 to 26.07%. High genotypic coefficient of variation was found in characters viz. root diameter (26.07%), ascorbic acid (24.19%), average root weight without leaves (22.92%), average root weight with leaves (21.16%) and number of leaves per plant (21.12%). Similar observations with high GCV were also recorded by Roopa *et al*. (2018), Sivathanu *et al*. (2014) and Kumar *et al* (2012). Moderate genotypic coefficient of variation (GCV) were observed for marketable root yield per plot (18.58%), root length (15.72%), leaf length (14.18%), days to 50% germination (13.37%), TSS (12.16%) and crown diameter (11.14%). Similar findings with moderate GCV were observed by Mallikarjunarao *et al.* (2015) and Kumar *et al*. (2012). While, the horticultural trait plant height exhibited low genotypic coefficient of variation (7.24%) which were in accordance to the research findings of Ullah *et al*. (2010).

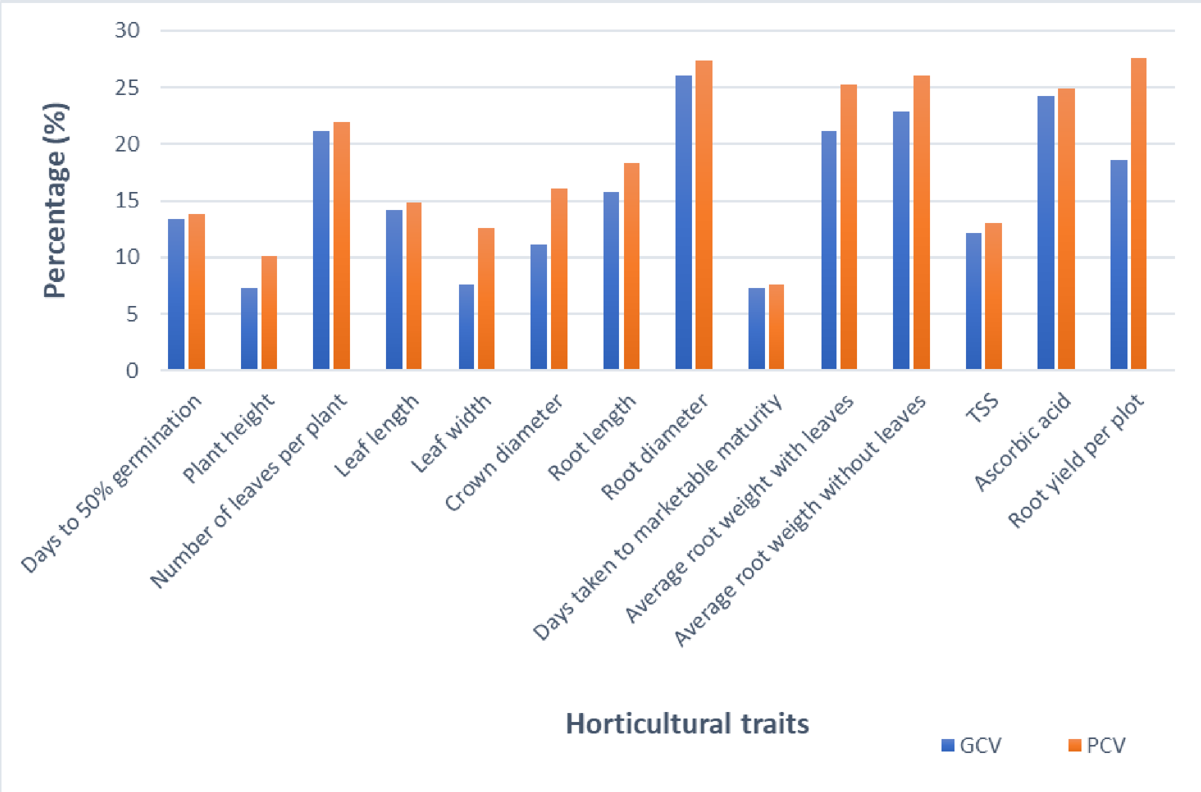


**Figure 1 Graphical presentation of Genotypic and Phenotypic coefficients of variation (%) in radish.**

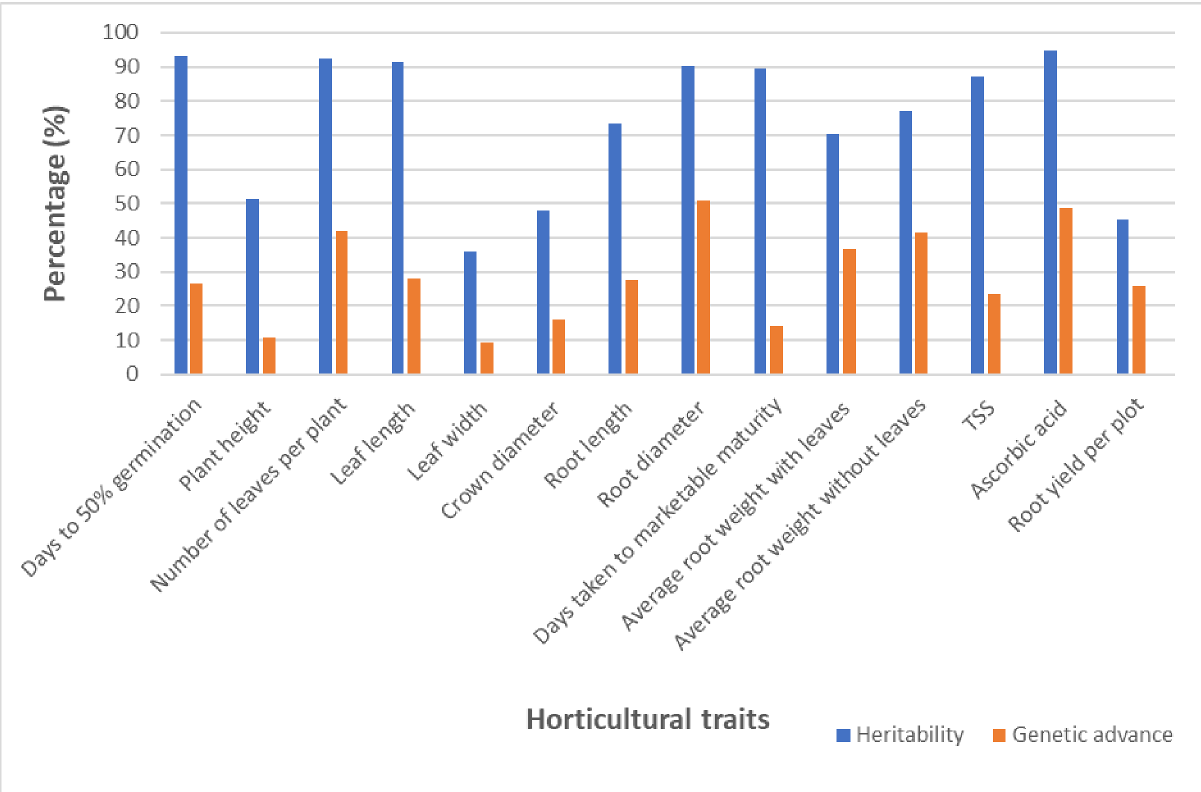


**Figure 2 Graphical presentation of heritability (%) and genetic advance (%).**

**Table 4.7 Estimates of phenotypic and genotypic coefficients of variation, heritability and genetic advance for various characters in radish.**

| Characters | Range | Mean ± S.E | Coefficients of variability (%) | | Heritability (%) | Genetic advance as % of mean (%) |
|---|---|---|---|---|---|---|
| | | | Genotypic | Phenotypic | | |
| Days to 50% germination | 7 – 13 | 11.11 ± 0.33 | 13.37 | 13.86 | 93.11 | 26.58 |
| Plant height (cm) | 51.00 – 59.87 | 54.50 ± 3.14 | 7.24 | 10.10 | 51.32 | 10.68 |
| Number of leaves per plant | 6.93 – 17.07 | 13.38 ± 0.65 | 21.12 | 21.95 | 92.57 | 41.86 |
| Leaf length (cm) | 21.48 – 35.27 | 29.45 ± 1.06 | 14.18 | 14.85 | 91.25 | 27.91 |
| Leaf width (cm) | 7.42 – 10.27 | 8.84 ± 0.73 | 7.55 | 12.62 | 35.76 | 9.30 |
| Crown diameter (mm) | 14.24 – 23.67 | 17.92 ± 1.70 | 11.14 | 16.10 | 47.87 | 15.88 |
| Root length (cm) | 15.03 – 29.50 | 24.90 ± 1.92 | 15.72 | 18.33 | 73.53 | 27.77 |
| Root diameter (mm) | 15.6 – 39.70 | 35.35 ± 2.32 | 26.07 | 27.42 | 90.40 | 51.06 |
| Days taken to marketable maturity | 46.33 – 58.67 | 53.14 ± 1.08 | 7.23 | 7.65 | 89.43 | 14.09 |
| Average root weight with leaves (g) | 135.40 – 279.40 | 224.86 ± 26.01 | 21.16 | 25.23 | 70.38 | 36.58 |
| Average root weight without leaves (g) | 89.53 – 241.56 | 182.18 ± 18.53 | 22.92 | 26.08 | 77.19 | 41.48 |
| TSS (°B) | 3.03 – 5.93 | 5.05 ± 0.19 | 12.16 | 13.02 | 87.17 | 23.39 |
| Ascorbic acid (mg/100g) | 14.51 – 29.47 | 20.01 ± 0.98 | 24.19 | 24.85 | 94.74 | 48.49 |
| Root yield/plot (kg) | 3.59 – 5.92 | 4.75 ± 0.82 | 18.58 | 27.60 | 45.33 | 25.77 |

### 4.3.1 Heritability

Heritability acts as an indicator of the level of genetic variation that can be passed on from parent to offspring. This forecasts the expression and reliability of phenotypic value as a guide to breeding performance. It reflects the genetic relationship between parent and its progeny. High heritability displayed by a character allows a breeder to make direct selection on single plant to enhance a specific trait of interest, while if the heritability is on the lower side then the breeder has to rely on the progeny testing and then make selection on the basis of desirable progenies.

The estimates of heritability (broad sense) varied from 35.76% to 94.74% for different characters under study (Table 4.8). High heritability estimates were obtained for ascorbic acid (94.74%), days to 50% germination (93.11%), number of leaves per plant (92.57%), leaf length (91.25%), root diameter (90.4%), days taken to marketable maturity (89.43%), TSS (87.17%), average root weight without leaves (77.19%), root length (73.53%) and average root weight with leaves (70.38%). Similar heritability levels were observed by Roopa *et al.* (2018) and Ullah *et al*. (2010). Moderate heritability levels were reported for the traits plant height (51.32%) only. Whereas, low heritability levels were obtained for the traits viz. crown diameter (47.87%), root yield per plot (45.33%) and leaf width (35.76%) in the current study. The results of present investigation were in close agreement with those of Kumar *et al.* (2012).

### 4.3.2 Genetic Advance

The estimates of the genetic advance as percentage of mean were calculated during the present investigation involving 18 genotypes of radish. The heritability estimates alone cannot be useful in determining the genetic potential of any horticultural trait. High heritability estimates coupled with high genetic advance as percentage of mean suggest that the corresponding trait is controlled mainly by additive genes and selection in such a scenario can be quite effective.

Genetic advance (expressed as per cent of population mean) was low to high in nature and ranged from 9.30–51.06 per cent for different characters under study (Table 4.8). Genetic gain was found high for characters viz. root diameter (51.06%), ascorbic acid (48.49%), number of leaves per plant (41.86%), average root weight without leaves (41.48%), average root weight with leaves (36.58%), leaf length (27.91%), root length (27.77%), days to 50% germination (26.58%), root yield per plot (25.77%) and TSS (23.39%). Similar results for high genetic advance were reported by Mallikarjunarao *et al*. (2015) and Roopa *et al.* (2018). Moderate genetic gain was recorded for crown diameter (15.88%), days taken to marketable maturity

(14.09%) and plant height (10.68%). Moderate values of genetic advance have also been reported by Kumar *et al*. (2012) and Roopa *et al.* (2018). Whereas, it was observed low for the horticultural trait leaf width (9.30%) which was in accordance with the findings of Sivathanu *et al*. (2014)

Both heritability and genetic advance were higher for characters viz. days to 50% germination, number of leaves per plant, leaf length, root length, root diameter, average root weight with leaves, average root weight without leaves, total soluble solid and ascorbic acid. High heritability coupled with high genetic advance as percentage of mean suggest that the constituent trait is controlled mainly by additive genes and selection can be quite effective for such type of horticultural traits. The character root yield per plot showed low heritability and moderate genetic advance (as percentage of mean) which suggesting that selection for root yield per plot was not much effective.

## 4.4 Correlation coefficient analysis

After acquiring knowledge about the genetic variation available in experimental material, it is important to learn about association between different characters within a species. Since most of the traits of economic value in crop plants rely on one or the other characteristics, and the degree of expression of one-character increases or decreases as the other character increases or decreases and vice versa. After knowing the essence of yield variability and related characteristics, it would be useful to know the extent and magnitude of associations between these characters to bring out improvement. Some of the horticultural traits can be directly and positively correlated with marketable root yield per plant and hence selection for these traits provides opportunity for crop improvement. In plant breeding generally two types of correlations are worked out which are genotypic and phenotypic correlations. The description of both of these correlations derived from the current study involving 18 genotypes of radish is as below:

### 4.4.1 Genotypic and Phenotypic correlations

The inherent or heritable association between two variables is known as the genotypic correlation. This type of correlation may be either due to pleiotropic action of genes or due to linkage or both. Whereas, phenotypic correlation is the association between the two variables which can be directly observed. It includes both genetic and environmental effects and therefore, differs under different environmental conditions. The character wise discussion of the various genotypic and phenotypic correlations observed in the study of various genotypes of radish is as follows:

#### 4.4.1.1 Days to 50% germination

Days to 50% germination expressed positive and highly significant correlation with the characters viz. days taken to marketable maturity (Genotypic 0.747 and Phenotypic 0.699), root diameter (0.553 and 0.487), crown diameter (0.474 and 0.272) and leaf width (0.368 and 0.193) at genotypic and phenotypic level. Similar correlations were obtained by Nagar (2015) in radish.

#### 4.4.1.2 Plant height

Plant height showed positive and highly significant correlations with the traits viz. root length (0.783 and 0.660), average root weight without leaves (0.680 and 0.541), average weight with leaves (0.565 and 0.444), root yield per plot (0.465 and 0.322), leaf length (0.402 and 0.351) and number of leaves per plant (0.326 and 0.250). However, plant height had negative and highly significant correlation with total soluble solid (-0.501 and -0.314). Whereas, the character showed positive significant association (0.465 and 0.322) with root yield per plant at genotypic level respectively. These findings were in line to the findings of Kaur *et al*. (2017) and Ullah *et al*. (2010) in the correlation's studies conducted in radish.

#### 4.4.1.3 Number of leaves per plant

The character Number of leaves per plant had positive and highly significant correlation with the trait average root weight with leaves (0.374 and 0.276) and average root weight without leaves (0.353 and 0.304) at genotypic and phenotypic level. These results were in confirmation to the research findings of Panwar *et al*. (2003) in radish.

#### 4.4.1.4 Leaf length

Leaf length is an important trait in radish and it observed positive and highly significant correlation with the traits leaf width (0.548 and 0.348), average root weight with leaves (0.422 and 0.324) both at genotypic and phenotypic levels respectively. Whereas, the positive significant association (0.326) was found with the character root yield per plant at genotypic level only. These findings were similar to those of Nagar (2016).

#### 4.4.1.5 Leaf width

Positive and highly significant associations were recorded by the character with the traits *viz*. average root weight with leaves (Genotypic correlation: 0.427), average root weight without leaves (Genotypic correlation: 0.422), root yield per plot (0.326 and 0.341), days taken to marketable maturity (Genotypic correlation: 0.358), root diameter (Genotypic correlation: 0.299) and crown diameter (Genotypic correlation: 0.283) whereas positive significant association of the character was observed with the trait root yield per plot at genotypic and phenotypic level respectively. These results were similar to those obtained by

Sivathanu *et al*. (2014) in radish.

#### 4.4.1.6 Crown diameter

Crown diameter exhibited positive and highly significant correlation coefficient with average root weight without leaves (0.298 and 0.275) at both genotypic and phenotypic levels. However, the present horticultural trait i.e. crown diameter expressed negative and significant correlation coefficient with the trait ascorbic acid (-0.663 and -0.442) at genotypic and phenotypic levels suggesting that increase in one-character lead to the decrease in other and vice versa. Guleria (2016) also obtained similar results for crown diameter in radish.

#### 4.4.1.7 Root length

Root length is very important character since it contributes to the yield. It was observed that positive and highly significant correlation was exhibited by the character root length with other horticultural traits *viz*. average root weight without leaves (0.756 and 0.675), root yield per plot (0.731 and 0.443) and average root weight without leaves (0.560 and 0.518) at genotypic and phenotypic levels. Similarly, a positive and highly significant correlation of the root length was observed with the economic character root yield per plot at genotypic and phenotypic levels respectively. These findings were in confirmation to those obtained by Rajput and Pal (2014) and Ullah *et al.* (2010).

#### 4.4.1.8 Root diameter

Highly significant and positive associations of root diameter were recorded with the other characters *viz*. root yield per plot (0.385 and 0.287), ascorbic acid (0.352 and 0.325) and average root weight without leaves (0.337 and 0.337) at genotypic and phenotypic levels**.** Kaur *et al.* (2017) also reported positive and highly significant association of root diameter with root yield per plot.

#### 4.4.1.9 Days taken to marketable maturity

The character days taken to marketable maturity had positive and highly significant association with the trait total soluble solid (0.437 and 0.422) at genotypic and phenotypic levels respectively. Similar findings were obtained by Guleria (2016) in radish.

#### 4.4.1.10 Average root weight with leaves

The character average root weight with leaves showed positive and highly significant association with other characters of horticultural importance viz. root yield per plot (0.939 and 0.757) and average root weight without leaves (0.970 and 0.861) at genotypic and phenotypic levels respectively suggesting that the increase in the character also lead to the increases in the economic character i.e. root yield per plot. Similar type of

**Table 4.8: Genotypic and phenotypic coefficients of correlation among different horticultural traits in radish.**

| | | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **X1** | **G** | 1.000 | -0.195 | -0.178 | 0.147 | 0.368** | 0.474** | -0.099 | 0.553** | 0.747** | -0.169 | -0.118 | 0.239 | 0.014 | -0.180 |
| | **P** | 1.000 | -0.178 | -0.167 | 0.140 | 0.193 | 0.272* | -0.086 | 0.487** | 0.699** | -0.151 | -0.103 | 0.242 | 0.004 | -0.126 |
| **X2** | **G** | | 1.000 | 0.326* | 0.402** | 0.022 | -0.071 | 0.783** | 0.074 | -0.145 | 0.565** | 0.680** | -0.501** | -0.103 | 0.465** |
| | **P** | | 1.000 | 0.250 | 0.351** | 0.071 | 0.184 | 0.660** | 0.115 | -0.085 | 0.444** | 0.541** | -0.314* | -0.105 | 0.322* |
| **X3** | **G** | | | 1.000 | -0.066 | 0.035 | 0.032 | 0.262 | -0.200 | -0.091 | 0.374** | 0.353** | 0.110 | -0.222 | 0.217 |
| | **P** | | | 1.000 | -0.059 | 0.001 | 0.012 | 0.237 | -0.160 | -0.097 | 0.276* | 0.304* | 0.068 | -0.211 | 0.141 |
| **X4** | **G** | | | | 1.000 | 0.548** | 0.117 | 0.024 | -0.023 | 0.199 | 0.402** | 0.252 | -0.004 | -0.034 | 0.326* |
| | **P** | | | | 1.000 | 0.348** | 0.135 | 0.011 | -0.009 | 0.193 | 0.324* | 0.235 | -0.028 | -0.046 | 0.203 |
| **X5** | **G** | | | | | 1.000 | 0.283* | -0.142 | 0.299* | 0.358** | 0.427** | 0.422** | -0.195 | -0.216 | 0.420** |
| | **P** | | | | | 1.000 | 0.234 | 0.011 | 0.239 | 0.205 | 0.397** | 0.254 | -0.130 | -0.123 | 0.341* |
| **X6** | **G** | | | | | | 1.000 | 0.031 | 0.176 | 0.175 | 0.170 | 0.298* | 0.112 | -0.663** | 0.140 |
| | **P** | | | | | | 1.000 | 0.081 | 0.206 | 0.137 | 0.242 | 0.275* | 0.081 | -0.442** | 0.180 |
| **X7** | **G** | | | | | | | 1.000 | 0.244 | 0.181 | 0.560** | 0.756** | -0.326* | 0.069 | 0.731** |
| | **P** | | | | | | | 1.000 | 0.254 | 0.145 | 0.518** | 0.675** | -0.228 | 0.026 | 0.443** |
| **X8** | **G** | | | | | | | | 1.000 | 0.213 | 0.199 | 0.337* | -0.039 | 0.352** | 0.385** |
| | **P** | | | | | | | | 1.000 | 0.197 | 0.225 | 0.337* | -0.051 | 0.325* | 0.287* |
| **X9** | **G** | | | | | | | | | 1.000 | 0.009 | 0.050 | 0.437** | 0.041 | 0.080 |
| | **P** | | | | | | | | | 1.000 | 0.000 | 0.016 | 0.422** | 0.039 | 0.009 |
| **X10** | **G** | | | | | | | | | | 1.000 | 0.970** | -0.215 | 0.116 | 0.939** |
| | **P** | | | | | | | | | | 1.000 | 0.861** | -0.203 | 0.081 | 0.757** |
| **X11** | **G** | | | | | | | | | | | 1.000 | -0.256 | 0.077 | 0.887** |
| | **P** | | | | | | | | | | | 1.000 | -0.214 | 0.034 | 0.720** |
| **X12** | **G** | | | | | | | | | | | | 1.000 | 0.042 | -0.191 |
| | **P** | | | | | | | | | | | | 1.000 | 0.039 | -0.138 |
| **X13** | **G** | | | | | | | | | | | | | 1.000 | 0.231 |
| | **P** | | | | | | | | | | | | | 1.000 | 0.183 |
| **X14** | **G** | | | | | | | | | | | | | | 1.000 |
| | **P** | | | | | | | | | | | | | | 1.000 |

*****Significant at 5% level**Significant at 1% level

X1 – Days to 50% germination
X2 – Plant height (cm)
X3 – Number of leaves per plant
X4 - Leaf length (cm)
X5 - Leaf width (cm)
X6 – Crown diameter (cm)
X7 – Root length (cm)
X8 – Root diameter (mm)
X9 – Days taken to marketable maturity
X10 – Average root weight with leaves (g)
X11– Average root weight without leaves (g)
X12 –Total soluble solid (ºB)
X13–Ascorbic acid (mg/100g)
X14 – Root yield per plot (kg)

results were also obtained by Kaur *et al.* (2017) in radish.

#### 4.4.1.11 Average root weight without leaves

Highly significant and positive association of the important horticultural trait i.e. average root weight without leaves was observed with the trait root yield per plot (0.887 and 0.720) both at genotypic and phenotypic level suggesting that the trait significantly contributed to the economic character and increase in one had increasing effect on the other character. These research findings were in accordance to those obtained by Panwar *et al*. (2003) in radish.

#### 4.4.1.12. Total soluble solids

Total soluble solid had positive and non-significant correlation with ascorbic acid (0.042 and 0.039). While negative though non-significant correlation was reported with trait root yield per plot (-0.191 and -0.138).

#### 4.4.1.13. Ascorbic Acid

Positive though non-significant correlation of ascorbic acid was observed with character root yield per plot (0.231 and 0.183).

#### 4.4.1.14 Root yield per plot

Root yield per plot have positive and significant association with the character *viz.*, average root weight with leaves (0.939 and 0.757), average root weight without leaves (0.887 and 0.720), root length (0.731 and 0.443), plant height (0.465 and 0.322), leaf width (0.420 and 0.341), root diameter (0.385 and 0.287) and leaf length (0.326 at genotypic level). These research findings were in accordance to those obtained by Kaur *et al*. (2017) and Ullah *et al.* (2010) in radish.

### 4.5 Path coefficient analysis (genotypic level)

The correlation coefficients only provide information about the combination of different characters among themselves, while the path coefficient analysis provides a better insight into the cause of the association. It tells us the effect of a character individually and in conjunction with other characters on the dependent character which is of economic value. It allows the partitioning of the coefficients of correlation into direct and indirect effects of the traits, which contribute to the dependent variable. Root yield per plot was taken as dependent variable in current study, and the rest of the characters were considered as independent variables. The results of the present study with respect to direct and indirect effects on root yield per plot at genotypic level are presented in Table

4.11. The discussion pertaining to various direct and indirect effects of the 13 independent traits on the dependent trait viz. Root yield per plot trait wise is as follows:

### 4.5.1 Days to 50% germination

Negative direct effect was reported for root yield per plot through days to 50 % flowering (-0.708). Maximum indirect effects were seen through plant height (0.138) followed by number of leaves per plant (0.126), average root weight with leaves (0.120), average root weight without leaves (0.083) and root length (0.070). However, maximum negative indirect effect was observed in days taken to marketable maturity (-0.529) succeeded by root diameter (-0.392), crown diameter (-0.335), leaf width (-0.261), total soluble solid (-0.169), leaf length (-0.104) and ascorbic acid (-0.010). These research findings were in accordance to those obtained by Sagar (2016). The days to 50% germination had negative direct effect on the dependent trait root yield per plot.

### 4.5.2 Plant height

Negative direct effect was seen for root yield per plot overplant height (-1.125) which suggests that the selection for less plant height will lead to increase in the root yield per plot. However, positive indirect effects of the plant height were observed through characters *viz*. total soluble solid (0.563), days to 50% germination (0.219), days taken to marketable maturity (0.120), ascorbic acid (0.116) and crown diameter (0.080). Whereas, high negative indirect effect over the dependent character root yield per plot were seen through root length (-0.881), average root weight without leaves (-0.765), average root weight with leaves (-0.636), leaf length (-0.452), number of leaves per plant (-0.366), root diameter (-0.083) and leaf width (-0.025). Similar results were obtained by Kaur *et al*. (2017) for characters plant height, days taken to marketable maturity, ascorbic acid through dependent character root yield per plot in radish.

### 4.5.3 Number of leaves per plant

The character number of leaves per plant recorded positive direct effect (0.055) on the dependent trait i.e. root yield per plot. Highest positive indirect effects by the character on dependent character were reported through trait average root weight with leaves (0.020) followed by average root weight without leaves (0.019), plant height (0.018), root length (0.014), total soluble solid (0.006), leaf width (0.002) and crown diameter (0.002). This suggested that the selection through average root weight with leaves along with the given character number of leaves per plant could be utilized to increase the root yield per plot in radish. On the other hand, the highest negative indirect effect was observed through the trait ascorbic acid (-0.012) which was followed by root diameter (-0.011), days to 50% germination (-0.010), days taken to marketable maturity (-0.005) and leaf length (-0.004). Naseeruddin *et al*. (2018) also observed the positive direct effect on the dependent trait root yield through the character number of leaves per plant.

### 4.5.4 Leaf length

Leaf length had positive direct effect on the important and dependent horticultural trait root yield per plot (0.426). Similarly, positive indirect effects were observed via traits *viz*. leaf width (0.233), average root weight with leaves (0.171), average root weight without leaves (0.107), days taken to marketable maturity (0.085), days to 50% germination (0.062), crown diameter (0.050) and root length (0.010). Whereas, negative indirect effect was detected over number of leaves per plant (-0.028), ascorbic acid (-0.015), root diameter (-0.010) and total soluble solid (-0.002) respectively. This suggested that selection for high leaf length along with a smaller number of leaves could help in increasing the root yield per plot in the given study. Similar finding were revealed by Kaur *et al*. (2017).

### 4.5.5 Leaf width

Negative direct effect was reported on dependent trait root yield per plot through the independent trait leaf width (-0.783). However, Positive indirect effects were exhibited by ascorbic acid (0.169), total soluble solid (0.153) and root length (0.111). While, maximum negative indirect effect over the dependent trait was observed through leaf length (-0.429) followed by the traits average root weight with leaves (-0.334), average root weight without leaves (-0.330), days to 50% germination (-0.288), days taken to marketable maturity (-0.280), root diameter (-0.234), crown diameter (-0.221), number of leaves per plant (-0.027) and plant height (-0.017). Likewise, Jatoi *et al*. (2011) also observed the negative direct effect on dependent horticultural trait i.e. root yield per plot via leaf width.

### 4.5.6 Crown diameter

Negative direct effect was exhibited by the important trait crown diameter (-0.221) over the dependent character root yield per plot. Maximum positive indirect effect was observed via ascorbic acid (0.169) followed by the trait plant height (0.016). This suggested that selection through higher ascorbic acid was more effective than the selection for crown diameter in increasing the root yield per plot. Whereas, maximum negative indirect effect was reported through days to 50% germination (-0.105) followed by average root weight without leaves (-0.066), leaf width (-0.063), root diameter (-0.039), days taken to marketable maturity (-0.039), average root weight with leaves (-0.038), leaf length (-0.026), total soluble solid (-0.025), number of leaves per plant (-0.007) and root length (-0.007). Guleria (2016) also exhibited that the dependent trait root yield per plot had positive direct effect through independent trait crown diameter.

### 4.5.7 Root length

Root length exhibited positive direct effect on root yield per plot (0.577). However, positive indirect effects were reported through the traits *viz*. plant height (0.452), average root weight without leaves (0.436), average root weight with leaves (0.224), number of leaves per plant (0.151), root diameter (0.141), days taken to marketable maturity (0.104), ascorbic acid (0.040), crown diameter (0.018) and leaf length (0.014). This showed that selection for root length along with plant height is more effective to increase the dependent trait root yield per plot. Whereas, negative indirect effects were exhibited through traits like total soluble solid (-0.188), leaf width (-0.082) and days taken to marketable maturity (-0.057). Kaur *et al*. (2017) also found that root length had positive direct effect on dependent character root yield in radish.

### 4.5.8 Root diameter

Positive direct effect was observed on the dependent character root yield per plot by independent trait root diameter (1.157) suggesting the importance of the trait in improvement of root yield per plot in radish. Maximum positive indirect effect was reported by the trait days to 50% germination (0.639) which was followed by the traits ascorbic acid (0.407), average root weight without leaves (0.389), leaf width (0.346), root length (0.282), days taken to marketable maturity (0.246), average root weight with leaves (0.130), crown diameter (0.204) and plant height (0.085).While, maximum negative indirect effects were observed through the trait number of leaves per plant (-0.231) which was followed by the horticultural characters total soluble solid (-0.045) and leaf length (-0.027). Similar findings were obtained by Ullah *et al*. (2010); according to the studies conducted by them the root diameter showed positive direct effect on the horticultural trait root yield.

### 4.5.9 Days taken to marketable maturity

Positive direct effect was reported on root yield per plot by days taken to marketable maturity (0.684). However, positive indirect effects were seen via characters *viz.* total soluble solid (0.299), leaf width (0.245), root diameter (0.146), leaf length (0.136), root length

(0.123), crown diameter (0.119), average root weight without leaves (0.034), ascorbic acid (0.028) and average root weight with leaves (0.006). Whereas, negative indirect effects were observed through characters *viz.* plant height (-0.099) and number of leaves per plant (-0.062). Nagar (2016) and Ullah *et al* (2010) observed that the independent trait days taken to marketable maturity showed positive direct effect on character trait root yield.

### 4.5.10 Average root weight with leaves

Average root weight with leaves is an important character from economic point of view and it had positive direct positive effect on the dependent trait root yield per plot (3.070). However, maximum positive indirect effect was exhibited via independent trait average root weight without leaves (2.776) followed by plant height (1.734), root length (1.720), leaf width (1.310), leaf length (1.234), number of leaves per plant (1.149), root diameter (0.611), crown diameter (0.522), ascorbic acid (0.355) and days taken to marketable maturity (0.028). Whereas, maximum negative indirect effect was seen via the horticultural trait total soluble solid (-0.659) which was followed by days to 50% germination (-0.518). Kaur *et al.* (2017) conducted path coefficient studies in radish and reported that average root weight with leaves had positive direct effect on average root yield.

### 4.5.11 Average root weight without leaves

Most of the time the radish is sold in market with leaves therefore it is an important character from marketing point of view. Negative direct effect was reported on dependent trait root yield per plot through the independent character average root weight without leaves (-1.878). Positive indirect effects were observed through the characters *viz.* total soluble solid (0.480) and days to 50% germination (0.221) suggesting that selection through these traits can also help in improvement of root yield per plot in radish. Whereas, negative indirect effects were exhibited via the character *viz.* average root weight with leaves (-1.821), plant height (-1.420), leaf width (-0.792), number of leaves per plant (-0.663), root diameter (-0.611), crown diameter (0.560), leaf length (-0.473), ascorbic acid (-0.145) and days taken to marketable maturity (-0.094). Similar positive direct effect of trait average root weight without leaves on dependent character root yield per plot has been reported by Guleria (2016) and Kaur *et al.* (2017).

### 4.5.12 Total soluble solid

The horticultural character i.e. total soluble solid had negative direct effect on root yield per plot (0.285). Positive indirect effects were exhibited via traits plant height (0.285),

**Table: 4.9 Path coefficient analysis in radish showing the direct and indirect effect of thirteen characters on root yield per plot at genotypic level.**

| | DTFG | PH | NLPP | LL | LW | CD | RL | RD | DTMM | ARWWL | ARWWOL | TSS | AA | GCCRYPP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DTFG** | **-0.708** | 0.219 | -0.010 | 0.062 | -0.288 | -0.105 | -0.057 | 0.639 | 0.511 | -0.518 | 0.221 | -0.136 | -0.012 | -0.180 |
| **PH** | 0.138 | **-1.125** | 0.018 | 0.171 | -0.017 | 0.016 | 0.452 | 0.085 | -0.099 | 1.734 | -1.277 | 0.285 | 0.085 | 0.465** |
| **NLPP** | 0.126 | -0.366 | **0.055** | -0.028 | -0.027 | -0.007 | 0.151 | -0.231 | -0.062 | 1.149 | -0.663 | -0.062 | 0.183 | 0.217 |
| **LL** | -0.104 | -0.452 | -0.004 | **0.426** | -0.429 | -0.026 | 0.014 | -0.027 | 0.136 | 1.234 | -0.473 | 0.002 | 0.028 | 0.326* |
| **LW** | -0.261 | -0.025 | 0.002 | 0.233 | **-0.783** | -0.063 | -0.082 | 0.346 | 0.245 | 1.310 | -0.792 | 0.111 | 0.178 | 0.420** |
| **CD** | -0.335 | 0.080 | 0.002 | 0.050 | -0.221 | **-0.221** | 0.018 | 0.204 | 0.119 | 0.522 | -0.560 | -0.064 | 0.547 | 0.140 |
| **RL** | 0.070 | -0.881 | 0.014 | 0.010 | 0.111 | -0.007 | **0.577** | 0.282 | 0.123 | 1.720 | -1.420 | 0.186 | -0.057 | 0.731** |
| **RD** | -0.392 | -0.083 | -0.011 | -0.010 | -0.234 | -0.039 | 0.141 | **1.157** | 0.146 | 0.611 | -0.632 | 0.022 | -0.290 | 0.385** |
| **DTMM** | -0.529 | 0.163 | -0.005 | 0.085 | -0.280 | -0.039 | 0.104 | 0.246 | **0.684** | 0.028 | -0.094 | -0.249 | -0.034 | 0.080 |
| **ARWWL** | 0.120 | -0.636 | 0.020 | 0.171 | -0.334 | -0.038 | 0.224 | 0.130 | 0.006 | **3.070** | -1.821 | 0.122 | -0.095 | 0.939** |
| **ARWWOL** | 0.083 | -0.765 | 0.019 | 0.107 | -0.330 | -0.066 | 0.436 | 0.389 | 0.034 | 2.776 | **-1.878** | 0.146 | -0.064 | 0.887** |
| **TSS** | -0.169 | 0.563 | 0.006 | -0.002 | 0.153 | -0.025 | -0.188 | -0.045 | 0.299 | -0.659 | 0.480 | **-0.570** | -0.035 | -0.191 |
| **AA** | -0.010 | 0.116 | -0.012 | -0.015 | 0.169 | 0.147 | 0.040 | 0.407 | 0.028 | 0.355 | -0.145 | -0.024 | **-0.825** | 0.231 |

*****Significant at 5% level

**Significant at 1% level

**Residual effect: 0.68804**

DTFG – Days to 50% germination

PH – Plant height (cm)

NLPP – Number of leaves per plant

LL - Leaf length (cm)

LW - Leaf width (cm)

CD – Crown diameter (cm)

RL – Root length (cm)

RD – Root diameter (mm)

DTMM – Days taken to marketable maturity

ARWWL – Average root weight with leaves (g)

ARWWOL – Average root weight without leaves (g)

TSS – Total soluble solids (°B)

AA – Ascorbic acid (mg/100g)

GCCRYPP – Genotypic correlation coefficient of root yield per plot (kg) root length (0.186), average root weight without leaves (0.146), average root weight with leaves (0.122), leaf width (0.111), root diameter (0.022) and leaf length (0.002). While highest value of negative indirect effect was reported through the trait root diameter (-0.249), days to 50% germination (-0.136), crown diameter (-0.064) and ascorbic acid (-0.024). Naseeruddin *et al.* (2018) also reported negative direct effect of total soluble solids on the dependent character root yield.

#### 4.5.13 Ascorbic acid

From nutritional point of view ascorbic acid is a very important character and the breeders often try to develop varieties with high ascorbic acid. Negative direct effect was described for root yield per plot via ascorbic acid (-0.825). This suggested that direct selection for ascorbic acid content will lead to reduction in root yield per plot and hence selection through indirect trait will be more effective. Maximum positive indirect effect was shown by the character crown diameter (0.547) and subsequently by number of leaves per plant (0.183), leaf width (0.178), plant height (0.085) and leaf length (0.028). However, highest degree of negative indirect effect was reported via the character root diameter (-0.290) followed by the other traits viz. average root weight with leaves (-0.095), average root weight without leaves (-0.064), root length (-0.057), total soluble solid (-0.035) and days taken to marketable maturity (-0.034). The findings of Kaur *et al.* (2017) and Neseeruddin *et al*. (2018) also revealed that the trait ascorbic acid showed negative direct effect on the dependent character root yield in radish.

# *Chapter-5*

# SUMMARY AND CONCLUSION

The present investigation entitled "**Assessment of genetic variability, correlation and path analysis studies in radish (*Raphanus sativus* L.)"** was carried out with 18 genotypes of radish including Japanese White as a standard check to ascertain the variability, heritability, genetic advance, correlations and path coefficient analysis. The experiment was laid out in Randomized Complete Block Design with three replications at Vegetable Research Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the months September to November. The sowing was done during third week of September 2019 at a spacing of 30 × 7.5 cm and the plot size was 1 × 1.2 m. The observations were recorded on 15 quantitative characters *viz.* days to 50% germination, plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), crown diameter (cm), root length (cm), root diameter (cm), days taken to marketable maturity, average root weight with leaves (g), average root weight without leaves (g), total soluble solids (°B), ascorbic acid (mg/100g), root yield per plot (kg) and prevalence of *Alternaria* blight (disease incidence and disease severity) and a qualitative character root colour and shape.

The analysis of variance showed highly significant differences among the genotypes for all the horticultural traits under study suggesting sufficient variability which is a pre requisite for crop improvement.

The genotype Japanese White (7 days) was earliest for days to 50% germination followed by R-COHF-NERI-9 (13.00 days) and R-COHF-NERI-12 (12.67 days). Minimum plant height was observed in Japanese White (51.00 cm) followed by R-COHF-NERI-9 (51.33 cm), R-COHF-NERI-1 (51.80 cm). Maximum number of leaves were observed in genotype R-COHF-NERI-3 (17.07) followed by genotype R-COHF-NERI-2 (16.03). The radish genotype COHF-NERI-12 (39.97 cm) recorded the maximum leaf length followed by R-COHF-NERI-16 (37.13 cm) and R-COHF-NERI-7 (35.27 cm). The maximum leaf width was observed in genotype R-COHF-NERI-2 (10.27 cm) followed by genotypes viz. R-COHF-NERI-12 (9.97 cm) and R-COHF-NERI-3 (9.60 cm). The highest value for crown diameter was recorded in genotype R-COHF-NERI-17 (23.67 mm) followed by genotype R-COHF-NERI-12 (21.88 mm). The highest root length was found in the genotype R-COHF-

NERI-3 (29.50 cm) followed by genotypes R-COHF-NERI-12 (29.43 cm) and R-COHF-NERI-2 (28.80 cm). The maximum value of root diameter (42.70 mm) was reported in the genotype R-COHF-NERI-9, followed by genotypes R-COHF-NERI-6 (42.10 mm) and R-COHF-NERI-3 (40.37 mm). The genotype R-COHF-NERI-6 was earliest in terms of marketable maturity (46.33 days) followed by genotype viz. R-COHF-NERI-7 (47.67 days). The highest average root weight with leaves was recorded by the genotype R-COHF-NERI-12 (339.07 kg) followed by genotype R-COHF-NERI-6 (275.85 g) and R-COHF-NERI-10 (272.40 g). Maximum average root weight with leaves was observed in the radish genotype R-COHF-NERI-12 (251.56 g) showing its superiority over rest of the radish genotypes, followed by genotypes R-COHF-NERI-6 (241.56 g) and R-COHF-NERI-3 (240.60 g). Maximum root yield per plot was observed in the radish genotype R-COHF-NERI-12 (7.18 kg) followed by genotype R-COHF-NERI-6 (7.12 kg). The highest total soluble solid content was found in genotype R-COHF-NERI-15 (5.93 °B) followed by genotypes R-COHF-NERI-1 (5.90 °B) and R-COHF-NERI-9 (5.83 °B). The genotype R-COHF-NERI-14 had maximum (29.92 mg/100g) ascorbic acid content followed by genotype R-COHF-NERI-6 (29.47 mg/100g). In case of character prevalence of *Alternaria* blight the disease incidence was minimum in R-COHF-NERI-3 (50.67%) followed by the genotype R-COHF-NERI-9 (53.96%) and the disease severity was minimum in R-COHF-NERI-9 (39.87 %) followed by in R-COHF-NERI-10 (43.40 %).

High phenotypic and genotypic coefficient of variation existed for root yield per plot (27.60 and 18.58), root diameter (27.42 and 26.07), average root weight with leaves (25.23 and 21.16), average root weight without leaves (26.08 and 22.92), ascorbic acid (24.85 and 24.19) and number of leaves per plant (21.95 and 21.12) respectively. Moderate phenotypic and genotypic coefficient of variations were exhibited for root length (18.33 and 15.72), crown diameter (16.10 and 11.14), leaf length (14.85 and 14.18), days to 50% germination (13.86 and 13.37), TSS (13.02 and 12.16) and leaf width (12.62 and 7.55) respectively. The characters like plant height (10.10 and 7.24), and days taken to marketable maturity (7.65 and 7.23), showed low magnitude of phenotypic and genotypic coefficients of variation.

High heritability estimates were observed for ascorbic acid (94.74%), days to 50% germination (93.11%), number of leaves per plant (92.57%), leaf length (91.25%), root diameter (90.40%), days taken to marketable maturity (89.43%), TSS (87.17%), average root weight without leaves (77.19%), root length (73.53%) and average root weight with leaves (70.38%). Moderate heritability was reported by the trait plant height (51.32%). While, low heritability was obtained for characters *viz*. crown diameter (47.87%), root yield per plot (45.33%) and leaf width (35.76%). High estimates of genetic advance as % of mean were observed for root diameter (51.06%), ascorbic acid (48.49%), number of leaves per plant (41.86%), average root weight without leaves (41.48%), average root weight with leaves (36.58%), leaf length (27.91%), root length (27.77%), days to 50% germination (26.58%), root yield per plot (25.77%) and TSS (23.39%).

The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. The character root yield per plot had positive and significant association with average root weight with leaves (0.939), average root weight without leaves (0.887), root length (0.731), plant height (0.465), leaf width (0.326) and root diameter (0.385).

The path coefficient analysis at genotypic level revealed that the maximum positive direct effect on root yield per plot was registered by the trait average root weight with leaves (3.070) followed by root diameter (1.157), days taken to marketable maturity (0.684), root length (0.577), leaf length (0.426) and number of leaves per plant (0.055); suggesting that selection through these traits can help in improving the marketable root yield per plot. The maximum negative direct contribution on root yield per plot was made by average root weight without leaves (-1.878) followed by plant height (-1.125), ascorbic acid (-0.825), leaf width (-0.783), days to 50% germination (-0.708), total soluble solid (-0.570) and crown diameter (-0.221).

**CONCLUSION**

- On the basis of overall performance, out of 18 genotypes R-COHF-NERI-12 (7.18 kg) was found superior for root yield per plot followed by R-COHF-NERI-6 (7.12 kg) and R-COHF-NERI-3 (5.92 kg). These genotypes were also found superior for the other horticultural traits like average root weight with leaves, average root weight without leaves, root length, root diameter and plant height.
- The horticultural trait root yield per plot showed low heritability (45.33%) and moderate genetic advance (as percentage of mean) with the value 25.77%. It is suggesting that selection for root yield per plot was not much effective.

**Table 5.1 Best three genotypes with respect to different horticultural traits in radish**

| Character | Genotypes | Mean |
|---|---|---|
| **Days to 50 % germination** | Japanese White | 7.00 days |
| | R-COHF-NERI-6 | 8.67 days |
| | R-COHF-NERI-7 | 9.67 days |
| **Plant height (cm)** | Japanese White (Check) | 51.00 cm |
| | R-COHF-NERI-9 | 51.33 cm |
| | R-COHF-NERI-1 | 51.8 cm |
| **Number of leaves** | R-COHF-NERI-3 | 17.07 |
| | R-COHF-NERI-16 | 17.03 |
| | R-COHF-NERI-2 | 16.03 |
| **Leaf length (cm)** | R-COHF-NERI-12 | 39.97 cm |
| | R-COHF-NERI-16 | 37.13 cm |
| | R-COHF-NERI-7 | 35.27 cm |
| **Leaf width (cm)** | R-COHF-NERI-2 | 10.27 cm |
| | R-COHF-NERI-16 | 10.23 cm |
| | R-COHF-NERI-12 | 9.97 cm |
| **Crown diameter (mm)** | R-COHF-NERI-17 | 23.67 mm |
| | R-COHF-NERI-12 | 21.88 mm |
| | R-COHF-NERI-1 | 19.87 mm |
| **Root length (cm)** | R-COHF-NERI-3 | 29.50 cm |
| | R-COHF-NERI-12 | 29.43 cm |
| | R-COHF-NERI-2 | 28.80 cm |
| **Root diameter (mm)** | R-COHF-NERI-9 | 42.70 mm |
| | R-COHF-NERI-6 | 42.10 mm |
| | R-COHF-NERI-3 | 40.37 mm |
| **Days taken to marketable maturity** | R-COHF-NERI-6 | 46.33 days |
| | R-COHF-NERI-7 | 47.67 days |
| | Japanese White | 49.00 days |
| **Average root weight with leaves (g)** | R-COHF-NERI-12 | 339.07 g |
| | R-COHF-NERI-6 | 336.00 g |
| | R-COHF-NERI-3 | 279.40 g |
| **Average root weight without leaves (g)** | R-COHF-NERI-12 | 251.87 g |
| | R-COHF-NERI-6 | 241.56 g |
| | R-COHF-NERI-3 | 240.6 g |
| **Total soluble solid (°B)** | R-COHF-NERI-15 | 5.93 °B |
| | R-COHF-NERI-1 | 5.90 °B |
| | R-COHF-NERI-9 | 5.83 °B |
| **Ascorbic acid (mg/100g)** | R-COHF-NERI-14 | 29.92 mg/100g |
| | R-COHF-NERI-6 | 29.47 mg/100g |
| | R-COHF-NERI-11 | 27.20 mg/100g |
| **Root yield per plot (kg)** | R-COHF-NERI-12 | 7.18 kg |
| | R-COHF-NERI-6 | 7.12 kg |
| | R-COHF-NERI-3 | 5.92 kg |
| **Disease incidence (%)** | R-COHF-NERI-3 | 50.67 % |
| | R-COHF-NERI-9 | 53.96 % |
| | R-COHF-NERI-10 | 55.39 % |
| **Disease severity (%)** | R-COHF-NERI-9 | 39.87 % |
| | R-COHF-NERI-10 | 43.33 % |
| | R-COHF-NERI-3 | 49.40 % |

- The character root yield per plot was significantly and positively correlated with the characters average root weight with leaves (0.939), average root weight without leaves (0.887), root length (0.731), plant height (0.465), leaf weight (0.326) and root diameter (0.385) suggesting that selection for improvement of these traits could help in improvement of the yield in case of radish.
- On the basis of path coefficient analysis, it was concluded that characters average root weight with leaves (3.070) followed by root diameter (1.157), days taken to marketable maturity (0.684), root length (0.577), leaf length (0.426) and number of leaves per plant (0.055) had positive direct effect on root yield per plot.

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# APPENDIX- I

## Analysis of variance for various horticultural traits in radish

| **Source** | **Mean sum of squares** | | |
|---|---|---|---|
| **Character** | **Replications** | **Genotypes** | **Errors** |
| **Degree of freedom** | 2 | 17 | 34 |
| Days to 50% germination | 0.17 | 6.784** | 0.225 |
| Plant height (cm) | 0.38 | 61.374** | 7.091 |
| Number of leaves per plant | 7.25 | 24.593** | 0.451 |
| Leaf length (cm) | 1.76 | 54.018** | 1.629 |
| Leaf width (cm) | 2.40 | 2.136** | 0.779 |
| Crown diameter (mm) | 11.08 | 16.033** | 4.272 |
| Root length (cm) | 12.53 | 51.531** | 5.590 |
| Root diameter (mm) | 28.41* | 73.908** | 8.385 |
| Days taken to marketable maturity | 4.46* | 46.073** | 0.973 |
| Average root weight with leaves (g) | 2493.73 | 8,165.655** | 907.019 |
| Average root weight without leaves (g) | 147.91 | 6,974.336** | 607.153 |
| Total soluble solids (°B) | 0.08 | 1.188** | 0.099 |
| Ascorbic acid (mg/100g) | 0.04 | 76.537** | 1.434 |
| Root yield per plot (kg) | 0.10** | 3.503** | 0.005 |
| Alternaria blight incidence (%) | 2.994 | 98.767** | 3.591 |
| Alternaria blight severity (%) | 140.925 | 83.753** | 28.427 |

***Significant at 5% level of significance**

****Significant at 1% level of significance**

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| | | |
|---|---|---|
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## ABSTRACT

The present investigation entitled, **"Assessment of genetic variability, correlation and path analysis studies in radish"** was carried out at Vegetable Research Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (HP) during winter season (Sept-Nov), 2020. Eighteen genotypes of radish including check variety Japanese White 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. Analysis of variance showed significant differences among all the genotypes for all the characters under study. The best genotypes in terms of root yield per plot was R-COHF-NERI-12 which was followed by R-COHF-NERI-6, R-COHF-NERI-3 and R-COHF-NERI-10. High PCV and GCV existed for marketable root yield per plot, root diameter, average root weight with leaves, average root weight without leaves, ascorbic acid and number of leaves per plant. High heritability estimates were observed for the characters ascorbic acid, days to 50% germination, number of leaves per plant, leaf length, root diameter, days taken to marketable maturity, TSS, average root weight without leaves, root length and average root weight with leaves; While high estimates of genetic advance (as percentage of mean) were observed for all the horticultural traits except crown diameter, days taken to marketable maturity, plant height and leaf width. The correlation studies at phenotypic and genotypic level revealed that the marketable rootyield per plot had positive and significant association with the traits average root weight with leaves, average root weight without leaves, root length, leaf weight, plant height and root diameter. However, path analysis revealed that the average root weight with leaves, root diameter, days taken to marketable maturity, root length, leaf length and number of leaves per plant had positive and direct effects on marketable root yield per plot.

**Signature of Student**
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