

**ASSESSMENT OF GENETIC VARIABILITY AND  
CORRELATION STUDIES IN TURNIP (*Brassica rapa* L.)**

***Thesis***

by

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(NH-2019-41-M)**

submitted to



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## CERTIFICATE – I

This is to certify that the thesis on entitled “**Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)**” submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE** in the discipline of **HORTICULTURAL SCIENCES** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) – 173230 is a bonafide research work carried out by **Ms. PALVI THAKUR (NH-2019-41-M)** daughter of Sh. Jagdish Chand 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 investigation has been fully acknowledged.

**Place: Neri, Hamirpur**  
**Dated:**

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## CERTIFICATE - II

This is to certify that the thesis entitled "Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)" submitted by Ms. PALVI THAKUR (NH-2019-41-M) daughter of Shri. Jagdish Chand to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) – 173230 India in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (HORTICULTURE) in the discipline of VEGETABLE 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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This is to certify that all the mistakes and errors pointed out by external examiner have been incorporated in the thesis entitled "**Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)**" submitted by **Ms. PALVI THAKUR (NH-2019-41-M)** daughter of Shri. Jagdish Chand to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) – 173230 India in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) in the discipline of VEGETABLE SCIENCE.**

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# CONTENTS

<b>Chapter</b>	<b>Title</b>	<b>Page (s)</b>
<b>1</b>	<b>INTRODUCTION</b>	<b>1-2</b>
<b>2</b>	<b>REVIEW OF LITERATURE</b>	<b>3-15</b>
<b>3</b>	<b>MATERIALS AND METHODS</b>	<b>16-28</b>
<b>4</b>	<b>RESULTS AND DISCUSSION</b>	<b>29-62</b>
<b>5</b>	<b>SUMMARY AND CONCLUSION</b>	<b>63-67</b>
➤	<b>LITERATURE CITED</b>	<b>68-71</b>
➤	<b>APPENDICES</b>	<b>i.</b>
➤	<b>ABSTRACT</b>	<b>72</b>
➤	<b>BRIEF BIO-DATA</b>	

## ABBREVIATIONS

%	:	Per cent
=	:	Equal to
X	:	Multiplication
°C	:	Degree Celsius
ANOVA	:	Analysis of Variance
C.V.	:	Coefficient of Variation
CD	:	Critical Difference
<i>et al.</i>	:	Co-workers
etc.	:	<i>et cetera</i>
H.P.	:	Himachal Pradesh
i.e.	:	That is
m <sup>2</sup>	:	Meter square
SE	:	Standard Error
UHF	:	University of Horticulture and Forestry
COHF	:	College of Horticulture and Forestry
<i>viz.</i>	:	Videlicet (namely)
PCV	:	Phenotypic Coefficient of Variation
GCV	:	Genotypic Coefficient of Variation
m	:	Meter
cm	:	Centimeter
g	:	Gram
mg	:	Milligram
/	:	Per
GA	:	Genetic Advance
&	:	And
TSS	:	Total Soluble Solids

## LIST OF TABLES

TABLE	TITLE	PAGE NO.
3.1	Agro-metrological data during the cropping period	16
3.2	List of genotypes of turnip used in the present investigation	18
4.1	Mean performance of various quantitative horticultural traits in different turnip ( <i>Brassica rapa</i> L.) genotypes	37 & 38
4.2	Observations with respect to various qualitative traits in different turnip ( <i>Brassica rapa</i> L.) genotypes	41
4.3	Genetic parameters of variation for various horticultural traits including average root yield with leaves per plant for various genotypes in turnip ( <i>Brassica rapa</i> L.)	47
4.4	Genotypic and Phenotypic correlation coefficients between average root yield with leaves and its component characters in turnip ( <i>Brassica rapa</i> L.)	53
4.5	Genotypic path coefficient analysis for direct and Indirect effects of component characters on yield in turnip ( <i>Brassica rapa</i> L.)	62
5.1	Top five promising genotypes for different characters studied in turnip ( <i>Brassica rapa</i> L.)	64 & 65

## LIST OF FIGURES

FIGURE	TITLE	PAGE NO.
3.1	Agro-metrological data during the present investigation	17
4.1	Graphical representation of heritability (%) and genetic advance (%) for different traits in turnip ( <i>Brassica rapa</i> L.)	45
4.2	Graphical representation of Genotypic and Phenotypic Coefficient of Variation (%)	46

## LIST OF PLATES

PLATE	TITLE	PAGE NO.
1	Crop at the time of germination	20
2	Crop at the time of harvesting	20
3(a)	Variability in Turnip Genotypes	39
3(b)	Variability in Turnip Genotypes	40

# Chapter-1

## INTRODUCTION

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Turnip (*Brassica rapa* L.) is one of the important hardy cool season root crop which belongs to the family cruciferae with chromosome number  $2n=20$ . Turnip is accepted by different local names in different regions of India e.g. Salyom in Assamese, Shalgam in Bangali, Salgum in oriya, Turnip in Telagu, Seema Mullanki in Malayalam, Turnip in Kannad, Salgum in Marathi, Shaljum in Hindi, and Gongru, Shalgam, Thipper in Punjabi (Chauhan, 1981). It's grown for the fleshy roots and green leaves and is a rich source of several vitamins (A, B and C), proteins, carbohydrates and minerals like calcium. It is broadly cultivated all over the world and is well adapted to a wide range of climatic conditions. Turnip is said to have two main centres of origin. The Mediterranean region is assumed to be the primary centre of European types, while Eastern Afghanistan is considered to be another primary centre with Asia Minor, Transcaucacus and Iran as secondary centers. It can be grown upto an elevation of 1,500 m above mean sea level but it is not appropriate for growing in low lands of wet tropics.

Turnips (including carrots) are cultivated in an area of 11,31,049 hectares with an annual production of 3,99,96,287 tonnes (Anonymous, 2018) all over the world. Whereas, in India, turnip (including carrots) are grown on an area of 37,480 hectares with a production of 5,83,405 tonnes (Anonymous, 2018). In India this crop is mainly grown in Himachal Pradesh, Punjab, Haryana, Tamil Nadu, Uttar Pradesh and Bihar. It is considered as highly remunerative crop in Himachal Pradesh and in plains of North India. The crop has the capability to fit excellently in various multiple cropping sequences owing to its rapid maturity and short growing period. Off season turnip crop is also grown in high hills of Himachal Pradesh during summer months, when there is no production in plains and thus it helps the farmers of these areas to fetch high returns during this period.

There is however, less incidence of disease in turnip crop in the low hills of Himachal Pradesh when the crop is raised for root crop; but still all the genotypes were closely monitored to record the prevalence of disease if, any in the turnip genotypes under present study.

Most widely grown popular cultivars of turnip are either introductions or selections from the existing varieties and very less work on the genetic improvement of this crop in India has been done. Thus, there is a tremendous need to conduct the genetic studies in the crop to detect the amount of variability existing in the available germplasm pool. This variability can be exploited for the development of the new varieties out of the existing varieties either by selection or hybridization. The heritability and genetic advance estimates help the breeder in knowing the suitability of a character for selection among the given genotypes. The Phenotypic and Genotypic coefficients help in adjudging the amount of variability which is there in the given germplasm due to environment and genetic factors. The knowledge of genetic correlation among different horticultural traits of a crop can help the breeder in the selection of the desirable combinations of traits in a given genotype and helps in decreasing the retarding effect of negative correlations. Path coefficient analysis determines the direct and indirect influence of the various independent variables on the dependent variable like yield and separates the correlation coefficient into the components of direct and indirect effects.

Hence, keeping in view the different attributes which are discussed above and recognizing the urgent need for genetic studies in turnip for its improvement. The present investigation entitled “**Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)**” was carried out at Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri with the following objectives:

- i. To study the performance and extent of genetic variability in the turnip genotypes.
- ii. To estimate heritability and genetic advance.
- iii. To study the character association and path coefficient analysis for different traits in various turnip genotypes.
- iv. To identify the best genotypes with desirable horticultural traits.

## Chapter-2

# REVIEW OF LITERATURE

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The literature pertaining to present investigation entitled “Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)” has been reviewed under the suitable headings in the present chapter. Little work pertaining to genetic variability, character association, heritability, genetic advance and path coefficient analysis has been done in turnip crop for different horticultural traits. Therefore the relevant literature pertaining to the related crops of turnip *viz.*, mustard, rapeseed and radish were also referred and has been reviewed under the suitable heads as follows:

### 1. Genetic variability:

Pauw and Baker (1978) studied components of variation for four traits in *Brassica campestris* at two different locations and found that the amount of variation due to genetic component was found to be greater for traits maturity and oil content as compared to the components seed yield and height of the plant.

Ali *et al.* (2002) conducted a study to estimate genetic variation in rape seed which involved twenty five different winter type rape seed cultivars. Their findings reflected that genotypic and phenotypic variances were higher for the traits *viz.*, pods per plant and plant height as compared to the rest of the traits like branches per plant, seeds per pod, seed weight and seed yield.

In an experiment conducted by Ali *et al.* (2003) to assess genetic variability in twenty five winter type rapeseed genotypes collected from different parts of world; the genotypic and phenotypic variances were found higher for the yield contributing trait pods/plant followed by plant height. However, the maximum genotypic and phenotypic coefficients of variation were observed for the traits seed yield/plant and pods/plant, respectively.

Makhdoomi (2003) worked out genetic variability in radish and found that the range for different horticultural traits *viz.*, days to maturity, leaf number, leaf weight, root weight and vitamin-C was moderate to high suggesting large amount of variation for these traits. The highest PCV and GCV values were observed for the traits average root length, average root weight and top to root ratio. Whereas, lowest PCV and GCV values were observed for the traits days to maturity and total dry matter content.

Fu and Gugel (2009) estimated genetic variability in Canadian elite cultivars of summer turnip rape (*Brassica rapa* L.) using simple sequence repeat markers. Genetic clustering of these cultivars revealed AC Sunbeam as genetically unique cultivar. However, in-order to identify genetically diverse genotypes for developing hybrid/synthetic varieties, two distinct groups of the cultivars were separated from remaining 9 cultivars with high vs. low glucosinate content.

Mehdi *et al.* (2010) conducted variability and correlation studies in turnip (*Brassica rapa* L.) under cold arid conditions. The results revealed that there was a wide range of phenotypic variation was noticed in different genotypes of turnip with respect to the traits studied *viz.*, root depth, root diameter, leaf length, number of leaf/plant, root yield and leaf yield.

Genetic variation studies performed by Talebi *et al.* (2010) within international collection of *Brassica rapa* genotypes using inter simple sequence repeat DNA markers suggested that the accessions were extremely genetically unique and were closer together in comparison to the oilseed and turnip types. Besides this a considerable genetic variation was observed between Chinese and European accessions.

The research conducted by Yildirim *et al.* (2010) in eleven turnip genotypes collected from diverse environments of the Erzurum region located in Eastern Anatolia in Turkey. They found that the average polymorphism ratio was 90.4% whereas, the genetic distance between turnip genotypes ranged from 0.302 to 0.733, indicating high genetic variability in different accessions of the genotypes collected.

Soengas *et al.* (2011) assessed genetic diversity in the *Brassica rapa* subsp. *rapa* germplasm collected from north-western Spain. In all, eighty populations were analyzed based on eighteen simple sequence repeats (SSRs). It was found that different populations showed a broad range of genetic diversity, thus offering good potential for further genetic improvement. However, most of the variability was found within the population level, probably due to high rates of allogamy, migration and interchange of seed among local growers.

In an experiment comprising thirty released varieties of Indian mustard (*Brassica juncea* L.), Yadava *et al.* (2011) observed high degree of PCV and GCV for the important traits *viz.*, point to first branch, seed yield/plant, point to first siliqua, number of secondary branches/plant and 1000-seed weight.

Zare and Sharafzadeh (2012) assessed eight rapeseed cultivars for variability studies with respect to the traits *viz.*, days from emergence to flowering, days from emergence to physiological maturity, plant height, pod length, pods number on main stem, pods per plant, seeds per pod, 1000-seed weight, harvest index and grain yield. Results showed that genetic variability of genotypes was significant for all traits except for pod length and seeds per pod.

The variability studies conducted by Ara *et al.* (2013) involving eight F<sub>2</sub> populations for different characters related to seed yield per plant in *Brassica rapa* observed considerable variation in all the genotypes under study. The values of phenotypic variances were higher than the corresponding genotypic variances for the characters studied. The traits *viz.*, number of branches per plant, length of siliqua, seeds per siliqua, 1000 seed weight and yield per plant showed least difference in terms of phenotypic and genotypic variances.

Helal *et al.* (2014) observed genetic variability in eight varieties and four lines of rapeseed/mustard *viz.*, Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, Bina Sarisha-4, BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205. The varieties Improved Tori, BARI Sarisha-8, BARI Sarisha-14 and BARI Sarisha-15 produced the highest seed yield and 15% variation at genotypic and phenotypic level respectively.

In an experiment planned to evaluate ten locally collected *Brassica rapa* lines with respect to eight quantitative parameters *viz.*, primary branches, silique main raceme-1, main raceme length, silique length, silique width, plant height, seed silique-1 and 100 seed weight. The researchers observed that indigenous accessions possessed higher genetic variability, which could be utilized for breeding new varieties (Iqbal *et al.*, 2014).

Khalf-Allah *et al.* (2014) studied variability in turnip cv. Balady with respect to various horticultural traits like plant weight, leaf number, leaf length, leaf area and root weight. The lowest variability was exhibited by the trait leaf length. Whereas the highest magnitude of variability was seen in the character root weight followed by plant weight, leaf number and leaf area.

Studies involving genetic variability in thirty three genotypes of *Brassica rapa* L. (Naznin *et al.*, 2015) revealed that the character plant height was highly influenced by the environment. Besides this, all other characters *viz.*, days to maturity, number of primary branches/plant, number of secondary branches/plant, number of siliquae/plant, siliqua length (cm), number of seeds/siliqua, 1000 seed weight (g) and seed yield/plant (g) were least influenced by the environment. However, the horticultural trait *viz.* number of secondary branches/plant exhibited the highest phenotypic and genotypic coefficient of variation respectively.

Joya *et al.* (2016) evaluated thirty eight rapeseed genotypes in-order to estimate the genetic variability and found that a considerable amount of genetic variability existed in various characters under study which ranged from 11.09% (1000 seed weight) to 44.00% (harvest index). On the other hand the phenotypic variability ranged from 13.36% (plant height) to 44.14% (harvest index).

In an experiment (Sikarwar *et al.* 2017) to assess the genetic variability, heritability and genetic advance in twenty one diverse genotypes of yellow sarson (*Brassica rapa* var. Yellow Sarson) for yield and its contributing characters; high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were observed for the traits number of secondary

branches per plant followed by seed yield per plant, number of primary branches per plant and number of siliqua on main raceme. Hence, it was found that direct selection of these traits could prove effective. Whereas, the horticultural traits *viz.*, days to flowering, plant height and length of siliqua showed low PCV and GCV values.

Maurya *et al.* (2018) assessed the extent of genetic variability among fifty germplasm accessions of Indian mustard with three check varieties for various quantitative traits. The genotypic coefficient of variation (GCV) was found to be higher for the characters *viz.* 1000-seed weight, biological yield per plant, secondary branches per plant and seed yield per plant.

Genetic variability studies were conducted by Prasad and Patil (2018) for yield and its attributes in Indian mustard involving thirty eight Indian mustard genotypes. The phenotypic and genotypic coefficient of variation was estimated. It was found that the characters *viz.*, number of secondary branches per plant, number of racemes per plant, economical yield, biological yield, harvest index, seed yield and oil yield registered high coefficients of variance both at genotypic and phenotypic levels respectively.

Raliya *et al.* (2018) studied genetic variability in Indian mustard and found high PCV and GCV values for the traits *viz.*, seed yield/ha, 1000-seed weight, number of primary and secondary branches/plant, siliqua length, plant height, days to flowering and number of siliqua on main shoot.

In a study involving sixty Toria genotypes including one check (Indira Toria) carried out by Mahendra *et al.* (2020); the genetic variability for eleven quantitative characters was worked out. High PCV coupled with high GCV was observed for the traits *viz.*, harvest index, seed yield per plant and siliquae per plant which suggested a wide range of variation exhibited by these genotypes for the traits under study and hence paved the way for the improvement of yield.

Ashraf *et al.* (2021) evaluated twenty eight genotypes of turnip with respect to various quantitative and qualitative traits and found that the genotypes showed a wide range of variation for almost all the traits under investigation. Hence, based on the mean performance of all the genotypes, the genotypes *viz.* Nageen, SKAU-T-4, SKAU-T-3, SKAU-T-9, SKAU-T-14 and

PTWG were found superior in terms of root yield/ha and showed potential for further use in various breeding programmes.

## **2. Heritability and Genetic Advance:**

Ali *et al.* (2002) worked out heritable variation and genetic advance in twenty five winter type rapeseed cultivars and found that broad sense heritability ranged from 0.146 (seeds per pod) to 0.488 (seed yield). While the high magnitude of genetic advance was found for the two traits *viz.* seed yield and seed weight respectively.

In a study on heritability and genetic advance in twenty five winter type rapeseed varieties Ali *et al.* (2003) found maximum heritability in the character days to maturity followed by flower duration, seed weight and seed yield. High heritability coupled with high genetic advance was observed in the traits *viz.*, flower duration, seed weight and seed yield.

Makhdoomi (2003) evaluated heritability and genetic advance in radish and observed high level of heritability in broad sense for characters *viz.*, days to maturity, leaf number, leaf weight, root length, root diameter, root weight, shoot to root ratio, total dry matter, vitamin C and TSS. The pooled data analysis revealed highest heritability value for the trait days to maturity and lowest for the horticultural trait leaf number. Genetic gain was found high for the characters like leaf number, leaf weight, root length, root diameter, root weight, shoot to root ratio and vitamin-C. However, moderate values were observed for the traits days to maturity and total dry matter in E1, E2, E3 environments and in the pooled analysis.

The investigations conducted by Khan *et al.* (2008) regarding genetic variability, heritability and correlation for quality traits in *Brassica* populations. The study showed higher estimates of heritability for the important traits like glucosinolate, linolenic acid, oleic acid and erucic acid content; whereas, low heritability value was observed for the trait protein content.

The observations pertaining to variability and correlation studies in turnip (*Brassica rapa* L.) under cold arid conditions taken by Mehdi *et al.* (2010) suggested that the characters namely

root depth, root diameter, leaf length, number of leaves per plant, root yield and leaf yield showed high degree of heritability and high genetic advance which further indicated that these characters are being controlled by additive genes.

Rameeh (2011) evaluated thirty six rapeseed genotypes including four cultivars and thirty two advanced lines in rapeseed and found that heritability estimates were high for the traits *viz.* siliquae on main raceme, seeds per siliqua and siliquae per plant.

The study conducted by Iqbal *et al.* (2014) involving ten locally collected *Brassica rapa* germplasm accessions exhibited high heritability coupled with high genetic advance for the horticultural trait plant height. There by suggesting that this trait was under the control of additive gene effect.

Naznin *et al.* (2015) estimated heritability and genetic advance in thirty three genotypes of *Brassica rapa* L. and deduced that the characters number of siliquae/plant, number of secondary branches/plant and number of primary branches/plant showed high level of heritability coupled with high degree of genetic advance expressed as per cent of mean.

In an experiment involving thirty eight rapeseed genotypes Joya *et al.* (2016) found high level of heritability for the characters *viz.* plant height, raceme length, siliqua per raceme, siliqua length, seeds per siliqua, harvesting index and yield/plants except 1000 seed weight. However, the lowest genetic advance expressed as *per cent* of mean was found in trait 1000 seed weight; while highest genetic advance was observed in trait harvest index.

Maurya *et al.* (2018) estimated heritability and genetic advance in fifty germplasm accessions of Indian mustard with three check varieties. High heritability coupled with high genetic advance in *per cent* of mean along with high GCV was observed for yield contributing traits *viz.* 1000-seed weight, biological yield per plant, secondary branches per plant, seed yield per plant, harvest index and siliqua on main raceme; thus suggesting selection to be effective for these traits.

Genetic variability studies conducted by Mahendra *et al.* (2020) for eleven quantitative characters in sixty Toria genotypes revealed high heritability coupled with high genetic advance as *per cent* of mean for the horticultural trait harvest index indicating the main role of additive gene action for the expression of this trait.

### **3. Correlation:**

Pauw and Baker (1978) carried out correlation studies in sixteen to twenty five lines of turnip rape (*Brassica campestris* L.). The phenotypic correlations between traits were tested for homogeneity and were found homogeneous over all the years. Out of the six pooled correlations, only one correlation between traits height and maturity was significantly different. Thus, it suggested that there could be difficulty in combining traits like yield, height, maturity and oil content in a single turnip rape genotype.

The correlation studies conducted by Ozer *et al.* (1999) involving fourteen characters in oilseed rape (*Brassica napus* ssp. *oleifera* L.) gave an idea of relationship between the traits yield and yield components. Positive correlation values were observed between seed yield and the characters *viz.*, days to flowering, plant height, number of branch, number of pods per plant, number of seeds per pod, pod diameter, pod length, 1000-seed weight and oil content.

Ali *et al.* (2002) studied twenty five winter type rapeseed varieties to estimate correlation among yield and yield components *viz.* plant height, branches per plant, pods per plant, seeds per pod and seed weight. Seed yield was positively correlated with all the above yield contributing components.

Correlation studies carried out by Ali *et al.* (2003) in twenty five winter type rapeseed varieties revealed that positive correlation existed between seed yield and the other important traits *viz.*, harvest index, seed weight and flower duration.

Makhdoomi (2003) performed character association studies in twenty three genotypes of radish and obtained highly significant positive correlation of root weight with the characters *viz.*,

days to maturity, leaf number, leaf weight, root length and root diameter. The quality traits like total dry matter and TSS showed a significant positive correlation with root weight. Significant positive correlations existed between the traits days to maturity and leaf weight, root length and TSS, leaf number, leaf weight, root length and TSS; leaf weight and root length; root length and total dry matter.

Correlation studies performed by Tuncturk and Ciftci (2007) in sixteen rapeseed cultivars exhibited positive and significant correlations between the characters seed yield and number of branches per plant, pods per plant, number of seeds per pod and 1000-seed weight respectively.

Basalma (2008) performed an investigation on correlation in twenty five winter oilseed rape cultivars. The correlation analysis showed a high, positive and statistically significant correlation between the characters yield and branches per plant, the number of pods on the main stem and plant height, respectively. The character plant height showed negative correlation with the traits *viz.* seed yield, 1000-seed weight and oil ratio.

The correlation studies conducted by Khan *et al.* (2008) in *Brassica* population for quality traits revealed low level of correlation among different traits. However, some of the related characters like oil, protein, oleic acid and erucic acid were highly significant and negatively correlated with each other as compared to the remaining traits like glucosinolate and linolenic acid which were non-significantly correlated with each other.

Mehdi *et al.* (2010) carried out correlation studies in turnip (*Brassica rapa* L.) under cold arid conditions. The association studies revealed that character root yield exhibited significant positive correlation with the traits root diameter and leaf length at genotypic levels. Whereas, the trait number of leaf per plant exhibited significant positive correlation at both levels i.e. phenotypic and genotypic. However, leaf yield recorded significant positive correlation with the characters leaf length and number of leaves per plant.

The correlation studies in thirty six rapeseed genotypes including four cultivars and thirty two advanced lines performed by Rameeh (2011) lead to the conclusion that the character

siliquae per plant observed significant positive correlation with the most important trait seed yield.

Ara *et al.* (2013) evaluated eight F<sub>2</sub> populations generated through inter-varietal crosses, along with three check varieties of *Brassica rapa*. The correlation studies between pairs of different characters confirmed that yield per plant showed significant and highest positive correlation with the traits *viz.*, plant height, days to 50% maturity, length of siliqua and seeds per siliqua.

Studies on correlation with respect to various yield components in *Brassica napus* performed by Peydayesh and Mamghani (2013) suggested significant positive correlation between the characters grain yield and planting to emergence.

Helal *et al.* (2014) conducted correlation studies with eight varieties and four lines of rapeseed/mustard. Correlation between seed yield and yield contributing characters *viz.*, number of siliqua/plant, 1000 seed weight, straw yield, plant height, biological yield and harvest index showed significant and positive type of correlation among themselves.

In correlation studies conducted by Joya *et al.* (2016) involving thirty eight rapeseed genotypes it was found that characters *viz.*, plant height, raceme length and 1000 seed weight showed positive association with the economic character yield.

The correlation studies (Raliya *et al.* 2018) in Indian mustard suggested that the seed yield per hectare was positively correlated with the traits *viz.*, 1000-seed weight, siliqua length, plant height, main shoot length and days to maturity at genotypic level.

Jia *et al.* (2020) performed an experiment with two commercial turnip cultivars, Wenzhoupancai and Qiamagu to study the physiological responses of turnip (*Brassica rapa* subsp. *rapa*) seedlings to salt stress. The results revealed that growth parameters of turnip seedlings had significant negative correlation with the characters *viz.* reactive oxygen content,

osmo-regulation substances and antioxidant enzyme activities. However, growth parameters showed positive correlation with the characters chlorophyll-b and total chlorophyll content.

#### **4. Path coefficient analysis:**

Ozer *et al.* (1999) conducted path analysis studies on fourteen oilseed rape (*Brassica napus* ssp. *oleifera* L.) genotypes with respect to path analysis. They found that the character 1000-seed weight had the greatest effect on the dependent economic trait seed yield. While the trait number of pods per plant showed large indirect effect on the dependent trait.

The path analysis studies (Ali *et al.* 2002) in twenty five winter type rapeseed varieties revealed that characters pods per plant, seeds per pod and seed weight showed direct positive effect on the dependent character seed yield. While the character pods per plant showed highest positive indirect effect on the yield.

In a study conducted by Ali *et al.* (2003) in twenty five rapeseed varieties it was found that the characters harvest index, seed weight and pods/plant showed a considerable direct positive effect on the dependent trait i.e. seed yield.

Path coefficient analysis conducted by Makhdoomi (2003) in twenty three genotypes of radish suggested that at genotypic level the root length exhibited maximum direct effect on dependent character root weight followed by leaf weight and root diameter. In addition to direct effects these characters also exerted indirect positive effect via other characters towards the dependent trait root yield.

Tuncturk and Ciftci (2007) performed a study in sixteen rapeseed cultivars to determine the path coefficient analysis. Their studies indicated that positive direct effect was exerted by the traits number of pods per plant, number of seeds per pod and number of branches per plant on the dependent trait i.e. seed yield.

Path coefficient analysis studies conducted by Basalma (2008) in twenty five winter oilseed rape cultivars suggested that seed yield was directly affected by the character oil content. However, among the indirect effects on the dependent trait oil yield the character seed yield had the greatest effect.

Ullah *et al.* (2010) assessed twenty one varieties of radish for path coefficient analysis with respect to yield and yield contributing traits. They found that the trait plant height exerted the maximum positive direct effect on the dependent character root yield followed by the traits *viz.* root diameter, leaf width and days to harvest.

In a study involving thirty released varieties of Indian mustard [*Brassica juncea* (L.) Czern and Coss.] (Yadava *et al.* 2011) the path coefficient analysis indicated that the independent traits *viz.* 1000-seed weight, total siliquae/plant, secondary branches/plant and point to first siliqua exhibited positive phenotypic and genotypic direct effects on the dependent trait seed yield/plant. However, the phenotypic direct effect of siliqua length on seed yield/plant was found positive, while its genotypic direct effect was negative.

Ara *et al.* (2013) performed a path analysis study in *Brassica rapa* involving eleven different populations taken from eleven different cross consideration materials in which eight were F<sub>2</sub> segregating generations and three were checks varieties. The research concluded that the trait siliqua per plant had the highest positive direct effect on the dependent trait yield followed by the traits seeds per siliqua, length of siliqua and plant height.

The studies conducted by Helal *et al.* (2014) with eight varieties and four lines of rapeseed/mustard for path coefficient analysis. The results depicted that out of different yield contributing characters the character biological yield contributed maximum to the dependent trait seed yield.

Joya *et al.* (2016) performed path coefficient analysis in thirty eight rapeseed genotypes and found that the traits *viz.*, plant height, raceme length, 1000 seed weight and harvest index exhibited direct positive effect on the dependent character i.e. yield per plant.

Path coefficient analysis studies were conducted by Kaur *et al.* (2017) with respect to yield and its contributing traits in seventeen radish genotypes; the observations were recorded on eighteen parameters related to plant growth, root yield and root quality. The path coefficient analysis both at phenotypic and genotypic levels, revealed strong positive direct effect of independent traits *viz.*, marketable yield, root weight and foliage weight on the dependent character total root yield. It was found that greater emphasis on direct and desirable selection for traits such as root diameter, root length and higher root: plant ratio could be effective in increasing the overall root yield and quality in radish genotypes.

## Chapter-3

# MATERIALS AND METHODS

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The present investigation entitled “**Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)**” was conducted during rabi season of 2020 at the Experimental Research Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, District Hamirpur of Himachal Pradesh in order to adjudge the amount of variability present in the various genotypes under study.

### 3.1 About Experimental Site:

The Experimental Research Farm of Department of Vegetable Science, COH&F Neri, Hamirpur, Himachal Pradesh is situated in the low hill zone of Himachal Pradesh within latitude 31°41’47.6” N and longitude of 76°28’6.3” E. This area is located at an altitude of 650m above mean sea level.

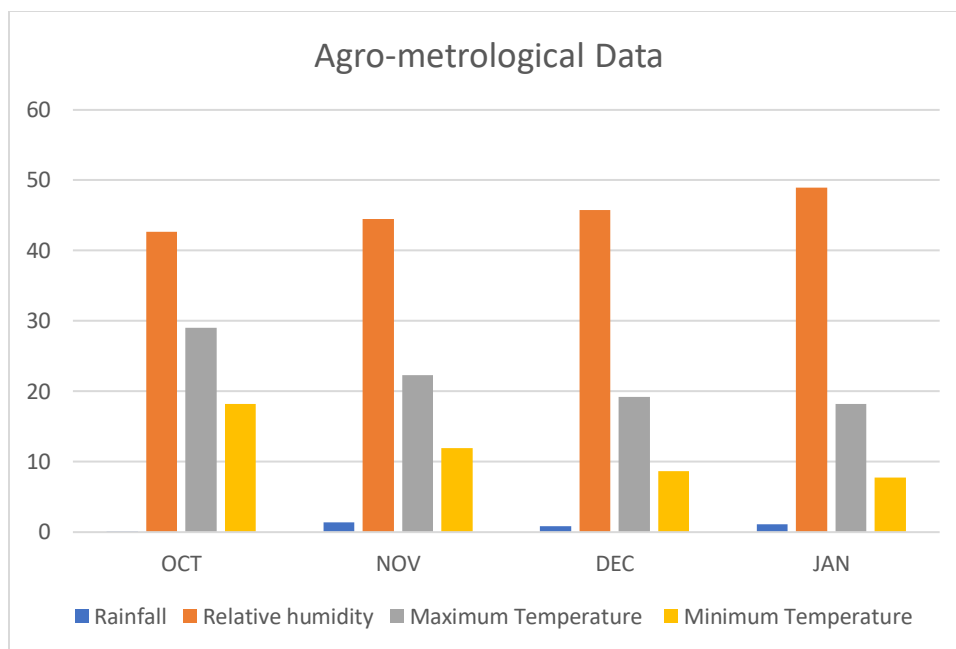
#### 3.1.2 Climate:

This region is characterized with mild winters and hot summers. More than 90% rainfall is received during July-August. Data recorded for mean monthly weather parameters during the present investigation have been presented on table 3.1 and figure 3.1.

**Table 3.1 Agro-metrological data during the cropping period:**

Month	Rainfall (mm)	Relative Humidity (%)	Maximum Temperature ( °C)	Minimum Temperature ( °C)
October, 2020	0.00	42.65	29.04	18.23
November, 2020	1.36	44.52	22.27	11.96
December, 2020	0.84	45.77	19.23	8.69
January, 2020	1.15	48.93	18.22	7.73

Source: Metrological observatory, COH&F Neri, Hamirpur.



**Figure 3.1 Agro-metrological data during the present investigation**

### 3.2 Experimental Design and layout:

<b>Number of genotypes</b>	: 12 (including check)
<b>Plot Size</b>	: 1.2 m × 1.0 m
<b>Spacing</b>	: 30 cm × 10 cm
<b>Design</b>	: Randomized Complete Block Design
<b>No. of Replications</b>	: 3
<b>Number of plants/plot</b>	: 40

### 3.3 Planting Material:

Present investigation comprised of twelve (seven local and five commercial) different genotypes of turnip (*Brassica rapa* L.) which are as follows (table 3.2):

**Table 3.2. List of genotypes of turnip used in the present investigation**

<b>S. No.</b>	<b>Genotype</b>	<b>Source</b>
1.	T-COHF-NERI-1	Department of Vegetable Science COHF, Neri Hamirpur
2.	T-COHF-NERI-2	Department of Vegetable Science COHF, Neri Hamirpur
3.	T-COHF-NERI-3	Department of Vegetable Science COHF, Neri Hamirpur
4.	T-COHF-NERI-4	Department of Vegetable Science COHF, Neri Hamirpur
5.	T-COHF-NERI-5	Department of Vegetable Science COHF, Neri Hamirpur
6.	T-COHF-NERI-6	Department of Vegetable Science COHF, Neri Hamirpur
7.	T-COHF-NERI-7	Department of Vegetable Science COHF, Neri Hamirpur
8.	Pusa Chandrima	IARI Regional Station, Katrain
9.	Pusa Swarnima	IARI Regional Station, Katrain
10.	Pusa Sweti	IARI Regional Station, Katrain
11.	L-1	PAU, Ludhiana
12.	Purple Top White Globe (Check)	IARI Regional Station, Katrain

### **3.4. Seed Sowing:**

Seeds of different genotypes of turnip were directly sown in the field on 27<sup>th</sup> October, 2020 at a spacing of 30 x 10 cm in randomized complete block design. Seedlings were thinned

after 10-15 days of germination in order to maintain proper spacing between the plants. All the recommended cultural practices as per package of practices (Anonymous, 2014) were followed to get quality turnip roots.

### **3.5. Observations recorded:**

The observations were recorded on five randomly selected plants from each replication and then average of these five plants was taken to record the reading for most of the traits under study. The detailed methodology of recording observations with respect to various horticultural traits studied is as follows:

#### **3.5.1. Days to 50% germination:**

The number of days to 50% germination was recorded visually by counting the total number of days taken by the seed for 50% germination in a given plot from the date of its sowing.

#### **3.5.2. Days to first harvest:**

Five random plants were selected from each plot and tagged. Days taken from sowing till final harvest of roots when the roots attained marketable maturity was recorded. The average value was computed from the days to first harvest of all the five plants in the given plot.

#### **3.5.3. Duration of availability of marketable roots (days):**

It was worked out by counting the number of days between the first and the last harvest of the marketable roots.

#### **3.5.4. Number of leaves per plant:**

Total leaves from the selected five plants were counted and data was calculated by taking mean of the selected plants at the time of uprooting of the turnip roots.

#### **3.5.5. Leaf length (cm):**

Leaf length (cm) was taken from the tip to the base of the five randomly selected leaves of the tagged plants in a plot with the help of meter scale and average was calculated.



**Plate: 1 CROP AT THE TIME OF GERMINATION**



**Plate: 2 CROP AT THE TIME OF HARVESTING**

### **3.5.6. Leaf width (cm):**

Leaf width (cm) was taken at the time of uprooting the roots from the point of maximum width of the leaf in five randomly selected leaves of each of the tagged plants in a plot with the help of meter scale and average leaf width was worked out.

### **3.5.7. Leaf area (cm<sup>2</sup>):**

Leaf area was recorded by multiplying length (in cm) and the width (in cm) of the 5 randomly selected leaves from each of the tagged plants. The area was expressed in cm<sup>2</sup> and mean value was calculated.

### **3.5.8. Plant height (cm):**

Plant height was taken in centimeters from the junction of the root and shoot to the tip of the longest leaf of the plant at the time of harvest of the crop and average value was calculated for each replication.

### **3.5.9. Plant spread (cm<sup>2</sup>):**

Plant spread was calculated at the time of harvest of the plant and the extent of plant spread in east to west and north to south directions was recorded in centimeters for each of the tagged plant. Then these values were multiplied and averaged for the 5 plants tagged to get plant spread (in cm<sup>2</sup>).

### **3.5.10. Average root yield without leaves (g):**

Weight of root per plant was taken after detaching the leaves of the five tagged plants with the help of the digital weighing balance at the time of harvest. The average value was calculated for recording observation in each of the replication.

### **3.5.11. Average root yield with leaves (g):**

Weight (in grams) of roots along with the leaves was obtained with the help of the digital weighing balance in the tagged five plants at the time of harvest and the average value was recorded.

### **3.5.12. Root Shoot Ratio:**

It was calculated by dividing fresh weight of the root with the fresh weight of the shoot of the same plant at the time of harvesting and average value was derived for each plot from the tagged turnip plants.

### **3.5.13. Root length (cm):**

Root length was recorded in centimeters with the help of the meter scale by measuring the total length from the junction of the shoot and root to the base of the root.

### **3.5.14. Root diameter (cm):**

Root diameter was obtained from the same tagged plants for which root length was taken. It was expressed in centimeters and recorded with the help of vernier calipers from the point where maximum width of the root occurred.

### **3.5.15. Root shape:**

Root shape was recorded on the basis of visual observation at the time of harvesting of roots it was broadly classified into flat-round, globe round or tapering types.

### **3.5.16. Root flesh color:**

Root flesh color was observed visually by cutting the transverse section of the roots at the time of harvest. The root flesh color in the current study was mainly divided into two discrete groups viz. white and yellow on the basis of visual observation only.

### **3.5.17. External skin color:**

Visual observation of external root color was done for recording this qualitative trait. External root color for various genotypes was mainly divided into the 4 categories viz. white, yellow, red and purple.

### **3.5.18. TSS (°Brix):**

Total Soluble Solid (TSS) values were recorded with the help of the hand refractometer in °Brix by putting few drops of the juice extracted from the turnip root at the time of its harvest by crushing it in mortar and pestil.

### 3.5.19. Ascorbic acid content (mg/100g):

Ascorbic acid content of the fresh turnip roots was estimated at the time of harvest with the help of the procedure given in Association of Official Agricultural Chemists (AOAC, 1980) by using the dye 2, 6-dichlorophenol indophenol. Ascorbic Acid was calculated by using the following formula:

$$\text{Ascorbic Acid (mg/100g)} = \frac{\text{Dyefactor} \times \text{Titrevalue} \times \text{Volume madeup}}{\text{Volume of aliquat} \times \text{Volume of sample taken for estimation}} \times 100$$

### 3.5.20. Prevalence of diseases (if any):

Daily observations were recorded in the field to note any disease incidence in the field on the five tagged plants in each plot for the purpose. These plants were not given any pesticide spray during the course of investigation.

## 3.6. Statistical Analysis:

Present investigation was conducted in the field with three replications and the result was statistically recorded using Randomized Complete Block Design (RCBD).

### 3.6.1 Analysis of Variance (ANOVA)

The analysis of variance was carried out for different quantitative characters as per the procedure given by Panse and Sukhatme (2000).

$$Y_{ab} = \mu + g_a + r_b + e_{ab}$$

Where,

$Y_{ab}$  = Phenotypic observation of  $a^{\text{th}}$  entry grown in  $b^{\text{th}}$  replication

$\mu$  = General population mean

$g_a$  = Effect of  $a^{\text{th}}$  entry

$r_b$  = Effect of  $b^{\text{th}}$  replication

$e_{ab}$  = Error component

Source of variation	Degree of freedom	Sum of square	Mean sum of square	Expected mean sum of squares
Replication (r)	r-1	S <sub>r</sub>	S <sub>r</sub> /(r-1)=M <sub>r</sub>	σ <sup>2</sup> e+gσ <sup>2</sup> r
Genotypes (g)	g-1	S <sub>g</sub>	S <sub>g</sub> /(g-1)=M <sub>g</sub>	σ <sup>2</sup> e+rσ <sup>2</sup> g
Error (e)	(r-1)(g-1)	S <sub>t</sub>	S/(r-1)(g-1)=M <sub>t</sub>	σ <sup>2</sup> e

Where,

r = Number of replications

g = Number of genotypes

S<sub>r</sub> = Sum of squares due to replications

S<sub>g</sub> = Sum of squares due to genotypes

S<sub>t</sub> = Sum of squares due to error

M<sub>r</sub> = Mean sum of squares due to replications

M<sub>g</sub> = Mean sum of squares due to genotypes

M<sub>t</sub> = Mean sum of squares due to error

σ<sup>2</sup>r = Variance due to replications

σ<sup>2</sup>g = Variance due to entries

σ<sup>2</sup>e = Error variance

Tests were conducted for the replications and genotypes mean sum of squares against error mean sum of squares by 'F' test for (r-1), (r-1)(g-1) and (g-1), (r-1)(g-1) degree of freedom at P= 0.05. Comparison between calculated F-value and tabulated F-value were done. When significant F-test was found, calculation of critical difference was done to find out the superiority of one genotype over the other.

The standard error and critical differences was calculated as follows:

$$SE (m) \pm = \sqrt{\frac{M_e}{r}}$$

$$SE (d) \pm = \sqrt{\frac{2M_e}{r}}$$

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

Where,

SE (m)  $\pm$  = Standard error of mean

SE (d)  $\pm$  = Standard error of difference

CD<sub>0.05</sub> = Critical difference at 5% level of significance

### 3.7 Parameters of Variability:

Study on parameters of variability were calculated as per suggested by Burton and De Vane (1953) as follows:

#### 3.7.1 Genotypic coefficient of variation

$$GCV (\%) = \frac{\sqrt{\text{Genotypic Variance } (V_g)}}{\text{General mean of population } (\mu)} \times 100$$

#### 3.7.2 Phenotypic coefficient of variation

$$PCV (\%) = \frac{\sqrt{\text{Phenotypic Variance } (V_{px})}}{\text{General mean of population } (\mu)} \times 100$$

Where,

$$V_g = \text{Genotypic variance } \frac{(Mg - M_e)}{r}$$

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

The estimation of PCV and GCV for all the traits under study were categorized as low (< 10 %), moderate (10-20 %) and high (> 20 %) as per given by Sivasubramanian and Menon (1973).

### 3.8 Heritability:

Heritability in broad sense was studied as per the formula given by Burton and De Vane (1953) and Allard (1960).

$$\text{Heritability (\%)} = \frac{\text{Genotypic Variance (}V_g\text{)}}{\text{Phenotypic Variance (}V_p\text{)}} \times 100$$

The estimates of heritability in broad sense were categorized as low (< 80 %), moderate (80-90 %) and high (> 90 %).

### 3.9 Genetic Advance:

The expected genetic advance was worked out by selecting five per cent superior individuals as per the formula given by Allard (1960):

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

Where,

H = Heritability (%) in broad sense

$\sigma_p$  = Phenotypic standard deviation

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

### 3.10 Genetic Advance as percentage of mean/ Genetic Gain:

Genetic Advance as percentage of mean was calculated as per the formula given by Johnson *et al.* (1955):

$$\text{Genetic Advance as percentage of mean (\%)} = (GA / \mu) \times 100$$

Where,

GA = Genetic advance

$\mu$  = General mean of population

The estimates of Genetic advance as percentage of mean were classified as low (< 10 %), moderate (10-30 %) and high (> 30 %).

### 3. 11 Correlation Analysis Study:

The genotypic and phenotypic correlation was studied as per formula given by Al-Jibouri *et al.* (1958) which is given below:

a) **Genotypic correlation between characters x and y:**

$$r_{xy}(g) = \frac{Cov_{xy}(g)}{\sqrt{V_x(g) \times V_y(g)}}$$

b) **Phenotypic correlation between characters x and y:**

$$r_{xy}(p) = \frac{Cov_{xy}(p)}{\sqrt{V_x(p) \times V_y(p)}}$$

Where,

$Cov_{xy}(g)$  = Genotypic co-variance between x and y characters

$Cov_{xy}(p)$  = Phenotypic co-variance between x and y characters

$V_x(g)$  = Genotypic variance of character 'x'

$V_x(p)$  = Phenotypic variance of character 'x'

$V_y(g)$  = Genotypic variance of character 'y'

$V_y(p)$  = Phenotypic variance of character 'y'

The test of significance for association between different characters was obtained by comparing tabulated 'r' values at n-2 error degree of freedom for phenotypic and genotypic correlations with estimated values, respectively.

### 3.12 Path Coefficient Analysis:

Path coefficient was studied as per the procedure suggested by Wright (1921) and was elaborated by Dewey and Lu (1959).

Yield components were included in the path coefficient analysis to reveal their direct and indirect effects upon yield. Residual factor was also included in the causal system which represents all other factor, which might affect yield.

For estimation of direct and indirect effects, following formula was used:

$$r_{iy} = r_{in}P_{iy} + \dots + P_{iy} \dots + r_{in}P_{ny}$$

Where,

$r_{iy}$  = coefficient of correlation between causal factor  $X_i$  and dependent character  $Y$ .

$r_{in}$  = coefficient of correlation among all possible combinations of causal factors.

$P_{iy}$  = direct effect of character  $X_i$  upon the character  $Y$ .

Residual factor was worked out as follows:

$$P_z Y_n = \sqrt{1 - R^2}$$

Where,

$$R^2 = \sum_{t=1} P_{iy}^2 + 2 \sum_{i < j} P_{iy} P_{jy} r_{ij}$$

Which is the square of the multiple correlation coefficient ( $R$ ) and is known as coefficient of determination.

## Chapter–4

# Results and Discussion

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Turnip is an important cool season crop belonging to the cruciferae family whose roots are rich source of vitamins and minerals. The results with respect to the present study entitled “**Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)**” comprising twelve genotypes of turnip collected from various sources are presented in the following text and are elaborately discussed with supporting tables, graphs etc. wherever, necessary under the following subheads:

### 4.1 Analysis of variance

### 4.2 Variability studies

#### 4.2.1 Mean performance of turnip genotypes

#### 4.2.2 Parameters of Variability

### 4.3 Heritability and genetic advance

### 4.4 Correlation coefficient analysis studies

### 4.5 Path coefficient analysis studies

### 4.1 Analysis of Variance:

The perusal of analysis of variance table (Appendix-I) for sixteen quantitative traits of turnip (excluding character prevalence of diseases, if any) viz. Days to 50% germination (1.18), days to first harvest (6.93), duration of availability of marketable roots (36.57), number of leaves per plant (5.18), leaf length (18.70), leaf width (6.45), leaf area (12462.24), plant height (21.21), root shoot ratio (0.96), plant spread (133621.43), root length (1.25), root diameter (0.87), TSS (0.24), ascorbic acid content (86.04), average root yield without leaves (583.64) and average root yield with leaves (2075.08) showed significant mean sum of squares due to genotypes indicating that sufficient genetic variability exists among the various genotypes for the above characters. Thus, it paved the way for carrying out further variability analysis with respect to the above

sixteen quantitative traits. However, mean sum of squares due to replications were not significant for any of the characters suggesting the absence of variation among the replications.

## **4.2 Variability Studies:**

Variability studies were conducted with respect to sixteen quantitative traits *viz.*, days to 50% germination, days to first harvest, duration of availability of marketable roots (days), number of leaves per plant, leaf length (cm), leaf width (cm), leaf area (cm<sup>2</sup>), plant height (cm), root shoot ratio, root length (cm), root diameter (cm), TSS (°B), ascorbic acid content (mg/100g), average root yield without leaves (g) and average root yield with leaves (g) in twelve genotypes of turnip (*Brassica rapa* L.). The observations with respect to three qualitative traits i.e. root shape, root flesh color and external skin color were also recorded in the above genotypes of turnip. During the course of investigation no disease was observed; therefore, no observation was recorded for the character prevalence of diseases (if any). The results pertaining to all the quantitative and qualitative characters studied in the present investigation have been discussed under the suitable headings as follows:

### **4.2.1 Mean performance of genotypes:**

Mean performance of the twelve genotypes with respect to sixteen quantitative traits is tabulated in Table 4.1 and the observations with respect to three qualitative traits have been compiled in Table 4.2, respectively.

#### **4.2.1.1 Days to 50% germination:**

Days to 50% germination refers to the number of days taken from sowing till 50% germination of the seedlings in the given plot. Lesser numbers of days taken to 50 % germination is desirable as it leads to early establishment and lesser weed competition to the crop. The values with respect to this character ranged from 4.66 to 6.66 days with an overall mean of 5.63 days. The maximum number of days to 50% germination were recorded in genotype T-COHF-NERI-3 (6.66 days). Whereas, the minimum number of days to 50% germination were recorded by the genotype Pusa Sweti (4.66 days). However, it was statistically at par with the genotypes T-

COHF-NERI-6 (5.00 days), T-COHF-NERI-5 (5.00 days) and Purple Top White Globe (5.00 days). Similar findings have been reported by Swarup (2006) in turnip crop.

#### **4.2.1.2 Days to first harvest:**

Days to first harvest is an important character in turnip as the early harvests fetch higher price in the market. Lesser number of days to first harvest is desirable in crop like turnip. Days to first harvest ranged from 60.66 to 65.00 days with an overall mean of 63.44 days. Minimum number of days to first harvest was recorded in the genotype L-1 (60.66 days) which was statistically at par with the genotype Pusa Sweti (61.00 days). Maximum number of days to first harvest was observed in the turnip genotypes Pusa Swarnima (65.00 days) and T-COHF-NERI-7 (65.00 days). Sadia *et al.* (2013) recorded similar observations for the trait i.e. days to first harvest in turnip.

#### **4.2.1.3 Duration of availability of marketable roots (days):**

The longer duration of availability of marketable roots help in ensuring supply of the roots for longer time in turnip crop and helps to reduce gluts in the market. This trait was measured in days and the values for it ranged from 14.00 to 25.33 days. Maximum duration of availability of marketable roots was exhibited by the genotype T-COHF-NERI-7 (25.33 days); while the least duration of availability of marketable roots was found in turnip genotype Pusa Sweti (14.00 days) which was found to be statistically at par with the genotype T-COHF-NERI-4 (14.66 days). Similar findings have been reported by Pathania (1984) in his investigations pertaining to turnip.

#### **4.2.1.4 Number of leaves per plant:**

Leaves in case of turnip are sometimes utilized for edible purposes; more over leaves help in the synthesis of photosynthates which are accumulated in turnip roots and increase their weight. Thus more number of leaves is a desirable trait in turnip. Number of leaves per plant in different genotypes of turnip under study ranged from 8.13 to 13.06; the maximum number of leaves were found in the turnip genotype T-COHF-NERI-3 (13.06). While, the minimum number of leaves were recorded by the genotype Pusa Chandrima (8.13); which was statistically at par with the turnip genotypes *viz.* L-1 (8.33), T-COHF-NERI-7 (8.49), T-COHF-NERI-5 (8.73), T-

COHF-NERI-2 (9.13), Pusa Swarnima (9.26), Pusa Sweti (9.40), T-COHF-NERI-1 (9.46), T-COHF-NERI-4 (9.50) and check Purple Top White Globe (9.72). These findings were in line to those obtained by Moghadam *et al.* (2014) and Ashraf *et al.* (2021) in turnip genotypes.

#### **4.2.1.5 Leaf length (cm):**

Leaf length was recorded by measuring the length of leaf from the tip of the leaf to its base in cm. The range of Leaf length in various genotypes of turnip varied from 28.16 to 37.60 cm with an overall mean of 32.36 cm. The maximum leaf length was observed in the turnip genotype T-COHF-NERI-3 (37.60) which was statistically at par with the genotypes T-COHF-NERI-1 (34.40), L-1 (33.93) and T-COHF-NERI-7 (33.86). Least leaf length was seen in genotype Purple Top White Globe (28.16), however, it was found statistically at par with the turnip genotypes *viz.* Pusa Chandrima (29.90), T-COHF-NERI-2 (30.23), T-COHF-NERI-5 (30.86) and Pusa Swarnima (31.33). Similar findings have also been reported by Moghadam *et al.* (2014) and Ashraf *et al.* (2021) in turnip germplasm.

#### **4.2.1.6 Leaf width (cm):**

Considerable variation in terms of leaf width was observed in various genotypes of turnip studied and the values for the character ranged from 8.58 to 13.06 cm with an overall mean of 10.66 cm. The maximum leaf width was found in the turnip genotype T-COHF-NERI-1 (13.06) which was statistically at par with the genotypes T-COHF-NERI-7 (12.73) and T-COHF-NERI-3 (11.93) respectively. The least leaf width was recorded in the genotype T-COHF-NERI-6 (8.58) which was found to be statistically at par with the genotypes Pusa Sweti (8.73) and T-COHF-NERI-4 (8.87). The results were in conformity to those obtained by Moghadam *et al.* (2014) and Ashraf *et al.* (2021).

#### **4.2.1.7 Leaf area (cm<sup>2</sup>):**

Leaf area is an important character as it is a measure of photosynthetic active area; the more is the leaf area the more photosynthates are produced which in turn help in obtaining higher yields. Leaf area in various genotypes of turnip studied was recorded and varied from 280.06 to

454.30 cm<sup>2</sup> with mean value of 346.90 cm<sup>2</sup>. The highest value in terms of leaf area was recorded in the genotype T-COHF-NERI-3 (454.30); which was statistically at par with the genotypes T-COHF-NERI-1 (449.17) and T-COHF-NERI-7 (429.76). The least leaf area was exhibited by the genotype T-COHF-NERI-6 (280.06) which was statistically at par with genotypes T-COHF-NERI-4 (288.72), Pusa Sweti (290.44), Purple Top White Globe (294.23), T-COHF-NERI-2 (311.46), T-COHF-NERI-5 (320.20) and Pusa Chandrima (323.00). Similar variation in terms of leaf area has been reported by Khalf-Allah *et al.* (2014) and Ashraf *et al.* (2021).

#### **4.2.1.8 Plant height (cm):**

Plant height was recorded from the joint of root and shoot to the tip of the longest leaf of the plant. Plant height in various genotypes of turnip in the present study ranged from 29.37 to 38.80 cm; however, the overall mean value for the character was 33.05 cm. The maximum plant height was observed in the genotype T-COHF-NERI-3 (38.80); which was statistically at par with genotype T-COHF-NERI-4 (35.49). The minimum plant height was exhibited by the genotype Pusa Swarnima (29.37) which was statistically at par with the genotypes *viz.* Purple Top White Globe (29.66), T-COHF-NERI-1 (31.26), T-COHF-NERI-2 (31.33) and Pusa Chandrima (31.56). These results were in line to those obtained by Aisha *et al.* (2014) and Ashraf *et al.* (2021) in a study involving various genotypes of turnip.

#### **4.2.1.9 Root Shoot Ratio:**

Root shoot ratio tells us the relative length of root with respect to the shoot in the turnip crop. It varied from 0.79 to 2.59 with an overall mean value of 1.64. The maximum root shoot ratio was found in the genotype L-1 (2.59) which was statistically at par with the genotype Pusa Chandrima (2.31). Whereas, the minimum root shoot ratio was shown by the genotype Pusa Sweti (0.79) which was statistically at par with the genotypes *viz.* T-COHF-NERI-2 (0.92), T-COHF-NERI-3 (1.17) and T-COHF-NERI-5 (1.17). Similar findings were obtained by Pathania (1984) in turnip.

#### **4.2.1.10 Plant spread (cm<sup>2</sup>):**

Plant spread determines the amount of space covered by the leaves. It is an important character for the proper interception of light by the leaves and affective photosynthesis. Plant

spread in various genotypes varied from 530.66 to 1195.33 cm<sup>2</sup> with an overall mean value of 844.04 cm<sup>2</sup>. The maximum plant spread was recorded in the genotype L-1 (1195.33) which was found statistically at par with the genotypes T-COHF-NERI-1 (1064.08) and Pusa Swarnima (1061.14) of turnip. However the minimum plant spread was observed by the genotype T-COHF-NERI-4 (530.66), which was statistically at par with the genotype T-COHF-NERI-6 (551.66), T-COHF-NERI-5 (628.77) and T-COHF-NERI-2 (687.91). Similar findings were obtained by Mashkey *et al.* (2021) in radish crop.

#### **4.2.1.11 Root length (cm):**

Root length is an important character which influences yield. In the present investigation, root length exhibited the values in the range of 4.25 to 6.33 cm and the overall mean value shown by the various genotypes under study was 5.18 cm. The highest root length was found in the genotype Purple Top White Globe (6.33) which was statistically at par with the genotype T-COHF-NERI-6 (5.87). The lowest root length was found in the genotype T-COHF-NERI-7 (4.25) which was statistically at par with the genotypes Pusa Sweti (4.33) and T-COHF-NERI-1 (4.66). Studies conducted by Moghadam *et al.* (2014) and Ashraf *et al.* (2021) reported similar results in turnip germplasm.

#### **4.2.1.12 Root diameter (cm):**

The character root diameter greatly affects the yield in case of turnip. Root diameter in various genotypes of turnip studied ranged from 4.49 to 6.08 cm with an overall mean value of 5.31 cm. The maximum root diameter was observed in the genotype L-1 (6.08) which was statistically at par with the genotypes *viz.* T-COHF-NERI-5 (5.98), T-COHF-NERI-7 (5.91), T-COHF-NERI-6 (5.55) and Purple Top White Globe (5.49). However, the minimum root diameter value was observed in the genotype T-COHF-NERI-1 (4.49) which was statistically at par with the genotypes *viz.* Pusa Sweti (4.54), T-COHF-NERI-4 (4.83) and Pusa Chandrima (4.87). Similar variation with respect to root diameter in turnip has been reported by Aisha *et al.* (2014) and Ashraf *et al.* (2021).

#### **4.2.1.13 TSS (°B):**

Total Soluble Solids (TSS) is a measure of total sugar content in the turnip roots. TSS value of the various genotypes of the turnip studied varied from 3.10 to 4.10 °B with an overall mean value of 3.50 °B. The highest TSS was obtained in the turnip genotype Pusa Chandrima (4.10) which was statistically at par with the genotypes *viz.* T-COHF-NERI-2 (3.83), Purple Top White Globe (3.63) and T-COHF-NERI-5 (3.63). Whereas, lowest TSS value was recorded by the genotype T-COHF-NERI-1 (3.10) which was statistically at par with the genotypes T-COHF-NERI-3 (3.23), T-COHF-NERI-6 (3.26), Pusa Sweti (3.30), T-COHF-NERI-7 (3.33), T-COHF-NERI-4 (3.46) and Pusa Swarnima (3.53). Similar findings have been reported by Ashraf *et al.* (2021) for the character in turnip crop.

#### **4.2.1.14 Ascorbic acid content (mg/100g):**

Turnip is a good source of ascorbic acid and its deficiency can lead to several diseases in human beings; therefore high content of ascorbic acid in turnip roots is a desirable character. The ascorbic acid content in different genotypes of turnip varied from 15.20 to 33.20 mg/100g with an overall mean of 26.06 mg/100g. The highest amount of ascorbic acid content was found in the roots of the genotype T-COHF-NERI-4 (33.20); however, it was statistically at par with the genotypes Pusa Sweti (32.80), L-1 (30.80) and T-COHF-NERI-2 (30.80). Whereas, the least content of ascorbic acid was estimated in the turnip genotype T-COHF-NERI-6 (15.20). These findings were in accordance to those obtained by Ashraf *et al.* (2021) in turnip.

#### **4.2.1.15 Average root yield without leaves (g):**

Average root yield without leaves was recorded in order to know the net weight of the turnip roots. This character exhibited a range of 65.00 to 109.66 g for different genotypes of the turnip studied. The overall mean value with respect to various genotypes was 92.84 gram. The highest average root yield without leaves was shown by the genotype L-1 (109.66) which was statistically at par and followed by the genotypes *viz.* Pusa Swarnima (103.66), Purple Top White Globe (103.55) and T-COHF-NERI-5 (100.44). The genotype T-COHF-NERI-4 (65.00) recorded the highest average yield of roots without leaves and was statistically at par to the genotype T-COHF-NERI-2 (66.60). Similar results were obtained by Aisha *et al.* (2014) and Moghadam *et al.* (2014) in their investigations on turnip genotypes.

#### **4.2.1.16 Average root yield with leaves (g):**

Average root yield with leaves is the most important trait from breeding point of view in turnip as it is the principal economic character. The values for this character varied from 104.00 to 200.66 g in different genotypes of turnip; however, the overall mean value for this character was 155.90 g. The best genotype with respect to this character with highest root yield was the genotype Pusa Sweti (200.66) which was statistically at par and followed by the genotype T-COHF-NERI-5 (185.77). The genotype poorest in terms of average root yield with leaves was T-COHF-NERI-4 (104.00).

Three genotypes *viz.*, Pusa Sweti (200.66), T-COHF-NERI-5 (185.77) and T-COHF-NERI-3 (177.26) yield higher as compared to the check variety “Purple Top White Globe” (174.88) which means that these genotypes can be used for further breeding programme. These findings were in accordance to those obtained by Khalf-Allah *et al.* (2014) in turnip.

#### **4.2.1.17 Root shape:**

Root shape was visually observed and classified into two discrete categories *viz.* “Globe Round” and “Flat Round” in 12 genotypes of turnip studied. The 6 genotypes *viz.* T-COHF-NERI-1, T-COHF-NERI-2, T-COHF-NERI-3, T-COHF-NERI-5, Pusa Chandrima and Purple Top White Globe possessed “Globe Round” shape; while the remaining half turnip genotypes *viz.* T-COHF-NERI-4, T-COHF-NERI-6, T-COHF-NERI-7, Pusa Swarnima, Pusa Sweti and L-1 had “Flat Round” type of root shape. Swarup (2006) studied similar shapes in turnip crop.

#### **4.2.1.18 Root flesh color:**

Root flesh color was observed visually for various genotypes of turnip and depending upon color, it was divided into 2 groups i.e. “White” and “Yellow”. “White” colour flesh was seen in 10 genotypes *viz.* L-1, T-COHF-NERI-1, T-COHF-NERI-2, Pusa Chandrima, Purple Top White Globe, T-COHF-NERI-3, Pusa Sweti, T-COHF-NERI-4, T-COHF-NERI-6 and T-COHF-NERI-7. Whereas, only 2 genotypes had “Yellow” colored flesh and these genotypes were Pusa Swarnima and T-COHF-NERI-5 respectively.

**Table: 4.1 Mean performance of various quantitative horticultural traits in different turnip (*Brassica rapa* L.) genotypes.**

Genotypes	Parameters							
	Days to 50% germination	Days to first harvest	Duration of availability of marketable roots (days)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)	Leaf area (cm <sup>2</sup> )	Plant height (cm)
<b>T-COHF-NERI-1</b>	6.33	64.66	23.00	9.46	34.40	13.06	449.17	31.26
<b>T-COHF-NERI-2</b>	6.00	64.33	20.33	9.13	30.23	10.30	311.46	31.33
<b>T-COHF-NERI-3</b>	6.66	63.33	18.00	13.06	37.60	11.93	454.30	38.80
<b>T-COHF-NERI-4</b>	6.00	63.00	14.66	9.50	32.33	8.87	288.72	35.49
<b>T-COHF-NERI-5</b>	5.00	62.00	21.00	8.73	30.86	10.33	320.20	32.91
<b>T-COHF-NERI-6</b>	5.00	64.66	22.00	10.60	32.54	8.58	280.06	33.37
<b>T-COHF-NERI-7</b>	6.00	65.00	25.33	8.49	33.86	12.73	429.76	34.68
<b>Pusa Chandrima</b>	5.33	63.33	22.66	8.13	29.90	10.80	323.00	31.56
<b>Pusa Swarnima</b>	5.66	65.00	19.33	9.26	31.33	11.29	353.74	29.37
<b>Pusa Sweti</b>	4.66	61.00	14.00	9.40	33.20	8.73	290.44	34.58
<b>L-1</b>	6.00	60.66	23.66	8.33	33.93	10.84	367.72	33.60
<b>Purple Top White Globe (Check)</b>	5.00	64.33	22.33	9.72	28.16	10.44	294.23	29.66
<b>Mean</b>	5.63	63.44	20.52	9.48	32.36	10.65	346.90	33.05
<b>SE(m)</b>	0.21	0.19	0.25	0.54	1.36	0.47	23.63	1.14
<b>C D (0.05)</b>	0.62	0.58	0.76	1.59	4.02	1.38	69.77	3.38
<b>CV (%)</b>	6.48	0.54	2.19	9.86	7.30	7.63	11.80	6.01

**Table: 4.1 (Continued...) Mean performance of various quantitative horticultural traits in different turnip (*Brassica rapa* L.) Genotypes.**

Genotypes	Parameters							
	Plant spread (cm <sup>2</sup> )	Average root yield without leaves (g)	Average root yield with leaves (g)	Root Shoot Ratio	Root length (cm)	Root diameter (cm)	TSS (°B)	Ascorbic acid content (mg/100g)
<b>T-COHF-NERI-1</b>	1064.08	97.38	162.33	1.50	4.66	4.49	3.10	24.80
<b>T-COHF-NERI-2</b>	687.91	66.60	140.40	0.92	5.13	5.32	3.83	30.80
<b>T-COHF-NERI-3</b>	833.11	95.66	177.26	1.47	5.83	5.35	3.23	22.00
<b>T-COHF-NERI-4</b>	530.66	65.00	104.00	1.67	4.83	4.83	3.46	33.20
<b>T-COHF-NERI-5</b>	628.77	100.44	185.77	1.17	5.61	5.98	3.63	23.60
<b>T-COHF-NERI-6</b>	551.66	97.33	149.00	1.88	5.87	5.55	3.26	15.20
<b>T-COHF-NERI-7</b>	905.55	88.22	131.33	2.04	4.25	5.91	3.33	24.40
<b>Pusa Chandrima</b>	915.66	97.33	140.25	2.31	5.46	4.87	4.10	21.20
<b>Pusa Swarnima</b>	1061.14	103.66	152.00	2.14	4.93	5.33	3.53	28.40
<b>Pusa Sweti</b>	825.66	89.22	200.66	0.79	4.33	4.54	3.30	32.80
<b>L-1</b>	1195.33	109.66	153.00	2.59	5.00	6.08	3.60	30.80
<b>Purple Top White Globe (Check)</b>	928.99	103.55	174.88	1.47	6.33	5.49	3.63	25.60
<b>Mean</b>	844.04	92.84	155.90	1.64	5.18	5.31	3.50	26.06
<b>SE(m)</b>	59.67	3.63	5.81	0.13	0.16	0.20	0.16	0.82
<b>C D (0.05)</b>	176.16	10.72	17.15	0.40	0.48	0.60	0.48	2.43
<b>CV (%)</b>	12.24	6.77	6.45	14.29	5.51	6.68	8.17	5.47



**T-COHF-NERI-1**



**T-COHF-NERI-2**



**T-COHF-NERI-3**



**T-COHF-NERI-4**



**T-COHF-NERI-5**



**T-COHF-NERI-6**

**Plate 3(a): Variability in Turnip Genotypes**



**T-COHE-NERI-7**



**L-1**



**PUSA CHANDRIMA**



**PUSA SWARNIMA**



**PURPLE TOP WHITE GLOBE**



**PUSA SWETI**

**Plate 3(b): Variability in Turnip Genotypes**

#### 4.2.1.19 External skin color:

The external skin color of the various turnip genotypes was mainly divided into four categories i.e. “White”, ‘Red”, “Yellow” and “White with purple top” on the basis of visual observations. “White” external skin color was observed in 4 genotypes viz. L-1, Pusa Chandrima, Pusa Sweti and T-COHF-NERI-7. “Red” external skin was seen in the genotypes namely T-COHF-NERI-3, T-COHF-NERI-4 and T-COHF-NERI-6. However, only 2 genotypes of turnip comprising Pusa Swarnima and T-COHF-NERI-5 showed “Yellow” external skin colour. The only 3 genotypes having external skin color as “White with purple top” were T-COHF-NERI-1, T-COHF-NERI-2 and Purple Top White Globe respectively. Similar colors were studied by Swarup (2006) in turnip.

**Table: 4.2 Observations with respect to various qualitative traits in different turnip (*Brassica rapa* L.) genotypes.**

<b>Sr. No.</b>	<b>Genotype</b>	<b>Root shape</b>	<b>Root flesh color</b>	<b>External skin color</b>
1	T-COHF-NERI-1	Globe Round	White	White with purple top
2	T-COHF-NERI-2	Globe Round	White	White with purple top
3	T-COHF-NERI-3	Globe Round	White	Red
4	T-COHF-NERI-4	Flat Round	White	Red
5	T-COHF-NERI-5	Globe Round	Yellow	Yellow
6	T-COHF-NERI-6	Flat Round	White	Red
7	T-COHF-NERI-7	Flat Round	White	White
8	Pusa Chandrima	Globe Round	White	White
9	Pusa Swarnima	Flat Round	Yellow	Yellow
10	Pusa Sweti	Flat Round	White	White
11	L-1	Flat Round	White	White
12	Purple Top White Globe (Check)	Globe Round	White	White with purple top

#### **4.2.1.20 Prevalence of diseases (if any):**

All the genotypes were carefully examined for the prevalence of diseases throughout the growing season i.e. from germination of seedlings till final harvesting of the roots under natural epiphytotic conditions. During the present course of investigation, no disease appeared in any of the turnip genotypes till the harvesting of the crop.

### **4.2.2 PARAMETERS OF VARIABILITY**

For genetic improvement of any crop, genetic variability in the population plays an important role and the germplasm of the crop collected from various sources act as a base population in the plant breeding studies, to increase the variability in the given crop. Genetic variability is the basic requirement for the improvement of the various horticultural traits in a crop. Therefore, the knowledge of genetic variability with respect to yield and other important characters is indispensable for strengthening of any breeding programme.

In the present study involving twelve genotypes of turnip, the variation observed, for the traits under study, was the result of interaction of environment and the genotype. As the environmental variation is solely non-fixable therefore only genotypic and phenotypic coefficients of variation were studied to assess the magnitude of genotypic and phenotypic variability in the present investigation. The results pertaining to genotypic and phenotypic coefficients have been discussed as below:

#### **4.2.2.1 Coefficients of variability:**

The perusal of Table 4.3 clearly showed that phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the traits studied which indicated that environment played a greater role in creating variation among the various genotypes. However, there was smaller difference between the PCV and GCV values for all the traits studied.

Out of all 16 quantitative traits studied in the current investigation; high PCV and GCV values (> 20%) were found for four traits *viz.* leaf area (PCV- 20.93%), root shoot ratio (PCV- 36.45% and GCV- 33.53%), plant spread (PCV- 26.92% and GCV- 23.98%) and ascorbic acid content (PCV- 21.02% and GCV- 20.30%).

However, moderate values (10-20%) PCV and GCV were observed in the traits *viz.* days to 50% germination (PCV- 12.31%), duration of availability of marketable roots (PCV- 17.10% and GCV- 16.96%), number of leaves per plant (PCV- 16.02% and GCV- 12.63%), leaf width (PCV- 15.10% and GCV- 13.03%), leaf area (PCV- 20.93% and GCV- 17.28%), root length (PCV- 13.20% and GCV- 12.00%), root diameter (PCV- 11.50%), TSS (PCV- 10.44%), average root yield without leaves (PCV- 16.01% and GCV- 14.50%) and average root yield with leaves (PCV- 17.67% and GCV- 16.45%).

Whereas, the low values (< 10%) for PCV and GCV were exhibited by only 4 traits *viz.* days to first harvest (PCV- 2.43% and GCV- 2.37%), leaf length (PCV- 9.75% and GCV- 6.46%), plant height (PCV- 9.42% and GCV- 7.25%) and TSS (GCV- 6.50%).

### **4.3 HERITABILITY AND GENETIC ADVANCE:**

#### **4.3.1. Heritability**

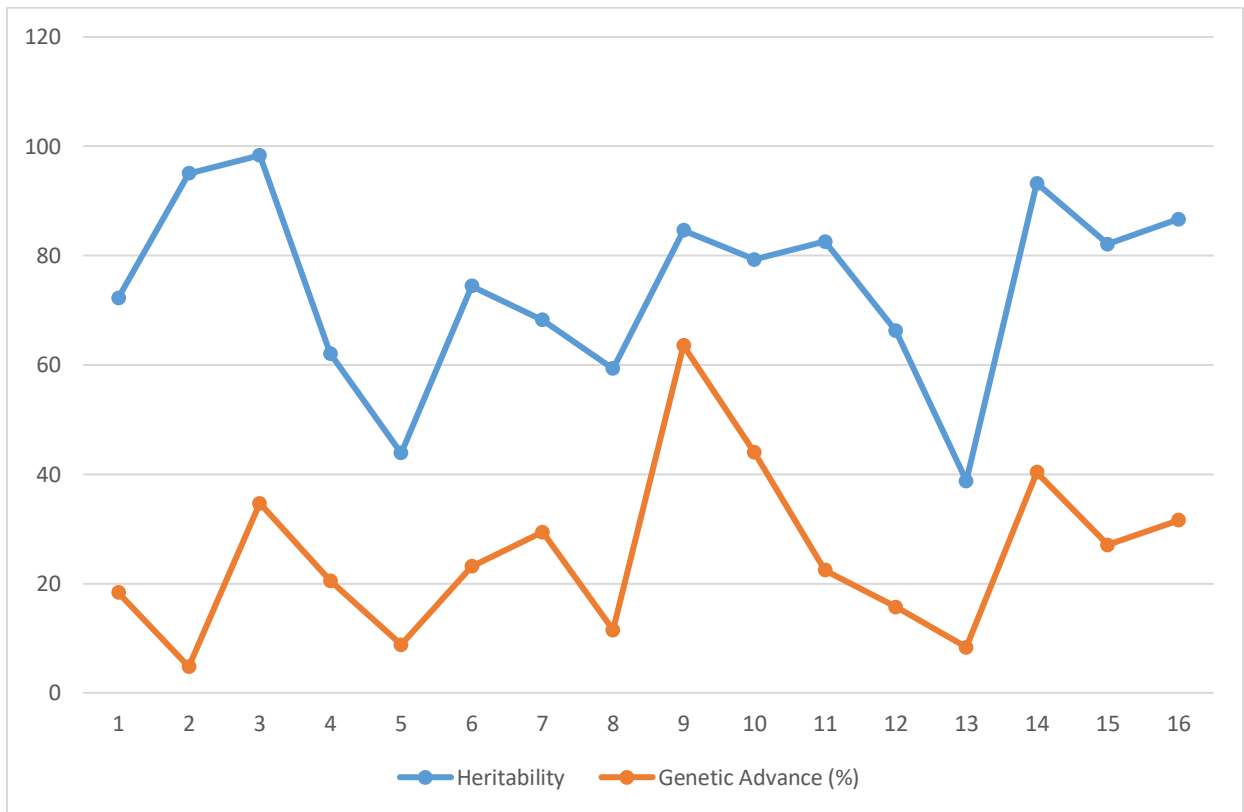
Genetic variability alone cannot give us the estimate of the heritable variation therefore the estimation of heritability is essential. Burton and Vane (1953) reported that a genetic coefficient of variability along with heritability estimates would give a best picture of the amount of advance expected from selection in a given population. Heritability can be defined as measure of genetic variability and determines the magnitude of characters passed to an offspring from its parents. High heritability allow us to make direct selection to improve a desirable trait from single parent whereas, in case of low heritability, we have to perform progeny tests before the selection based on desirable progeny.

The broad sense heritability with values >90% were considered as high, while those having values between 80-90% were classified as moderate and those which were < 80% were considered to be having low values. In the present investigation, heritability in broad sense was recorded in a range of 38.80 to 98.36%. The highest value of heritability was observed for the character duration of availability of marketable roots (98.36%) followed by days to first harvest (95.03%) and ascorbic acid content (93.22%). Whereas the moderate (80-90%) heritability was observed for the traits average root yield with leaves (86.65%), root shoot ratio (84.61%), root length (82.55%) and average root yield without leaves (82.08%). However, the low (< 80%) heritability value was seen for the traits *viz.* plant spread (79.31%), leaf width (74.42%), days to 50% germination (72.25%), leaf area (68.20%), root diameter (66.24%), number of leaves per plant (62.09%), plant height (59.31%) leaf length (43.89%) and TSS (38.80%). Similar results were obtained by Makhdoomi (2003) and Ullah *et al.* (2010) in radish crop.

#### **4.3.2 Genetic Advance (as percentage of mean)**

Genetic advance (Table 4.3) was calculated as percentage of mean for all the quantitative traits under study. Genetic advance values < 10% were put under low category, 10-30% were classified as moderate and while those which exhibited values >30% were considered as high. In the current investigation, the genetic advance values for all the traits ranged from 4.77 to 63.54%. The high amount of genetic advance was observed for the horticultural traits *viz.* root shoot ratio (63.54%) followed by the trait plant spread (44.00%), ascorbic acid content (40.37%), duration of availability of marketable roots (34.65%) and average root yield with leaves (31.55%). However, moderate level of genetic advance was recorded in the traits *viz.* leaf area (29.41%), average root yield without leaves (27.07%), leaf width (23.16%), root length (22.46%), number of leaves per plant (20.50%), days to 50% germination (18.33%), root diameter (15.70%) and plant height (11.51%). Whereas, lowest values in terms of genetic advance were found for the traits *viz.*, leaf length (8.82), TSS (8.35) and days to first harvest (4.77). Makhdoomi (2003) obtained similar type of genetic advance values in radish.

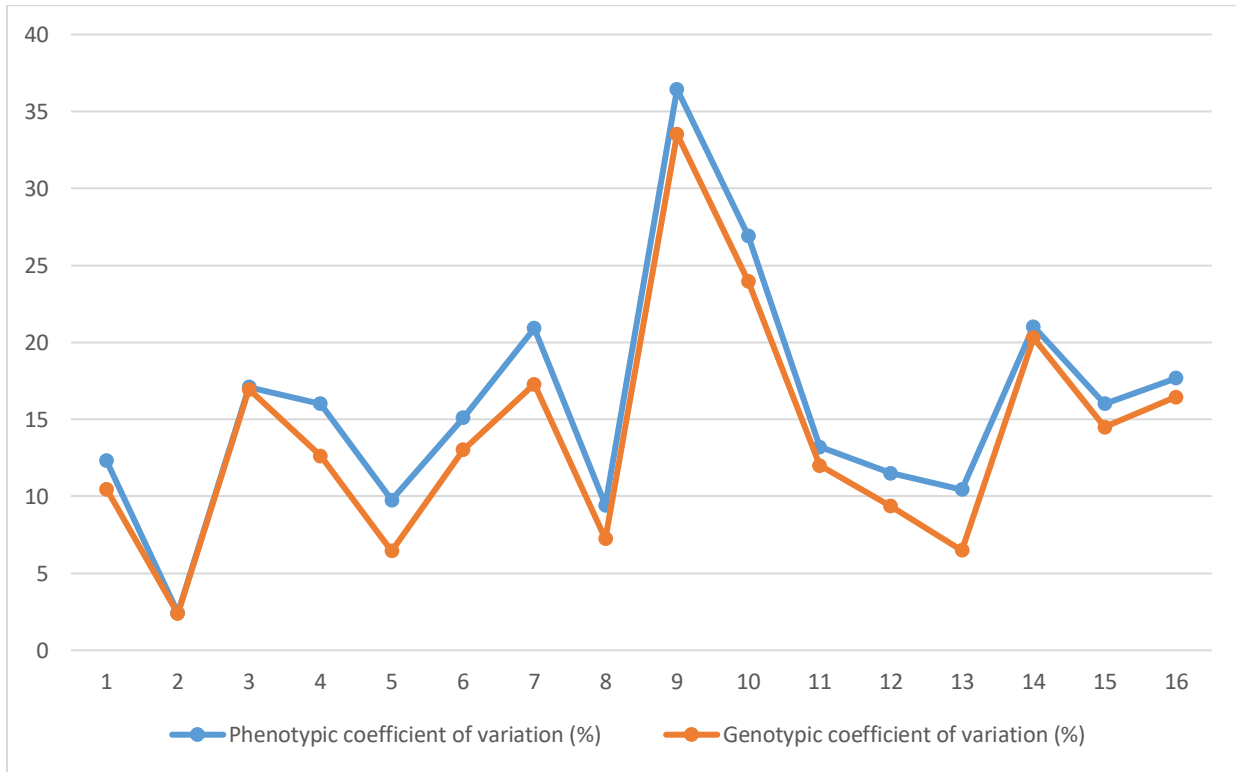
**Figure 4.1 Graphical representation of heritability (%) and genetic advance (%) for different traits in turnip (*Brassica rapa* L.)**



Where,

- |   |                                       |
|---|---------------------------------------|
| 1- Days to 50% germination                      | 9- Root shoot ratio                   |
| 2- Days to first harvest                        | 10- Plant spread                      |
| 3- Duration of availability of marketable roots | 11- Root length                       |
| 4- Number of leaves per plant                   | 12- Root diameter                     |
| 5- Leaf length                                  | 13- TSS                               |
| 6- Leaf width                                   | 14- Ascorbic acid content             |
| 7- Leaf area                                    | 15- Average root yield without leaves |
| 8- Plant height                                 | 16- Average root yield with leaves    |

**Figure 4.2 Graphical representation of Genotypic and Phenotypic Coefficient of Variation (%)**



Where,

- |   |                                       |
|---|---------------------------------------|
| 1- Days to 50% germination                      | 9- Root shoot ratio                   |
| 2- Days to first harvest                        | 10- Plant spread                      |
| 3- Duration of availability of marketable roots | 11- Root length                       |
| 4- Number of leaves per plant                   | 12- Root diameter                     |
| 5- Leaf length                                  | 13- TSS                               |
| 6- Leaf width                                   | 14- Ascorbic acid content             |
| 7- Leaf area                                    | 15- Average root yield without leaves |
| 8- Plant height                                 | 16- Average root yield with leaves    |

**Table: 4.3 Genetic parameters of variation for various horticultural traits including average root yield with leaves per plant for various genotypes in turnip (*Brassica rapa* L.)**

Sr. No.	Characters	Mean	Range		Coefficient of variation (%)		Heritability (%)	Genetic Advance as % of mean
			Minimum	Maximum	Genotypic	Phenotypic		
1	Days to 50% germination	5.63	4.66	6.66	10.46	12.31	72.25	18.33
2	Days to first harvest	63.44	60.66	65.00	2.37	2.43	95.03	4.77
3	Duration of availability of marketable roots (days)	20.52	14.00	25.33	16.96	17.10	98.36	34.65
4	Number of leaves per plant	9.48	8.13	13.06	12.63	16.02	62.09	20.50
5	Leaf length (cm)	32.36	28.16	37.60	6.46	9.75	43.89	8.82
6	Leaf width (cm)	10.65	8.58	13.06	13.03	15.10	74.42	23.16
7	Leaf area (cm <sup>2</sup> )	346.90	280.06	454.30	17.28	20.93	68.20	29.41
8	Plant height (cm)	33.05	29.37	38.80	7.25	9.42	59.31	11.51
9	Root shoot ratio	1.64	0.79	2.59	33.53	36.45	84.61	63.54
10	Plant spread (cm <sup>2</sup> )	844.04	530.66	1195.33	23.98	26.92	79.31	44.00
11	Root length (cm)	5.18	4.25	6.33	12.00	13.20	82.55	22.46
12	Root diameter (cm)	5.31	4.49	6.08	9.36	11.50	66.24	15.70
13	TSS (°B)	3.50	3.10	4.10	6.50	10.44	38.80	8.35
14	Ascorbic acid content (mg/100g)	26.06	15.20	33.20	20.30	21.02	93.22	40.37
15	Average root yield without leaves (g)	92.84	65.00	109.66	14.50	16.01	82.08	27.07
16	Average root yield with leaves (g)	155.90	104.00	200.66	16.45	17.67	86.65	31.55

## 4.4 CORRELATION STUDIES

Character association plays a major role in any plant breeding programme which aims at improving the quality and yield traits. Correlation determines the relationship among different characters and thus, helps in making selection more effective. Further, the knowledge pertaining to the magnitude of association between different characters of the crop enhances the precision of genetic improvement. In the present investigation correlation coefficient analysis was carried out both at phenotypic and genotypic levels respectively; for all possible combinations of sixteen quantitative traits in turnip. Perusal of Table 4.4 showed that the genotypic correlations were greater in magnitude as compared to the phenotypic correlations for most of the characters; which meant that environment played lesser role in governing the phenotype of the turnip genotypes studied. The various significant correlations among different characters have been discussed below under suitable headings:

**4.4.1 Days to 50% germination:** Days to 50% germination observed positive and highly significant correlation with the traits leaf length (genotypic= 0.751 and phenotypic= 0.469), leaf width (genotypic= 0.732 and phenotypic= 0.522) and leaf area (genotypic= 0.864 and phenotypic= 0.630) suggesting that the trait days to 50% germination increases with the increase of the characters *viz.*, leaf length, leaf width and leaf area. However, positive and significant character association was found with the characters number of leaves per plant (0.340) and the trait plant height (0.391) both at genotypic level.

Whereas the character expressed negative highly significant character association with the trait average root yield with leaves (-0.457) at genotypic level concluding that high average root with leaves increased in those genotypes which took lesser days to 50% germination.

**4.4.2 Days to first harvest:** The trait days to first harvest showed positive and significant correlation with the characters duration of availability of marketable roots (genotypic= 0.367 and phenotypic= 0.349) and leaf width at genotypic (0.420) level only which means that with the increase of one trait, other trait also increases.

However, the trait expressed negative and highly significant correlation with the trait ascorbic acid content (-0.436) at genotypic level while negative and significant character association with the traits plant height (genotypic= -0.387 and phenotypic= -0.333), ascorbic acid content at phenotypic (-0.409) and average root yield with leaves (genotypic= -0.386 and phenotypic= -0.349).

#### **4.4.3. Duration of availability of marketable roots:**

The horticultural trait duration of availability of marketable roots showed positive and highly significant correlation with the characters *viz.*, leaf width (genotypic= 0.610 and phenotypic= 0.516), root shoot ratio (genotypic= 0.567 and phenotypic= 0.508), root diameter (genotypic= 0.585 and phenotypic= 0.455) and average root yield without leaves (genotypic= 0.494 and phenotypic= 0.433) suggesting that the genotypes with greater duration of availability of marketable roots had larger leaf width, root shoot ratio, root diameter and more average root yield without leaves.

#### **4.4.4 Number of leaves per plant:**

Number of leaves per plant expressed negative and significant correlation for the trait was observed with the character duration of availability of marketable roots at genotypic level (-0.394) suggesting that the turnip genotypes with lesser number of leaves had the larger duration of marketable roots.

#### **4.4.5 Leaf length:**

Significant and positive correlation was exhibited by the trait leaf length with the character with the character number of leaves per plant (genotypic level= 0.720; phenotypic level= 0.384). The studies thus indicated that the genotypes of turnip with greater leaf length had more number of leaves.

#### **4.4.6 Leaf width:**

Leaf width exhibited positive and significant correlation with the trait leaf length (genotypic= 0.418) concluding that leaf width increases with the increase of leaf length.

#### **4.4.7 Leaf area:**

Leaf area showed positive and highly significant correlation with the traits *viz.*, leaf length (0.727 and 0.704) and leaf width (0.929 and 0.878) at both genotypic and phenotypic levels respectively. Whereas, positive and significant correlation was found between the traits under study i.e. leaf area and the character duration of availability of marketable roots (0.394) at genotypic level only indicating that increase in the leaf area led to increase in the duration of availability of the marketable roots in turnip.

#### **4.4.8 Plant height:**

Positive and highly significant correlation was found for the trait plant height with the character leaf length (genotypic= 0.836 and phenotypic= 0.716) and the character number of leaves per plant (genotypic= 0.673) suggesting that the genotypes of turnip having more plant height also recorded increased leaf length and more number of leaves per plant. Whereas, plant height showed positively significant correlation with the trait number of leaves per plant (phenotypic= 0.414) and leaf area (phenotypic= 0.358).

However, the trait plant height exhibited negatively significant correlation with the trait duration of availability of marketable roots (genotypic=-0.417) which suggested that the genotypes which were earlier and had shorter duration of marketable roots had higher plant height. Ullah *et al.* (2010) reported similar results in radish.

#### **4.4.9 Root shoot ratio:**

Negative and highly significant correlation was observed between the traits root shoot ratio and the character number of leaves per plant (genotypic= -0.461); thus it was inferred that the genotypes of the turnip with lesser number of leaves had higher root shoot ratio.

#### **4.4.10 Plant spread:**

Positive and highly significant correlation for the trait plant spread was observed with the traits *viz.*, leaf width (0.669 and 0.586) and leaf area (0.580 and 0.454) at genotypic and phenotypic levels respectively; and with the trait root shoot ratio (0.517) at genotypic level only.

Thus it could be inferred that the turnip genotypes with greater plant spread had also greater leaf width, leaf area and higher root shoot ratio.

Negatively significant correlation was found between the traits plant spread and the plant height (-0.391) at genotypic level indicating that the plants having larger spread had lesser height in the genotypes of turnip under study.

#### **4.4.11 Root length:**

Root length registered positive and highly significant correlation with the trait number of leaves per plant (0.486) at genotypic level indicating that the root length increased in various turnip genotypes with the increase in number of leaves per plant; however positive and significant correlation was shown by the character under study with the trait number of leaves per plant at phenotypic level (0.336). Negatively significant correlation was exhibited by the character root length with the trait leaf length (-0.414) at genotypic level only suggesting that the turnip genotypes with higher root length and had shorter leaf lengths. Similar results have been reported by Ullah *et al.* (2010) in radish.

#### **4.4.12 Root diameter:**

Root diameter showed positive significant correlation with the trait root shoot ratio (0.388) at genotypic level only. Similar results were obtained by Ullah *et al.* (2010) in radish.

#### **4.4.13 TSS:**

The trait TSS reported positive and significant correlation with the trait root length (0.350) at phenotypic level suggesting that high TSS values were observed for the roots with greater length. Negative and highly significant correlation was found for the traits *viz.* number of leaves per plant (-0.696), leaf length (-1.131), leaf area (-0.654) and plant height (-0.679) at genotypic level indicating that TSS value in turnip genotypes decreased with the increase in number of leaves per plant, leaf length, leaf area and the plant height.

#### **4.4.14 Ascorbic acid content:**

Ascorbic acid content exhibited a highly negative significant correlation with the character root length (-0.574 and -0.507) at both genotypic and phenotypic levels; and with the trait number of leaves per plant (-0.334) at genotypic level only suggesting that the genotypes of turnip which had higher content of ascorbic acid had lesser number of leaves and lesser root length.

#### **4.4.15 Average root yield without leaves:**

Average root yield without leaves reported positive and highly significant correlation with the traits plant spread (genotypic=0.685 and phenotypic=0.519), root shoot ratio (genotypic=0.439), leaf width (genotypic=0.344), root length (genotypic=0.333) and root diameter (genotype=0.366) suggesting that the root yield without leaves increased with the increase in the traits plant spread, root shoot ratio, leaf width, root length and the root diameter.

However, negative and highly significant correlation was observed by the trait average root yield without leaves with the trait ascorbic acid content (-0.444) at genotypic level indicating that the turnip genotypes where average root yield without leaves was on higher side had lesser content of ascorbic acid.

#### **4.4.16 Average root yield with leaves:**

Average root yield with leaves observed highly significant and positive character association with the trait average root yield without leaves (genotypic=0.515 and phenotypic=0.551) which suggested that average root yield with leaves increased with increase in the character average root yield without leaves.

Whereas, highly significant negative correlation was exhibited by the trait average root yield with leaves and the traits root shoot ratio (genotypic= -0.517 and phenotypic= -0.486) indicating that the average root yield with leaves increased in those genotypes which exhibited lesser root shoot ratio.

**Table-4.4 Genotypic and Phenotypic correlation coefficients between average root yield with leaves and its component characters in turnip (*Brassica rapa* L.)**

		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	G	1															
	P	1															
X2	G	0.263	1														
	P	0.195	1														
X3	G	0.138	0.367*	1													
	P	0.111	0.349*	1													
X4	G	0.340*	0.190	-0.394*	1												
	P	0.288	0.127	-0.297	1												
X5	G	0.751**	-0.181	-0.156	0.720**	1											
	P	0.469**	-0.142	-0.115	0.384*	1											
X6	G	0.732**	0.420*	0.610**	-0.025	0.418*	1										
	P	0.522**	0.323	0.516**	0.042	0.285	1										
X7	G	0.864**	0.256	0.394*	0.289	0.727**	0.929**	1									
	P	0.630**	0.170	0.314	0.260	0.704**	0.878**	1									
X8	G	0.391*	-0.387*	-0.417*	0.673**	0.836**	-0.101	0.272	1								
	P	0.323	-0.333*	-0.307	0.414*	0.716**	-0.008	0.358*	1								
X9	G	0.136	0.097	0.567**	-0.461**	-0.066	0.238	0.136	-0.262	1							
	P	0.139	0.060	0.508**	-0.316	0.001	0.187	0.120	-0.123	1							
X10	G	0.325	-0.058	0.445**	-0.320	0.213	0.669**	0.580**	-0.391*	0.517**	1						
	P	0.187	-0.059	0.400*	-0.140	0.081	0.586**	0.454**	-0.214	0.401*	1						
X11	G	-0.211	0.136	0.162	0.486**	-0.414*	-0.222	-0.307	-0.124	-0.070	-0.233	1					
	P	-0.223	0.113	0.146	0.336*	-0.223	-0.154	-0.199	-0.116	-0.016	-0.217	1					
X12	G	-0.045	-0.084	0.585**	-0.139	-0.192	0.095	-0.010	-0.034	0.388*	0.043	0.327	1				
	P	0.057	-0.025	0.455**	-0.077	0.117	0.139	0.163	0.143	0.265	0.058	0.235	1				
X13	G	-0.224	-0.125	0.210	-0.696**	-1.131**	-0.277	-0.654**	-0.679**	0.236	-0.012	0.215	0.211	1			
	P	-0.274	-0.123	0.131	-0.369*	-0.364*	-0.066	-0.240	-0.199	0.247	0.023	0.350*	0.107	1			
X14	G	0.098	-0.436**	-0.512**	-0.334*	-0.097	-0.175	-0.185	-0.053	-0.213	0.201	-0.574**	-0.263	0.132	1		
	P	0.137	-0.409*	-0.492**	-0.303	-0.038	-0.140	-0.130	0.006	-0.155	0.104	-0.507**	-0.172	0.064	1		
X15	G	-0.274	-0.130	0.494**	-0.007	0.031	0.344*	0.268	-0.286	0.439**	0.685**	0.333*	0.366*	-0.109	-0.444**	1	
	P	-0.138	-0.132	0.433**	-0.018	0.076	0.231	0.203	-0.197	0.415*	0.519**	0.314	0.320	-0.016	-0.383*	1	
X16	G	-0.457**	-0.386*	-0.143	0.322	0.105	0.013	0.058	0.020	-0.517**	0.207	0.234	-0.046	-0.261	-0.092	0.515**	1
	P	-0.324	-0.349*	-0.132	0.186	0.098	-0.026	0.035	-0.013	-0.486**	0.168	0.203	0.023	-0.191	-0.106	0.551**	1

\*Significant at 5% level

\*\*Significant at 1% level

**Where,**

X1 Days to 50% germination	X9 Root shoot ratio
X2 Days to first harvest	X10 Plant spread
X3 Duration of availability of marketable roots	X11 Root length
X4 Number of leaves per plant	X12 Root diameter
X5 Leaf length	X13 TSS
X6 Leaf width	X14 Ascorbic acid content
X7 Leaf area	X15 Average root yield without leaves
X8 Plant height	X16 Average root yield with leaves

#### **4.5 PATH COEFFICIENT ANALYSIS STUDIES**

Path coefficient analysis studies were conducted in 12 genotypes of turnip and the direct and indirect effects of different independent characters on the dependent character average root yield with leaves has been tabulated in Table 4.5; the genotypic correlation coefficient of the character average root yield with leaves along with its all components was partitioned into direct and indirect effects taking the character average root yield with leaves as dependent variable.

The path analysis concept was first given by Wright (1921) and this technique was used first of all by Dewey and Lu (1959) which proved very helpful in-order to determine various yield contributing characters and therefore proved beneficial for indirect selection. Path coefficient analysis together with correlation studies give very effective results and show their utility in further improving of the crops. If a particular character shows greater direct effect on the correlation with the yield than this character is very important and the improvement in yield can be directly done by selection of this trait. Whereas, if the correlation between yield and a character is mainly due to the indirect effect of a character through some other trait, then the indirect selection through that trait is effective in bringing improvement in yield rather than the direct selection.

The genotypic correlation coefficients of the trait root yield with leaves and its components were divided into two effects *viz.* direct effect and indirect effect. Average root yield with leaves was taken as dependent variable however, rest all of the characters were taken as independent variables.

##### **4.5.1 Days to 50% germination**

The trait days to 50% germination (0.5116) showed positive direct effect on dependent trait average root yield with leaves. However it showed negative genotypic correlation with the average root yield with

leaves which is desirable. Therefore selection should be done through the other traits showing negative indirect effects.

The highest negative indirect effects were shown by the traits leaf area (-1.4863) followed by plant height (-0.5178), average root yield without leaves (-0.2153), days to first harvest (-0.1713), plant spread (-0.0721), ascorbic acid content (-0.0633), duration of availability of marketable roots (-0.0579) and root diameter (-0.0145); thus showing that maximum improvement in the yield can be brought if selection is done through the trait leaf area. Whereas, highest positive indirect effect was observed through trait leaf length (0.9689) followed by leaf width (0.7417), root length (0.0626), TSS (0.0012) and number of leaves per plant (0.0005).

#### **4.5.2 Days to first harvest**

Negative direct effect (-0.6524) and negative genotypic correlation (-0.386) with the character average root yield with leaves was observed by the character. Negative type of correlation with the economic character average root yield with leaves helps to improve yield and minimize the number of days taken to first harvest; therefore the selection through negative direct effect could be beneficial in this case.

Negative indirect effects were expressed by the characters *viz.* leaf area (-0.4408), leaf length (-0.2333), duration of availability of marketable roots (-0.1547), average root yield without leaves (-0.1018), root length (-0.0404), root diameter (-0.0271) and root shoot ratio (-0.1033). However positive indirect effect values were reported by the traits *viz.* plant height (0.5118), leaf width (0.4261), ascorbic acid content (0.2820), days to 50% germination (0.1343), plant spread (0.0128), TSS (0.0007) and number of leaves per plant (0.0003).

#### **4.5.3 Duration of availability of marketable roots**

Negative direct effect was observed by the trait duration of availability of marketable roots (-0.4214) on the dependent trait average root yield which is not desirable as it tends to make genotypic correlation with average root yield without leaves more negative and thus decreasing the duration of availability of marketable root with an increase in yield. Therefore in this scenario selection through positive indirect effects is favorable for improving the dependent trait.

Highest positive indirect effect was observed through character leaf width (0.6184) followed by plant height (0.5523), average root yield without leaves (0.3884), ascorbic acid content (0.3308), root

diameter (0.1886) and days to 50% germination (0.0704). Whereas, negative indirect effect was exhibited through the traits *viz.* leaf area (-0.6767), root shoot ratio (-0.6043), days to first harvest (-0.2396), leaf length (-0.2013), plant spread (-0.0988), root length (-0.0483), TSS (-0.0011) and number of leaves per plant (-0.0006).

#### **4.5.4 Number of leaves per plant**

The character number of leaves per plant showed positive direct effect (0.0014) and positive genotypic correlation (0.322) with the dependent trait average root yield with leaves which suggested that the selection directly through the trait number of leaves per plant is effective in increasing the values of the dependent trait.

Highest positive indirect effects were exhibited by the character leaf length (0.9294) followed by the trait root shoot ratio (0.4907), ascorbic acid content (0.2160), days to 50% germination (0.1739), duration of availability of marketable roots (0.1659), plant spread (0.0709) and TSS (0.0039). However, the negative indirect effects were shown by the characters *viz.* plant height (-0.8902), leaf area (-0.4964), root length (-0.1446), days to first harvest (-0.1237), root diameter (-0.0446), leaf width (-0.0252) and average root yield without leaves (-0.0054). Similar findings have been obtained, as per the studies conducted by Mapari *et al.* (2009) in radish.

#### **4.5.5 Leaf length (cm)**

Positive direct effect (1.2905) along with positive genotypic correlation (0.105) was shown by the character leaf length with the dependent trait average root yield with leaves; which indicated that yield can be increased by direct selection of the genotypes which have higher leaf length.

Maximum positive indirect effect was seen in the character leaf width (0.4236) followed by days to 50% germination (0.3841), root length (0.1231), days to first harvest (0.1179), root shoot ratio (0.0704), duration of availability of marketable roots (0.0657), ascorbic acid content (0.0629), average root yield without leaves (0.0242), TSS (0.0063) and number of leaves per plant (0.0012). Mallikarjunarao *et al.* (2015) also obtained positive direct effect of leaf length over the average root yield with leaves.

Whereas, negative indirect effects were exerted through the characters leaf area (-1.2496), plant height (-1.106), root diameter (-0.0618) and plant spread (-0.0473) on the dependent trait *i.e.* average root yield with leaves.

#### 4.5.6 Leaf width (cm)

Leaf width (1.0137) reported positive direct effect on the dependent trait average root yield with leaves. Similarly, positive association at genotypic level (0.013) was observed between the characters leaf width and average root yield with leaves which is desirable. Thus selection in this case through the direct effect will be effective as positive direct effect will make the correlation more positive and hence will help in increasing the yield in the turnip genotypes.

Maximum positive indirect effect was shown by the trait leaf length (0.5393) followed by days to 50% germination (0.3743), average root yield without leaves (0.2705), plant height (0.1336), ascorbic acid content (0.1133), root length (0.0661), root diameter (0.0306) and TSS (0.0015). However, negative indirect effects were shown by the characters *viz.*, leaf area (-1.5976), days to first harvest (-0.2742), duration of availability of marketable roots (-0.2570), root shoot ratio (-0.2531), plant spread (-0.1484) and number of leaves per plant (-0.0004). Similar trends in terms of the indirect effects were obtained by Ullah *et al.* (2010) in radish.

#### 4.5.7 Leaf area (cm<sup>2</sup>)

Negative direct effect was exerted by the character leaf area (-1.7197) on the dependent character average root yield with leaves. However, positive genotypic correlation (0.058) was found for leaf area with average root yield with leaves; which suggested that negative direct effect tend to reduce the positive correlation between the leaf area and yield and hence in this case the selection through positive indirect effects can help to increase yield.

Maximum positive indirect effect was shown by the independent trait leaf width (0.9418) followed by leaf length (0.9377), days to 50% germination (0.4422), average root yield without leaves (0.2105), ascorbic acid content (0.1196), root length (0.0914), TSS (0.0036) and number of leaves per plant (0.0004) on the dependent trait average root yield with leaves. On the other side the negative indirect effects were found through the independent traits *viz.*, plant height (-0.3603), days to first harvest (-0.1672), duration of availability of marketable roots (-0.1658), root shoot ratio (-0.1444), plant spread (-0.1287) and root diameter (-0.0033), respectively.

#### 4.5.8 Plant height

The trait plant height (-1.3235) exhibited negative direct effect on the dependent trait average root yield with leaves in turnip with respect to the various genotypes studied; which showed that it tends to decrease the genotypic correlation with the character average root weight with leaves i.e. a yield character. Hence, in this case the selection through indirect effect with positive value will lead to increase in the dependent trait.

Positive indirect effect was observed through the characters *viz.* leaf length (1.0793), root shoot ratio (0.2788), days to first harvest (0.2523), days to 50% germination (0.2001), duration of availability of marketable roots (0.1758), plant spread (0.0867), root length (0.0368), ascorbic acid content (0.0344), TSS (0.0038) and number of leaves per plant (0.0009). Whereas, negative indirect effect on the dependent trait was shown by the independent characters *viz.* leaf area (-0.4682), average root yield without leaves (-0.2245), leaf width (-0.1023) and root diameter (-0.0108).

#### 4.5.9 Root shoot ratio

Direct effect of this trait on the dependent trait was negative (-1.0653) in direction; further the genotypic correlation coefficient with the dependent trait was also negative. Therefore to decrease the negative type of association of the character root shoot ratio with yield character i.e. average root yield with leaves the selection through the trait showing positive indirect effect will be effective in this particular case.

Positive indirect effect was expressed through the independent traits like plant height (0.3464), average root yield without leaves (0.3454), leaf width (0.2408), ascorbic acid content (0.1375), root diameter (0.1252), days to 50% germination (0.0697) and root length (0.0206). However, negative indirect effects were seen in the independent traits *viz.* duration of availability of marketable roots (-0.2390), leaf area (-0.2331), plant spread (-0.1149), leaf length (-0.0853), days to first harvest (-0.0632), TSS (-0.0013) and number of leaves per plant (-0.0006). Kaur *et al.* (2017) also reported similar results in radish crop.

#### 4.5.10 Plant spread (cm<sup>2</sup>)

Negative direct effect was exerted by the character plant spread (-0.2221) on the dependent trait average root yield with leaves. Whereas positive association (0.207) at genotypic level was observed between plant spread and the dependent trait; which is desirable as the increase in plant spread helps to

increase the yield. Hence, in-order to increase the yield component i.e. average root yield with leaves we have to select the turnip genotypes on the basis of independent traits showing positive indirect effects.

Highest indirect effect with positive sign was reported through the character leaf width (0.6779) followed by average root yield without leaves (0.5381), plant height (0.5173), leaf length (0.2753), days to 50% germination (0.1662), root length (0.0694), days to first harvest (0.0378), root diameter (0.0139) and TSS (0.0001). Whereas, negative indirect effect was seen through the traits *viz.* leaf area (-0.9974), root shoot ratio (-0.5513), duration of availability of marketable roots (-0.1876), ascorbic acid content (-0.1300) and number of leaves per plant (-0.0004) on the dependent trait average root yield with leaves.

#### **4.5.11 Root length (cm)**

The character root length showed negative direct effect (-0.2976) on the dependent character average root weight. But the trait root length showed positive association with the trait average root yield with leaves which is helpful; as increase in the root length helped to increase the average root yield with leaves in the various genotypes of turnip studied. Therefore, to maximize the chances of increasing yield character, the selection through independent traits showing positive indirect effect was effective.

Positive indirect effects were reported through the independent traits like leaf area (0.5283), ascorbic acid content (0.3711), average root yield without leaves (0.2614), plant height (0.1640), days to 50% germination (0.1077), root diameter (0.1055), root shoot ratio (0.0741), plant spread (0.0517) and number of leaves per plant (0.0007) on the dependent trait average root yield without leaves. Whereas, negative indirect effects were observed through the independent traits *viz.* leaf length (-0.5340), leaf width (-0.2253), days to first harvest (-0.0887), marketable roots (-0.0684) and TSS (-0.0012). The results obtained were in line to those found by Mallikarjunarao *et al.* (2015).

#### **4.5.12 Root diameter**

Root diameter (0.3224) showed positive direct effect on the dependent trait average root yield with leaves. Therefore increase in the dependent character average root yield with leaves could be improved through the independent trait i.e. root diameter itself.

Positive indirect effects on the dependent trait average root yield without leaves was recorded by the traits *viz.* average root yield without leaves (0.2874), ascorbic acid content (0.1696), leaf width (0.0964), days to first harvest (0.0549), plant height (0.0447) and leaf area (0.0178). Whereas negative

indirect effects were observed through the traits root shoot ratio (-0.4136), leaf length (-0.2473), duration of availability of marketable roots (-0.2465), root length (-0.0974), days to 50% germination (-0.0230), plant spread (-0.0095), TSS (-0.0011) and number of leaves per plant (-0.0002). These findings were in accordance to those obtained by Ullah *et al.*, (2010) in radish crop.

#### **4.5.13 TSS (°Brix)**

Negative direct effect (-0.0056) and negative association was observed by the character TSS with the dependent trait average root yield with leaves. Therefore to improve yield in various turnip genotypes the selection through the independent traits showing positive direct effect could be effective.

Maximum positive indirect effect for the selection of genotypes with high average root weight without leaves was recorded by the trait leaf area (1.1242) followed by plant height (0.8990), days to first harvest (0.0815), root diameter (0.0681) and plant spread (0.0027). However, negative indirect effects were observed through the traits *viz.* number of leaves per plant, leaf length (-1.4600), leaf width (-0.2811), root shoot ratio (-0.2509), days to 50% germination (-0.1147), duration of availability of marketable roots (-0.0884), average root yield without leaves (-0.0857), ascorbic acid content (-0.0850), root length (-0.0641) and number of leaves per plant (-0.0009).

#### **4.5.14 Ascorbic acid content (mg/100g)**

Ascorbic acid content (-0.6463) observed negative direct effect over the dependent trait i.e. average root yield with leaves. Therefore in-order to increase the dependent character i.e. average yield without leaves in various turnip genotypes the selection through the independent traits showing positive direct effect could be effective.

Positive indirect effect on the dependent trait average root yield without leaves was recorded through the independent traits *viz.*, leaf area (0.3182), days to first harvest (0.2846), root shoot ratio (0.2267), duration of availability of marketable roots (0.2156), root length (0.1709), plant height (0.0705) and days to 50% germination (0.0501). Whereas, negative indirect effect was exerted by the independent trait average root yield without leaves (-0.3489) followed by leaf width (-0.1778), leaf length (-0.1256), root diameter (-0.0846), plant spread (-0.0446), TSS (-0.0007) and number of leaves per plant (-0.0005).

#### **4.5.15 Average root yield without leaves (g)**

Positive direct effect was shown by the character average root yield without leaves (0.7861). Further the positive genotypic correlation was observed with the dependent trait average root yield with leaves by this character; therefore in-order to improve the dependent yield trait the selection through the trait average root yield without leaves can be effective.

Positive indirect effects were recorded through the characters *viz.*, plant height (0.3781), leaf width (0.3488), ascorbic acid content (0.2868), root diameter (0.1179), days to first harvest (0.0845), leaf length (0.0398) and TSS (0.0006) on the dependent trait. However, highest negative indirect effect was shown by the trait root length (-0.989), root shoot ratio (-0.4681), leaf area (-0.4605), duration of availability of marketable roots (-0.2082), plant spread (-0.1519), days to 50% germination (-0.1401) and number of leaves per plant (-0.0001). Similar direct and indirect effects over the dependent trait i.e. average root yield with leaves were obtained by Mapari *et al.*, (2009) in path analysis studies which was conducted in the crop radish.

**Table 4.5 Genotypic path coefficient analysis for direct and Indirect effects of component characters on yield in turnip (*Brassica rapa* L.)**

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	<b>0.5116</b>	-0.1713	-0.0579	0.0005	0.9689	0.7417	-1.4863	-0.5178	-0.1452	-0.0721	0.0626	-0.0145	0.0012	-0.0633	-0.2153	-0.457
X2	0.1343	<b>-0.6524</b>	-0.1547	0.0003	-0.2333	0.4261	-0.4408	0.5118	-0.1033	0.0128	-0.0404	-0.0271	0.0007	0.2820	-0.1018	-0.386
X3	0.0704	-0.2396	<b>-0.4214</b>	-0.0006	-0.2013	0.6184	-0.6767	0.5523	-0.6043	-0.0988	-0.0483	0.1886	-0.0011	0.3308	0.3884	-0.143
X4	0.1739	-0.1237	0.1659	<b>0.0014</b>	0.9294	-0.0252	-0.4964	-0.8902	0.4907	0.0709	-0.1446	-0.0446	0.0039	0.2160	-0.0054	0.322
X5	0.3841	0.1179	0.0657	0.0012	<b>1.2905</b>	0.4236	-1.2496	-1.1068	0.0704	-0.0473	0.1231	-0.0618	0.0063	0.0629	0.0242	0.105
X6	0.3743	-0.2742	-0.2570	-0.0004	0.5393	<b>1.0137</b>	-1.5976	0.1336	-0.2531	-0.1484	0.0661	0.0306	0.0015	0.1133	0.2705	0.013
X7	0.4422	-0.1672	-0.1658	0.0004	0.9377	0.9418	<b>-1.7197</b>	-0.3603	-0.1444	-0.1287	0.0914	-0.0033	0.0036	0.1196	0.2105	0.058
X8	0.2001	0.2523	0.1758	0.0009	1.0793	-0.1023	-0.4682	<b>-1.3235</b>	0.2788	0.0867	0.0368	-0.0108	0.0038	0.0344	-0.2245	0.020
X9	0.0697	-0.0632	-0.2390	-0.0006	-0.0853	0.2408	-0.2331	0.3464	<b>-1.0653</b>	-0.1149	0.0206	0.1252	-0.0013	0.1375	0.3454	-0.517
X10	0.1662	0.0378	-0.1876	-0.0004	0.2753	0.6779	-0.9974	0.5173	-0.5513	<b>-0.2221</b>	0.0694	0.0139	0.0001	-0.1300	0.5381	0.207
X11	0.1077	-0.0887	-0.0684	0.0007	-0.5340	-0.2253	0.5283	0.1640	0.0741	0.0517	<b>-0.2976</b>	0.1055	-0.0012	0.3711	0.2614	0.234
X12	-0.0230	0.0549	-0.2465	-0.0002	-0.2473	0.0964	0.0178	0.0447	-0.4136	-0.0095	-0.0974	<b>0.3224</b>	-0.0011	0.1696	0.2874	-0.046
X13	-0.1147	0.0815	-0.0884	-0.0009	-1.4600	-0.2811	1.1242	0.8990	-0.2509	0.0027	-0.0641	0.0681	<b>-0.0056</b>	-0.0850	-0.0857	-0.261
X14	0.0501	0.2846	0.2156	-0.0005	-0.1256	-0.1778	0.3182	0.0705	0.2267	-0.0446	0.1709	-0.0846	-0.0007	<b>-0.6463</b>	-0.3489	-0.092
X15	-0.1401	0.0845	-0.2082	-0.0001	0.0398	0.3488	-0.4605	0.3781	-0.4681	-0.1519	-0.0989	0.1179	0.0006	0.2868	<b>0.7861</b>	0.515

**Residual effect: 0.0125**

X1-Days to 50% germination

X2-Days to first harvest

X3-Duration of availability of marketable roots

X4-Number of leaves per plant

X5 Leaf length

X6 Leaf width

X7 Leaf area

X8 Plant height

X9- Root shoot ratio

X10- Plant spread

X11- Root length

X12- Root diameter

X13- TSS

X14- Ascorbic acid content

X15- Average root yield without leaves

X16- Genotypic correlation coefficient with Average root yield with leaves.

## Chapter-5

# Summary and Conclusion

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The present study entitled “Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)” was carried out during rabi season of year 2020 at the Experimental Research Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, District Hamirpur of Himachal Pradesh.

In all 12 different genotypes of turnip with one check variety (Purple Top White Globe) were included to carry the present study. The experiment was laid out using Randomized Complete Block Design (RCBD) with three replications of each genotype. The turnip genotypes were directly sown in the field on 27<sup>th</sup> October, 2020 with a spacing of 30 X 10 cm and 40 plants were accommodated in a single plot. Proper thinning operation was done to maintain the optimum plant population and the above specified planting distance. The observations were recorded on traits *viz.*, days to 50% germination, days to first harvest, duration of availability of marketable roots (days), number of leaves per plant, leaf length (cm), leaf width (cm), leaf area (cm<sup>2</sup>), plant height (cm), plant spread (cm<sup>2</sup>), average root yield without leaves (g), average root yield with leaves (g), root shoot ratio, root length (cm), root diameter (cm), root shape, root flesh color, external skin color, TSS (° B), ascorbic acid content (mg/100g) and prevalence of diseases (if any). Estimation of the parameters of variability (PCV and GCV), heritability, genetic advance was done for all the quantitative traits under study. Besides this the correlation studies and path analysis studies were conducted to know the association of the various characters and the contribution of these characters in terms of direct and indirect effects on the genotypic correlation of the character with the dependent trait average root yield with leaves.

Analysis of Variance (ANOVA) for 12 genotypes depicted that the mean sum of squares due to the genotypes were significant for all the characters indicating presence of considerable variability among the various turnip genotypes. No disease incidence was recorded in any of the 12 genotypes of turnip under natural epiphytotic conditions. Overall mean performance of all the genotypes indicated that the turnip genotype Pusa Sweti (200.66 g) recorded highest average root

**TABLE: 5.1 Top five promising genotypes for different characters studied in turnip (*Brassica rapa* L.)**

<b>Sr. No.</b>	<b>Characters</b>	<b>Genotypes</b>
1.	Days to 50% germination (days)	Pusa Sweti (4.66), Purple Top White Globe (5.00), T-COHF-NERI-5 (5.00), T-COHF-NERI-6 (5.00) and Pusa Chandrima (5.33)
2.	Days to first harvest (days)	L-1 (60.66), Pusa Sweti (61.00), T-COHF-NERI-5 (62.00), T-COHF-NERI-4 (63.00) and T-COHF-NERI-3 (63.33)
3.	Duration of availability of marketable roots (days)	T-COHF-NERI-7 (25.00), L-1 (23.66), T-COHF-NERI-1 (23.00), Pusa Chandrima (22.66) and Purple Top White Globe (22.33)
4.	Number of leaves per plant	T-COHF-NERI-3 (13.06), T-COHF-NERI-6 (10.60), Purple Top White Globe (9.72), T-COHF-NERI-4 (9.50) and T-COHF-NERI-1 (9.46)
5.	Leaf length (cm)	T-COHF-NERI-3 (37.60), T-COHF-NERI-1 (34.40), L-1 (33.93), T-COHF-NERI-7 (33.86) and Pusa Sweti (33.20)
6.	Leaf width (cm)	T-COHF-NERI-1 (13.06), T-COHF-NERI-7 (12.73), T-COHF-NERI-3 (11.93), Pusa Swarnima (11.29) and L-1 (10.84)
7.	Leaf area (cm <sup>2</sup> )	T-COHF-NERI-3 (454.30), T-COHF-NERI-1 (449.17), T-COHF-NERI-7 (429.76), L-1 (367.72) and Pusa Swarnima (353.74)
8.	Plant height (cm)	T-COHF-NERI-3 (38.80), T-COHF-NERI-4 (35.49), T-COHF-NERI-7 (34.68), Pusa Sweti (34.58) and T-COHF-NERI-6 (33.37)

**TABLE: 5.1 (Continued...) Top five promising genotypes for different characters studied in turnip (*Brassica rapa* L.)**

<b>Sr. No</b>	<b>Characters</b>	<b>Genotypes</b>
9.	Plant spread (cm <sup>2</sup> )	L-1 (1195.33), T-COHF-NERI-1 (1064.08), Pusa Swarnima (1061.14), Purple Top White Globe (928.99) and Pusa Chandrima (915.66)
10.	Average root yield without leaves (g)	L-1 (109.66), Pusa Swarnima (103.66), Purple Top White Globe (103.55), T-COHF-NERI-5 (100.44) and T-COHF-NERI-1 (97.38)
11.	Average root yield with leaves (g)	Pusa Sweti (200.66), T-COHF-NERI-5 (185.77), T-COHF-NERI-3 (177.26), Purple Top White Globe (174.88) and T-COHF-NERI-1 (162.33)
12.	Root Shoot Ratio	L-1 (2.59), Pusa Chandrima (2.31), Pusa Swarnima (2.14), T-COHF-NERI-7 (2.04) and T-COHF-NERI-6 (1.88)
13.	Root length (cm)	Purple Top White Globe (6.33), T-COHF-NERI-6 (5.87), T-COHF-NERI-3 (5.83), T-COHF-NERI-5 (5.61) and Pusa Chandrima (5.46)
14.	Root diameter (cm)	L-1 (6.08), T-COHF-NERI-5 (5.98), T-COHF-NERI-7 (5.91), T-COHF-NERI-6 (5.55) and Purple Top White Globe (5.49)
15.	TSS (°B)	Pusa Chandrima (4.10), T-COHF-NERI-2 (3.83), Purple Top White Globe (3.63), T-COHF-NERI-5 (3.63) and L-1 (3.60)
16.	Ascorbic acid content (mg/100g)	T-COHF-NERI-4 (33.20), Pusa Sweti (32.80), L-1 (30.80), T-COHF-NERI-2 (30.80) and Pusa Swarnima (28.40)

yield with leaves followed by T-COHF-NERI-5 (185.77 g) and T-COHF-NERI-3 (177.26 g) which was higher than the check variety Purple Top White Globe (174.88 g). However, Pusa Sweti was found to be statistically at par to the genotype T-COHF-NERI-5. The best genotype Pusa Sweti in terms of Average root yield with leaves was found superior for other horticultural traits *viz.*, leaf length (cm), plant height (cm) and ascorbic acid content (mg/100g).

High magnitude of Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were recorded by the traits leaf area (PCV=20.93), root shoot ratio (PCV=36.45 and GCV=33.53), plant spread (PCV=26.92 and GCV=23.98) and ascorbic acid content (GCV=20.3). It was clearly observed that phenotypic coefficient of variation was higher than the genotypic coefficient of variation and the difference among the two coefficients was quite less in magnitude. High level of heritability was exhibited by the traits *viz.*, duration of availability of marketable roots (98.36), days to first harvest (95.03) and ascorbic acid content (93.22); Whereas the highest genetic advance as *per cent* of mean was observed in the traits root shoot ratio (63.54), plant spread (44.00), ascorbic acid content (40.37), duration of availability of marketable roots (34.65) and the trait average root yield with leaves (31.55).

Correlation studies revealed that generally the genotypic correlations were higher in magnitude as compared to the phenotypic correlations indicating that apparent association is due to genetic reasons. The most important economic character i.e. average root yield with leaves showed positive and significant correlations with the traits average root yield without leaves (genotypic=0.515 and phenotypic= 0.551). Whereas, the path analysis studies suggested that the character leaf length (cm) showed maximum direct positive effect on the dependent trait average root yield with leaves followed by leaf width (cm), average root yield without leaves (g), days to first harvest (days), days to 50% germination (days), TSS ( °B) and number of leaves per plant.

## CONCLUSION

- On the basis of investigations carried out during the present study, it can be concluded that the genotype Pusa Sweti (200.66 g) was the best genotype in terms of average root yield with leaves followed by the genotypes T-COHF-NERI-5 (185.77 g), T-COHF-NERI-3 (177.26 g). These genotypes were found significantly superior to other genotypes

for the traits such as average root yield with leaves and few other traits like leaf length, plant height and ascorbic acid content and thus these superior genotypes can be recommended; after multi-location testing for direct cultivation and can be used in further breeding programmes.

- High variability coupled with high heritability and genetic advance was observed for the horticultural traits *viz.*, average root yield with leaves, leaf area, root shoot ratio, plant spread, duration of availability of marketable roots, days to first harvest and ascorbic acid content and thus making selection effective for these traits.
- Correlation studies suggested the importance of the trait average root yield without leaves as it highly affected the economic trait average root yield with leaves in the positive direction.
- Path analysis studies showed that the character leaf length exhibited the maximum direct effect on the economic yield character and hence selection through this trait can help in evolving genotypes with high average root weight with leaves.

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## APPENDIX- 1

Analysis of Variance for various horticultural traits in Turnip (*Brassica rapa* L.)

Sr. No.	Characters	Mean Sum of squares		
		Replication	Genotype	Error
		2 (Degree of freedom)	11 (Degree of freedom)	22 (Degree of freedom)
1	Days to 50% germination	0.19	1.18	0.13
2	Days to first harvest	1.03	6.93	0.12
3	Duration of availability of marketable roots	0.11	36.57	0.20
4	Number of leaves per plant	1.83	5.18	0.88
5	Leaf length	17.09	18.70	5.59
6	Leaf width	5.53	6.45	0.66
7	Leaf area	14,208.29	12,462.24	1,676.14
8	Plant height	12.34	21.21	3.95
9	Root shoot ratio	0.03	0.96	0.05
10	Plant spread	13,095.90	133,621.43	10,684.62
11	Root length	0.13	1.25	0.08
12	Root diameter	0.44	0.87	0.13
13	TSS	0.01	0.24	0.08
14	Ascorbic acid content	2.08	86.04	2.04
15	Average root yield without leaves	98.74	583.64	39.57
16	Average root yield with leaves	128.76	2,075.08	101.35

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### **ABSTRACT**

The present study entitled “Assessment of Genetic Variability and Correlation Studies in Turnip (*Brassica rapa* L.)” was conducted during rabi season of 2020 at the Experimental Research Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (HP). Twelve genotypes of turnip including check “Purple Top White Globe” were evaluated in Randomized Complete Block Design to check the extent of genetic variability, heritability, genetic advance, character association and path coefficient analysis for various horticultural traits including yield. Analysis of Variance indicated significant difference among all the genotypes of turnip for the traits studied. Best genotype in terms of average root yield with leaves was Pusa Sweti (200.66g) along with T-COHF-NERI-5 (185.77g) which was statistically at par with the best genotype. The traits *viz.* leaf area, root shoot ratio, plant spread and ascorbic acid content expressed high GCV and PCV values. High heritability was exhibited by the trait duration of availability of marketable roots followed by days to first harvest and ascorbic acid content. However high genetic advance as percentage of mean was observed for the traits root shoot ratio followed by the traits plant spread, ascorbic acid content, duration of availability of marketable roots and average root yield with leaves. The trait average root yield with leaves had positive and significant character association with the trait *viz.* average root yield without leaves both at genotypic and phenotypic level. Path analysis studies showed that positive direct effect on average root yield with leaves was observed by the characters leaf length, leaf width, average root yield without leaves, days to first harvest, days to 50% germination, TSS and number of leaves per plant.

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## BRIEF BIO-DATA

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