

**VARIABILITY AND CORRELATION
STUDIES IN RADISH (*Raphanus sativus* L.)**

MOHD. IQBAL MAKHDOOMI



DIVISION OF OLERICULTURE

THESIS

**SUBMITTED TO THE FACULTY OF POST-GRADUATE STUDIES
SHER-E-KASHMIR
UNIVERSITY OF AGRICULTURAL SCIENCES AND TECHNOLOGY
OF KASHMIR, SRINAGAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
AWARD OF THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(OLERICULTURE)**

2003

Registration No. 2001/A/620/M

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2003



**DEDICATED
TO MY
BELOVED PARENTS**

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar, Srinagar 191 121 (J&K)

CERTIFICATE-I

This is to certify that the thesis entitled “**Variability and Correlation Studies in Radish (*Raphanus sativus* L.)**” submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Olericulture)** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of *bona fide* research carried out by **Mr. Mohd. Iqbal Makhdoomi** (Registration No. 2001/A/620/M) under my supervision and guidance and that no part of the thesis has been submitted for any other degree or diploma.

It is further certified that such help and information received during the course of investigation have been duly acknowledged.

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Chairman
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ABSTRACT

The present investigation on variability and correlation studies in radish (*Raphanus sativus* L.) was carried out at the research field of Division of Olericulture, SKUAST-K, Shalimar Campus Srinagar during the year 2002 at 3 different dates viz., 22.3.2002, 24.5.2002 and 29.8.2002.

The analysis of variance revealed highly significant differences among genotypes for different characters during the different sowings.

Both phenotypic as well as genotypic coefficient of variation were high for all the characters except for days to maturity and vitamin-C content. Heritability in broad sense was high for all the characters. Genetic gain was maximum for root length followed by shoot to root ratio. Root weight was significantly and positively correlated with days to maturity, leaf number, leaf weight, root length, root diameter, total dry matter and total soluble solids while it showed negative significant correlation with top to root ratio both at phenotypic as well as genotypic levels. The root length showed maximum

direct effect on root weight followed by root diameter and leaf weight.

In general no significant differences were observed in the characters studied from the individual sowings and the pooled analysis.

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CERTIFICATE

This is to certify that all the corrections and modifications suggested by the external examiner in the thesis script of **Mr. Mohd. Iqbal Makhdoomi** (Regd. No. 2001/A/620/M), “**Variability and Correlation Studies in Radish (*Raphanus sativus* L.**” have been taken care of before final binding of the same.

Dr. Gulam-ud-Din
Chairman
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ACKNOWLEDGEMENT

"In the name of Almighty Allah, the most beneficent and merciful".

A formal presentation of mere words is scarcely indicative of my feelings of venerable gratitude and indebtedness to my major Advisor, **Dr. Gulam-ud-Din**, Assistant Professor, Division of Olericulture for his highly imaginative, inspiring and enthusiastic guidance, sound counselling, meticulous suggestions, enduring encouragement, constructive criticism and for developing in me the spirit of an independent research worker.

I am extremely grateful to **Dr. Nazeer Ahmed**, Professor & Head, Division of Olericulture, SKUAST (K) for his adroit guidance. Not only did his critical reading of the manuscript lead to the elimination of many avoidables but also helped in lending a presentable division to this work.

I place on record my thanks to **Dr. Raj Narayan**, Assistant Professor, Division of Olericulture, SKUAST (K), **Dr. Gul Zaffer**,

Associate Professor, Division of Plant Breeding and Genetics, SKUAST (K), and **Mr. A. H. Lone**, Assistant Professor, Division of Agri. Statistics and Economics SKUAST (K) and **Dr. M. Y. Zargar**, Associate Professor, Division of Environmental Sciences SKUAST (K) for their help and suggestions during the course of this study.

I thankfully acknowledge the cooperation and helping hand extended by **Mr. Shabir Hussain Khan, Dr. G. M. Lankroo, Mrs. Nayeema Jabeen** and **Mrs. Parveen Kousar**. My sincere thanks are due to all the members of teaching, research and supporting staff of Division of Olericulture, SKUAST (K).

I also extend thanks to my colleagues viz., Nayar, Zahoor, Shahid, Sandeep, Abida, Waheed, Gowher, Ishfaque and Maqbool.

I find myself hard pressed for words to reciprocate the affection, warmth, help and sincere cooperation offered to me by my parents.

I can never forget to acknowledge the cooperation give go me by my wife and the great zeal of patience exhibited by my Children **Fahmee** and **Mutahar**.

I also acknowledge sincere thanks to the Incharge Central Library and staff, SKUAST (K), for rendering all possible help while collecting the research literature.

Last but not least I thankfully acknowledge the great help extended to me by **Miss Nasima Jan**, Mokhdoomi Computers, Malik Sahib Gojwara.

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Chapter-I

INTRODUCTION

Radish (*Raphanus sativus* L.) $2n=2x=18$ belongs to family *Cruciferae*; has its origin in the mediterrian region and is believed to have originated from *Raphanus raphanistrum* a widely distributed weed in Europe. It is an important root vegetable and is widely grown in both tropical and temperate regions. It is mainly grown for its edible roots but some varieties are also grown for their green leaves and young seedpods. It is also grown as an inter crop between the rows. The crop becomes ready for harvest in 5-8 weeks. The fleshy roots of long types are eaten raw, used as salad, pickled and round types are usually cooked as vegetable. Roots and leaves are rich in vitamin A, vitamin C, minerals and Carbohydrates. Fresh roots have cooling effect, prevent constipation, increase appetite and are beneficial to patients suffering from piles, liver troubles, enlarged spleen and jaundice (Purewal, 1957).

Radish is one of the most ancient vegetables and has been under extensive cultivation in Egypt since 2000 B.C. It has spread to China about 500 B.C. and to Japan in 700 A.D. It reached to England in 1548 A.D. and America in 1629 AD. In India radish was introduced by Portuguese and /or by British. In India Radish is grown over an area of 40675 ha. with a total production of 8.05 ha. tonnes (Thumburaj and Singh, 2001).

In J&K, it is grown in 1765 ha. with a production of 28.35 thousand tonnes, out of which Kashmir region occupies 980 ha. with a production of

15.25 thousand tonnes (Anonymous, 2001).

The cultivated Radish has a small short season cool climate type salad radish and a large type radish with a wide range of temperature adaptations. Four botanical varieties are recognised within the species *Raphanus sativus* namely *Raphanus sativus ridicula*, *Raphanus sativus niger*, *Raphanus sativus olerifera* and *Raphanus sativus mougri*, out of which *Raphanus sativus ridicula* and *Raphanus sativus niger* are grown for tuberous roots while as *Raphanus sativus olerifera* is grown for oil in its seeds and *Raphanus sativus mougri* is grown for its pods (Bose *et al.*, 1999).

Under the agroclimatic conditions of Kashmir, the main season for radish is August to September with a good quality roots being available from October to January. Radish is also grown during March and April under the valley conditions. However, during summer radish of good quality is not available particularly during May to August.

Being a highly cross-pollinated crop, radish exhibits considerable variation for different traits. The availability of large amount of natural variation present in various characters among the land races/varieties of this crop reveals that there is ample scope of improvement in the economic traits of the crop both by conventional selection procedures and by heterosis breeding.

The scope of improvement through selection in any character depends on the genetic variability present in the germplasm, greater the variability in the available germplasm better would be the chances of selecting superior genotypes (Vavilov, 1951).

Further, in the total variability only the heritable genetic component is

important. Burton (1952) suggested that genetic variability along with heritability should be considered for assessing maximum and accurate effect of selection. Therefore it is necessary to partition phenotypic variation into genotypic and environmental variation. The estimates of genotypic and phenotypic coefficients of variation coupled with heritability gives an insight about the extent of heritable and non-heritable variation. The extent of transmission of quantitative characters from parent to off spring depends upon the heritability of the particular character. The heritability value alone does not have much significance as it fails to account for the magnitude of absolute variability. It is therefore necessary to utilize heritability along with genetic advance while attempting for selection.

Root yield being complex in nature, can be improved by improving its component characters such as root size, average root weight, leaf number, leaf weight etc. The knowledge of nature and degree of association among themselves and with yield is essential as they serve as an aid in selection programme.

Therefore in any improvement programme, a study of nature and magnitude of variability, heritability and association between characters becomes a pre-requisite.

To assess the extent of variability and correlation between various characters, the present study was therefore undertaken with the following objectives:

1. To study phenotypic, genotypic and environmental variation of different root and shoot characters.
2. To estimate heritability and genetic advance
3. To study correlation between different characters.

On the basis of information generated a suitable selection criteria can therefore be suggested to identify genotypes having high yielding potential coupled with reasonably improved quality.

Chapter-II

REVIEW OF LITERATURE

The success of any breeding programme depends on the presence of sufficient genetic variability to pursue effective selection. In crop improvement, the selection of plants is made on the basis of their phenotype and the effectiveness of selection would largely depend on proportion of phenotype due to genotype which is heritable. Classification of total variability into its heritable and non-heritable components such as phenotypic and genotypic coefficient of variation, heritability estimation and expected genetic advance is of paramount importance in understanding the genetic makeup of any breeding material under improvement.

Statistically the amount of variation is measured and expressed as variance. Genotypic variance is a pre-requisite for an effective breeding programme. Genetic coefficient of variation is used to measure the range of genetic variability present in a particular character. It is important to assess the relative magnitude of components of variability in order to use such information, together with other selection parameters for improvement of the plant type through adoption of effective breeding method (Johnson *et al.*, 1955a; Hanson *et al.*, 1956; Willison, 1946 Briggs and Knowles, 1967).

It is necessary to divide the total phenotypic variability into its

components, as these are basis for genetic analysis and the dimensions of these components divide the breeding behaviour of the population. Such selection parameters, particularly genetic variability (ECV) helps to choose a potential genotype, where as heritability (h^2) along with genetic advance as percentage of mean are more useful in predicting the effects from selection of best genotypes. Equally important is the information on direct and indirect (correlations and path coefficient) selection parameters as to formulate coherent breeding programme for future use.

Taking into consideration the objectives of present investigation the available literature relevant to various aspects of the study was collected from various sources and reviewed and is presented in the following page.

2.1 Components of variability

One of the important considerations in the formulation of an efficient breeding programme is the knowledge regarding the relative contribution of genes in the expression of a particular trait. If all or most of the variability among the individuals in the base population is attributable to non-heritable agencies, selection of phenotypically superior individuals from the population will not lead to desired improvement. Success of breeder in changing the characteristics of population therefore, depends upon the correspondence between the phenotypic values and the genotypic values.

The importance of variability in the germplasm was first apprehended by Vivilov (1951) for production of desirable types of plants. Johansson (1909) partitioned the genotypic and environmental variation from the total variation while working on princess variety of Beans. The work done by Nilson *et al.*

(1909) and East (1916) firmly supported the findings of Johannson.

A wide range of variability has been reported for different characters by various workers in radish. Tuzikov (1965) found reduction in coefficient of variation for root size and weight by 75-100% in radish. He further reported that the progenies of the largest roots often produced smaller roots as compared to root size of their parental lines alongwith large deviations for other characters. Nieuwhof and Kraai (1969) reported that varieties with abundant foliage were earliest to mature and were prone to premature bolting.

Yousuf and Shafi (1969) evaluated some exotic material in radish and found French Breakfast, Scarlet Globe and Sparkler to be superior in terms of appearance, earliness and root weight.

Vikova (1971) reported a high degree of variability for root yield, ascorbic acid and sugar content in triploid and tetraploid progenies of radish as compared with diploids. Muthukrishnan and Arumugam (1975) reported wide variability in root weight, leaf weight.

Kulikova (1975) reported variation in nutritional value of Chinese and European radish.

Prasad and Prasad (1977) reported a wide range of variability for different characters in radish like root length, root weight, leaf length, leaf weight and root diameter in different varieties.

Pujari *et al.* (1978) compared 12 radish cultivars and reported Pusa Himani as the highest yielder followed by Nothnagar local in winter under Sabour conditions.

Ono and Yoshida (1978) reported an increase in the coefficient of variation for fresh weight with the increase in plant density in radish.

Dowker *et al.* (1978) partitioned phenotypic variation and measured relative magnitude of genetic, macro-environmental and genotype

environmental interactions in carrot.

Bhagchandani and Chaudhary (1978) studied six inbred lines and their F1 and F2 and found considerable variability for top length, top weight, root length, root weight, root diameter and sugar content in carrot.

Similar variations were observed for different characters in turnip by Prasad and Prasad (1978).

Dixit *et al.* (1980) reported in radish that amongst seven cultivars tested, Japanese White gave the highest yield followed by Kalyanpur No. 1 and Scarlet Long. On the other hand Singh *et al.* (1980) reported highest root yield by PS-5 out of 13 cultivars tested.

Rangaswami and Shanmugavelu (1980) found more variability in radish for top weight, root yield and leaf area as evidenced by their coefficient of variation. Whereas top to root ratio showed higher genotypic coefficient of variation and was followed by top weight, root yield, number of leaves and root length.

Brar and Sukhija (1980) reported a high variance and coefficient of variation for root yield in carrot.

Natrajan and Arumugam (1981) reported that 89 per cent of total variation in yield of carrot was contributed by leaf number, top length and root weight. In radish Ponnuswami *et al.* (1982) observed highest variance for top weight, followed by top height and root weight. Similarly high genotypic and phenotypic variation for foliage, root weight and root yield was also recorded (Khan *et al.*, 1983).

Yadav, (1984) reported existence of wide variation for characters like leaf length, root length and root weight in radish. Singh and Gupta (1984) observed variation in the external and internal root colour, incidence of black

streaks pungency and forking in roots of 32 genotypes tested. Park and Kim

(1987) studied six Korean and five Japanese varieties of radish and reported that Korean varieties were harder in texture and possessed more dry matter, vitamin-C and isothiosyanates and less nitrate content than Japanese varieties.

Singh *et al.* (1987) observed highest genetic variability for leaf length and lowest for total soluble solids in a study of carrot genotypes.

A lot of variability for characters like flesh colour, total soluble solids, reducing sugars, fibre content and moisture content in radish was reported by Murralli *et al.* (1989). Similarly Ahmed and Tanki, (1992) reported highest coefficient of variation for shoot weight, followed by root weight and root yield and lowest coefficient of variation for root diameter in carrot.

Najjar *et al.* (1996) reported high variability in the ascorbic acid and isothiocyanate content of radish cultivars.

2.2 Heritability and Genetic Advance

Lush (1940) referred broad sense heritability as a ratio of genetic variance to the total variance. Estimates of heritability depend upon the amount of genetic variation existing in the population as well as the environment under which it is evaluated, therefore heritability estimates obtained from different populations grown under different environments are not directly comparable nor do individual estimates reflect it as a property of quantitative traits. This is

mainly used for estimating the proportion of phenotypic variance resulting due to genetic causes and it shows the reliability of phenotypic value as a guide to breeding values. It is also used as a parameter for predicting the genetic advance in response to selection.

Johnson *et al.*(1955a) reported that heritability and genetic advance when calculated together are more useful in predicting resultant effects of selection where as genetic advance as a percentage of mean (Genetic gain) indicates, the response of the characters to selection under different intensities.

Yukura (1960) in an experiment with turnip found low heritability for plant weight and leaf and root characteristics except for root shape, where as Hoen (1968) recorded high heritability for difference in diameter between upper and lower root halves, intermediate for percentage of dry mater and flatness of base and low for length/width ratio and fresh root weight in turnip.

High heritability for characters like 1000 seed weight number of seeds per siliqua and height of plants has been reported by Kubka *et al.* (1974), where as for seed yield and root weight, heritability was low in radish. While working on radish, Lal and Srivastava (1975) reported low heritability and high genetic advance for root thickness.

Srivastava *et al.* (1976) reported high estimates of heritability and genetic advance for root yield and root weight in sugar beet, where as high narrow sense heritability for earliness, days to bolting and flowering in radish was reported by Yun and Pyo, 1977.

Singh *et al.* (1977) observed high estimates of heritability for number of leaves with low genetic advance in a study of different radish genotypes.

Prasad and Prasad (1978) reported high heritability values for almost all the characters in radish. High heritability with high genetic advance was found for dry matter content of leaves suggesting that this character can be improved by practising phenotypic selection.

Rangaswami and Shanmugavelu (1980) found high heritability for most

of characters in both summer and winter sown crops and found that shoot weight and root length were reliable indices for plant selection in radish.

Brar and Sukhija (1980) reported a high heritability for all characters in carrot except core diameter.

Ponnuswami *et al.* (1982) observed high heritability and greater genetic advance for top weight followed by root weight. Similarly, Khan *et al.* (1983) reported high heritability for foliage weight, root length and root yield and suggested that yield improvement in radish can be brought about by selecting root length, root weight and foliage weight.

Yadav (1984) reported high heritability and high genetic advance estimates for root length, root weight and root diameter and suggested the possibility of an effective selection when leaf weight, root length and root weight are stressed upon.

Singh *et al.* (1987) reported high estimates of heritability for all characters in carrot.

Ahmed and Tanki, (1992) reported high genetic advance and genetic gain for all characters in carrot.

Nijjar *et al.* (1996) reported high heritability for the ascorbic acid content in radish.

2.3 Correlation Coefficients

The basic principle underlying the technique of correlation analysis was first of all promoted by Galton (1889) and later elaborated by Fisher (1918, 1936). The technique has since then been used in several analytical genetic studies both in plants and animals. Estimates of genotypic and phenotypic correlation among characters are useful in planning and evaluating

breeding programme (Johnson *et al.*, 1955b).

Root yield in radish is a complex polygenic character and is result of interaction between a number of factors inherent in the plant and environment in which plant grows, it becomes essential to have a clear picture

of the contribution of each of the character. As most of the traits of economic importance are complex involving several related traits, the knowledge of degrees of phenotypic and genotypic correlations of the trait is important

Yukura (1960) reported negative correlation between percentage dry matter and fresh root weight in turnip. Leshem (1961) observed a significant correlation for percentage of pink root colour change with age in crimson radish from three sources.

Bleasdale (1967) found the expression of relationship between the yield of plant per unit area and plant density.

Hoen (1968) reported negative correlation between percentage dry matter and fresh root weight in turnip. Association between abundant foliage and early maturity was reported by Nieuwhof and Kraai (1969) in radish. On the other hand Trenichova and Sharpik (1969) reported strong association between earliness and leaf number, earliness and low leaf weight, earliness and leaf number and resistance to bolting and high root leaf ratio in 42 radish cultivars.

Thumburaj (1973) found a significant correlation coefficient

between root weight and foliage weight, root weight and length of root and root weight

and girth of root in radish.

Hulenicz and Hortynski (1974) reported a significant positive correlation between plant weight and 1000 seed weight in radish.

Muthukrishnan and Arumugham (1977) observed positive correlation for root weight with root length, leaf number and foliage weight. They suggested root length as the most important yield component in radish. Similarly Singh *et al.* (1977) reported positive correlation of root yield with root diameter, skin thickness, leaf number and root to shoot ratio.

Bhagchandani and Chaudhury (1978) concluded that root weight was positively correlated with top length, top weight, root length, root diameter and core size in carrot, which was the only dependable selection trait for yield improvement in carrot.

Khan *et al.* (1983) observed significant positive association between yield in radish and foliage height, root length and root weight, foliage weight and percentage dry matter of foliage. Close association of root weight with root length and top weight was also reported (Parthasarthy and Medhi, 1983).

Sharma *et al.* (1983) observed significant positive correlation between yield and root length, days to maturity, leaf number and dry matter content and significantly negative correlation between root length and root diameter. The dry matter content, total soluble solids and Vitamin-C content appeared to be independent of each other as correlations among themselves were non-significant.

Yadav (1984) reported that correlation coefficients exhibited significant positive values between root length and root weight, diameter of root and leaf width, where as negative correlation was found between leaf weight and leaf/root ratio and root length and root diameter. He suggested that selection criteria based on root length and root weight could be more effective in maximizing the yield in radish. Singh *et al.* (1987) observed a positive correlation in yield of carrot with root weight, root length and leaf length.

Nieuwhof and Giezen (1988) reported that nitrate content was not correlated with root length or dry matter content in any cultivars of radish.

A significant and positive association of seedling root length with edible root length and yield was reported in radish by Verma and Singh (1989).

Danu and Lal (1998) reported that root weight was significantly correlated with root length, number of leaves/plant, average leaf size, leaf weight and plant weight.

Murralli *et al.*(1998) observed that root yield had a significant positive correlation with root girth and root dry weight, while number of leaves had a significant negative correlation with root girth.

2.4 Path Coefficient Analysis

The method of path coefficient was first published by Wright in 1921.

Previously known as results of various mating systems, obtained by laborious arithmetic procedures, were confirmed by more elegant method and many new results were recorded, some of which were later corroborated by the method of matrix algebra. It is a specific type of multivariate analysis- a system of dealing with a “closed” system of variables that are linearly related. In other words, the system is formally complete, enclosing all the basic factors (the “causes”) and their resultant variable (the “effects”). The practical application of this method is greatly facilitated by the formation of a casual net work showing the interrelationship of the variables concerned. Li (1956) emphasized that the employment of this method must be preceded by the formulation of a casual scheme, relations or based on a hypothesis, which the investigator chooses to accept or test. Consequently, the more we know of the true relationship among the variables, the more meaningful will be the result of path analysis. Based on the findings of Wright and Li; Dewey and Lu (1959) suggested a methodology to carryout path coefficient analysis to estimate the direct and indirect effects of the contributing traits toward the dependant trait.

Muthukrishnan and Arumugam (1977) observed that root length was the most important contributing factor of root yield in radish.

Bhagchandani and Chaudhury (1978) reported that in carrot root diameter had the highest direct effect on yield, followed by top weight and root length.

Sharma *et al.* (1983) observed that root length had highest direct effect on root yield and selection based on root length would prove rewarding.

Chapter-III

MATERIALS AND METHODS

The present investigation entitled “Variability and Correlation Studies in Radish (*Raphanus sativus* L.)” was carried out during Kharief 2002 at vegetable experimental farm, Division of Olericulture, Sher-e-Kashmir, University of Agricultural Sciences and Technology of Kashmir at three different dates viz., 22.3.2002, 24.5.2002 and 29.8.2002. The experimental site was situated at an altitude of 1650 m above sea level, at 34.1⁰ North altitude and 74.89⁰ East

longitude.

3.1 Climate conditions

The climate of the area is typically temperate. The mean temperature and rainfall during the season is given in Table-1.

3.2 Experimental material

Twenty three genotypes of radish, both tropical as well as temperate were grown for the present investigation, the detailed list of these genotypes are given in Table-2.

3.3 Experimental Details

The experiment was conducted in RBD with 3 replications. Each treatment consisted of a single row of 2m length with a row to row spacing of 30 cm and plant to plant spacing of 15 cm. Standard and uniform manurial and

Table 1 : Climatic conditions during Kharief 2002 at SKUAST-K, Shalimar

Month/Year	Temperature (Mean)		Relative Humidity (%)	Precipitation (mm)
	Max.	Min.		
4/2002	19.62	7.05	67.16	73.3
5/2002	26.45	8.99	63.01	36.7
6/2002	28.58	13.8	65.3	88.4
7/2002	30.66	15.35	70.35	16.7
8/2002	29.76	16.84	76.47	67.7
9/2002	25.11	13.27	73.43	39.6
10/2002	23.19	5.26	76.77	22.8

Table 2: List of Genotypes

S.No.	List of Genotypes	Source
1	French Breakfast	SKUAST-K
2	Selection- 9	IARI, Katrain
3	White Round	SKUAST-K
4	White Icicle	IARI, Katrain
5	SKAU-R-1	SKUAST-K
6	SKAU-R-2	SKUAST-K
7	Pusa Himani	IARI, Katrain
8	Japanese White	IARI, Katrain
9	Mino Early Long White	SKUAST-K
10		IARI, Katrain
11	Scarlet Globe	
12	SKAU-R-3	SKUAST-K
13	SKAU-R-4	SKUAST-K
14	SKAU-R-5	SKUAST-K
15	All Season	IARI, Katrain
16	Scarlet Long	SKUAST-K
17	Radish Long White	YSPUHF-Solan
18	Chinese Pink	CSAUAT-Kanpur
19	Kalyanpur No.1	SKUAST-K
20	Hill Queen	SKUAST-K
21	SKAU-R-6	SKUAST-K
22	SKAU-R-7	IARI, Katrain
23	Rapid Red White Tipped	SKUAST-K
	Early White Milano	

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cultural practices were followed for each treatment in each season. The observations were recorded from 10 randomly selected plants of each treatment on following characters and their means obtained were statistically analysed for the individual seasons as well as for the pooled data of the 3 seasons.

3.3.1 Days to maturity

From the sowing of seeds to the stage of maximum bulging, 10 root were randomly selected from each treatment and the average number of days taken for maturity were recorded.

3.3.2 Leaf number

The number of leaves were counted from each 10 randomly selected plants and mean was calculated.

3.3.3 Leaf weight (g)

The fresh weight of foliage of 10 randomly selected plants was recorded in grams and average leaf weight. per plant was calculated.

3.3.4 Root length (cm)

Root length of 10 randomly selected roots was taken after cutting the leaves at the point of maximum length by a Vernier Caliper for round types and a majoring tape for long types. Average was calculated and expressed as root length in cm.

3.3.5 Root diameter (cm)

Root diameter was measured from the same 10 roots used for measuring root length, by means of a Vernier Caliper at point of maximum diameter. Average was calculated and expressed as root diameter in cm.

3.3.6 Root weight (g)

For calculating root weight, the same 10 roots used for calculating length and diameter were properly washed to remove the soil sticking to them and weighed. The average root weight was calculated in grams.

3.3.7 Shoot to root ratio (%)

For calculating shoot to root ratio, the calculated mean values for root weight and leaf weight were used. The ratio was derived by dividing leaf weight by root weight.

3.3.8 Total dry matter (%)

The composite sample was drawn from each line and 100g sample was weighed. The sample was cut into smaller pieces and kept in oven at $60\pm 2^{\circ}\text{C}$ till dry weight of sample remains constant. It was expressed in %age.

3.3.9 Vitamin C (mg/100g)

The vitamin C content of radish was calculated by 2.6-

Dichlorophenol indophenol visual titration method of A. O. A. C. (1975).

The method in brief is as follows:

- a) Reagents: **3% metaphosphoric acid (HPO_3)-30 g of HPO_3 was dissolved in glass distilled water and volume made to 1 litre.**
- b) Ascorbic acid standard: **100g of 1-ascorbic acid was dissolved in 3% HPO_3 and volume made upto 100 ml. 10 ml from this solution was further diluted to 100 ml with 3% HPO_3 .**
- c) Dye solution: **50 g of sodium salt of 2, 6 dichlorophenol indophenol were dissolved in 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. It was cooled and diluted with glass distilled water to 20 ml and filtered. This dye solution was stored in refrigerator and standardized every day.**

Procedure

Standardization of dye: **5 ml of 3% HPO_3 were added to 5 ml of standard ascorbic acid and titrated with dye solution to pink colour which persisted for 15 seconds. The dye factor i.e. mg**

of ascorbic acid per ml of dye was determined using the formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titrate Preparation of sample}}$$

10 ml of juice extracted from 100 g of root was taken and filtered through a filter paper. The filtrate was dissolved in 3% HPO₃ to make volume to 100 ml.

Determination of Ascorbic acid

An aliquot sample of 5 ml of HPO₃ extract of sample was titrated with the standard dye to a pink end point. The titration was repeated three times and

volume of dye used was calculated.

Calculations

The ascorbic acid (Vitamin-C) content of sample was calculated by using the formula:

$$\text{Vitamin-C Content} = \frac{\text{Titrate} \times \text{dye factor} \times \text{volumemadeup} \times 100}{\text{Aliquot of extract taken for titration} \times \text{volume of sample taken for extraction}}$$

Where volume of sample taken for estimation = 20 ml

Volume made up = 100ml

Aliquot of extract taken for estimation = 5 ml

3.3.10 Total Soluble Solids (°Brix)

Total soluble solids content was determined by using ERMS hand refractometer. 2-3 drops of juice obtained by crushing a sample of root were placed on the prism of refractometer and directly recording the total soluble solid content on scale. 3 observations from each treatment were recorded and average calculated. The total soluble solids content was expressed in °Brix.

3.4 Statistical Analysis

The data obtained from different parameters was statistically analysed for the assessment of genetic variability, genetic gain and correlation coefficients.

3.4.1 Single environment data

This analysis was based on the following mathematical model given by Verma *et al.*, 1987.

$$Y_{ik} = \mu + g_i + r_k + (g)_{ik} + e_{ik}$$

Where,

Y_{ik} = Observation of i^{th} genotype ($g = 1$ to I) in k^{th} replication
($r = 1$ to k),

μ = general mean,

g_i = effect of the i^{th} genotype

r_k = effect of the k^{th} replication, and

e_{ik} = random error associated with ik^{th} observation.

3.4.1.1 Expectations of mean square

Based on the model given above the expectations of various mean squares were derived as follows :

Source of variation	d.f.	M. S.	Expected mean squares
Replication	(r-1)	MSR	$\sigma_e^2 + g\sigma_r^2$
Genotypes	(g-1)	MSG	$\sigma_e^2 + r\sigma_g^2$
Error	(g-1)(r-1)	ME	σ_e^2

3.4.2 Pooled over environments

The analysis was based on the following mathematical model given by Verma *et al.*, 1987

$$Y_{ijk} = \mu + g_i + E_j + r_{jk} + (G \times E)_{ij} + e_{ijk}$$

Where,

Y_{ijk} = Mean of i^{th} genotype in k^{th} replicate of j^{th} environment,

μ = Overall mean

g_i = Contribution of i^{th} genotype

E_j = Contribution of j^{th} environment

r_{jk} = Contribution of replicate k in environment j

$(G \times E)_{ij}$ = Interaction between i^{th} genotype and j^{th} environment,

e_{ijk} = residual variation of genotype i in replicate k of environment j.

Expectations of mean square

Based on the model given above the expectations of various mean square were derived as follows:

Source of variation	d.f.	M. S.	Expected mean squares
Environments	(n-1)	MSE	$\sigma_e^2 + rg\sigma_{ng}^2 + rg\sigma_e^2$
Replication	n(r-1)	MSRE	$\sigma_e^2 + g\sigma_{nr}^2$
Genotypes	(g-1)	MSG	$\sigma_e^2 + r\sigma_{ng}^2 + rn\sigma_g^2$
Genotypes ×			
Environments	(g-1)(n-1)	MSGE	$\sigma_e^2 + r\sigma_{ng}^2$
Error	n(g-1)(r-1)	ME	σ_e^2

3.4.3 Genotypic variance

Genotypic variance was calculated using the method suggested by Johnson *et al.* (1955) for the single environment and Al-Jibouri *et al.* (1958) for the data pooled over the environments.

3.4.3.1 Estimation of genotypic variance in single environment

$$\sigma_g^2 = \frac{MSG - ME}{r}$$

Where

$$\sigma_g^2 = \text{genotypic variance}$$

MSG = mean sum of squares for the genotypes, and

ME = error mean sum of square.

3.4.3.2 Estimation of genotypic variance from the data pooled over environments

$$\sigma_g^2 = \frac{MSG - ME}{rn}$$

Where

σ_g^2 = genotypic variance among the genotypes,

MSG = mean sum of squares for the genotypes,

MSGE = mean sum of squares for G x E interactions,

r = number of replications, and

n = number of environments.

3.4.4 Phenotypic variance

Phenotypic variance was also calculated by the formula advised by Johnson *et al.* (1955a) for the single environment and Al-Jibouri *et al.* (1958) for the data pooled over environments.

3.4.4.1 Estimation of phenotypic variance in single environment

$$\sigma_p^2 = \sigma_g^2 + \frac{\sigma_e^2}{r}$$

where,

σ_p^2 = phenotypic variance,

σ_g^2 = genotypic variance among the genotypes,

σ_e^2 = error variance , and

r = number of replications

3.4.4.2 Estimation of phenotypic variance in data pooled over environments

$$\sigma_p^2 = \sigma_g^2 + \frac{\sigma_{ge}^2}{n} + \frac{\sigma_e^2}{nr}$$

where,

σ_p^2 = phenotypic variance,

σ_g^2 = genotypic variance among the genotypes,

σ_{gn}^2 = genotypic x environment variance

σ_e^2 = error variance , and

n = number of environments

r = number of replications.

3.4.5 Coefficient of variation

3.4.5.1 Genotypic coefficient of variation

The magnitude of genotypic variation existing in a character was worked out by the formulae given by Burton and De Vane (1953):

$$G.C.V. = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

Where

G.C.V. = Genotypic coefficient of variance

V_g = Genotypic variance,

\bar{X} = Mean of character under study.

3.4.5.2 Phenotypic coefficient of variation

It was worked out by the formulae given by Burton and De Vane (1953):

$$P.C.V. = \frac{\sqrt{V_{ph}}}{\bar{X}} \times 100$$

Where

P.C.V. = **Phenotypic coefficient of variance**

V_{ph} = Phenotypic variance,

\bar{X} = Mean of character under study.

3.4.6 Heritability

Heritability in broad sense was estimated by using following formula proposed by Burton and De vane (1953), Johnson *et al.* (1955) and Hanson *et al.* (1956).

$$\text{Heritability in percent (bs)} \quad H_{(b/s)} = \frac{V_g}{V_{ph}} \times 100$$

Where

H_(b/s) = Heritability in broad sense

V_g = Genotypic variance

V_{ph} = Phenotypic variance

3.4.7 Genetic Advance

It refers to the shift in a population towards superiority under some specific selection pressure. It was computed using following formula given by Lush (1940) and Johnson *et al.* (1955a) at 5 per cent selection pressure taking value of K as 2.06 as proposed by Allard (1960).

$$\text{Genetic Advance} = \frac{V_g}{V_{ph}} \times K \times \sqrt{V_{ph}} = h^2 K \sqrt{V_{ph}}$$

Where

G. A. = Genetic advance

V_g = Genotypic variance

V_{ph} = Phenotypic variance

K = Selection differential

3.4.8 Genetic gain

It is the percentage of genetic advance based on the mean of a

particular character under study. It was calculated by the method suggested by Johnson *et al.* (1955a)

$$\text{Genetic gain} = \frac{G.A.}{\bar{X}} \times 100$$

Where

G. A. = Genetic advance

\bar{X} = Mean of character under study.

3.4.9 Correlation coefficients

Correlation coefficient between yield and other characters and among the characters were calculated by using the formula given by Al-Jibouri *et al.* (1958).

3.4.9.1 Genotypic correlation coefficients:

$$r_{xy(g)} = \frac{Cov_{xy(g)}}{\sqrt{V_{x(g)} \times V_{y(g)}}}$$

3.4.9.2 Phenotypic correlation coefficient

$$r_{xy(p)} = \frac{Cov_{xy(ph)}}{\sqrt{V_{x(ph)} \times V_{y(ph)}}}$$

Where,

$r_{xy(g)}$ = Genotypic correlation coefficient between a pair of characters viz. X and Y,

$r_{xy(ph)}$ = Phenotypic correlation coefficient between a pair of characters viz. X and Y,

$Cov_{xy(g)}$ = Genotypic covariance for a pair of characters viz. X and Y,

$Cov_{xy(ph)}$ = Genotypic covariance for a pair of characters viz. X and Y,

$V_{x(g)}$ = **Genotypic variance for character X,**

$V_{y(ph)}$ = **Phenotypic variance for character Y,**

$V_{x(ph)}$ = **Phenotypic variance for character X, and**

$V_{y(g)}$ = **Genotypic variance for character Y.**

3.4.9.3 Test of Significance

't' test was applied to test the significance of correlation by the following formula:

$$t = r \sqrt{\frac{n-2}{1-r^2}}$$

Where ,

n = Number of genotypes, and

r = Correlation coefficient.

Calculated (t) value was compared to the table values of t at (n-2) degree of freedom.

3.4.10 Path co-efficient analysis

Path analysis is simply a standardized partial regression analysis and as

such measures the direct influence of one variable upon the other and permits the separation of correlation coefficients into components of direct and indirect effects. In the present study the path coefficient analysis was carried out at the genotypic level only and accordingly the genotypic correlation coefficient among different character combinations were used for path coefficient analysis.

The methodology suggested by Wright (1921) and Li (1956) was adopted using formula given by Dewey and Lu (1959).

Path diagram representing cause and effect relationship among various traits studied was constructed. The analysis was carried out by the simultaneous solution of the following equations.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + r_{14}P_{4y} + \dots + r_{1n}P_{ny}$$

$$r_{2y} = P_{2y} + r_{23}P_{3y} + r_{24}P_{4y} + \dots + r_{2n}P_{ny}$$

$$r_{3y} = P_{3y} + r_{34}P_{4y} + \dots + r_{3n}P_{ny}$$

$$r_{4y} = P_{4y} + \dots + r_{4n}P_{ny}$$

$$r_{ny} = P_{ny} + r_{n1}P_{1y} + r_{n2}P_{2y} + r_{n3}P_{3y} + r_{n4}P_{4y} + \dots + r_{n(n-1)}P_{(n-1)y}$$

Where $P_{1y}, P_{2y}, \dots, P_{ny}$ = Direct effects of independent variables (1,2,3,...n) on dependent variable y.

$r_{12}, r_{13}, r_{14}, \dots, r_{1n}, \dots, r_{(n-1)n}$ = Correlation coefficients between independent variables

$r_{1y}, r_{2y}, r_{3y}, \dots, r_{ny}$ = Correlation coefficients between dependent

variables and various independent variables and

$r_{1n}P_{ny}$ = The indirect effect of variables (x_1) upon dependent variable y via variable (x_n).

The simultaneous equations given above are presented in matrix notation as;

$$\begin{bmatrix} r_{1y} \\ r_{2y} \\ \text{''} \\ \text{''} \\ \text{''} \\ r_{ny} \end{bmatrix} = \begin{bmatrix} 1 & r_{12} & r_{13} & \dots & r_{1n} \\ r_{21} & 1 & r_{23} & \dots & r_{2n} \\ \text{''} & \text{''} & \text{''} & \dots & \text{''} \\ \text{''} & \text{''} & \text{''} & \dots & \text{''} \\ \text{''} & \text{''} & \text{''} & \dots & \text{''} \\ r_{n1} & r_{n2} & r_{n3} & \dots & 1 \end{bmatrix} \times \begin{bmatrix} P_{1y} \\ P_{2y} \\ \text{''} \\ \text{''} \\ \text{''} \\ P_{ny} \end{bmatrix}$$

Using the values of direct effects and correlation coefficients, the residual effect was calculated using following formula.

$$\begin{aligned} P_{xy}^2 = & 1 - (P_{1y}^2 + 2P_{1y}P_{2y}r_{12} + 2P_{1y}P_{3y}r_{13} + 2P_{1y}P_{4y}r_{14} + \dots \\ & + (P_{2y}^2 + 2P_{2y}P_{3y}r_{23} + 2P_{2y}P_{5y}r_{25} + 2P_{2y}P_{5y}r_{25} + \dots + P_{23y} + \\ & 2P_{3y}P_{4y} + 2P_{3y}P_{5y}r_{35} + 2P_{3y}P_{6y}r_{36} + \dots + P_{2ny} \end{aligned}$$

$$\text{Residual effect } R = \sqrt{P_{xy}^2}$$

Chapter –IV

EXPERIMENTAL RESULTS

The present investigation entitled variability and correlation studies in radish (*Raphanus sativus* L.) was undertaken to generate information on the components of phenotypic variability with heritability and expected genetic gain for the important morphological yield and quality traits viz., days to maturity, leaf number, leaf weight, root length, root diameter, root weight, shoot to root ratio, total dry matter, vitamin-C and total soluble solids. Besides the nature of interrelationship existing among the economic traits together with contribution of different morphological and yield component traits towards root yield, through the study of cause and effect relation was also determined. The experimental findings are described in respect of following aspects:

Analysis of variance to estimate components of phenotypic variability.

Characterization of nature of direct selection parameters like heritability (broad sense) and estimation of genetic gain.

Estimation of the nature and magnitude of interrelationship among various traits and their characterization as index of indirect selection parameters.

Direct and indirect contribution of important yield component traits to root yield .

4.1 Analysis of variance and mean performance

Twenty-three genotypes of radish were evaluated in RBD with three replications at three different environments. The mean data collected for each character was subjected to analysis of variance at each environment and the

result of analysis of variance of various characters in individual environments and for pooled data of all environments is given in Annexure-I.

The analysis of variance revealed significant differences among the genotypes for all the characters under study at individual environments and for pooled data, indicating the presence of good amount of variability in the material. The performance of different genotypes in the different environments and in the pooled analysis with respect to different characters is revealed in Table-3.

4.1.1 Days to maturity

The genotypes showed considerable variability for days to maturity. During E1 sowing French Breakfast was early to mature (31.73), during E2 Rapid Red White Tipped was early to mature (32.33) and during E3 Scarlet Globe was early to mature (32.43) while as Kalyanpur No. 1 took maximum number of days for maturity in E1, E2 and E3 sowings (49.43), (42.16) and (47.53). Pooled data analysis showed Rapid Red White Tipped the early maturing variety (30.83) while as Kalyanpur No. 1 was the late maturing (48.54).

Table 3: Mean Performance of Various Characters in Radish

Genotype/Trait	Days to maturity				Leaf number				Leaf weight (g)			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled

French Breakfast	31.73	31.20	35.86	32.93	9.36	10.46	9.63	8.63	63.37	68.48	75.46	69.11
Selection- 9	35.26	32.26	37.86	35.13	9.53	10.33	12.43	9.66	53.33	47.89	49.46	50.22
White Round	41.46	41.06	45.50	42.68	10.13	11.06	9.53	10.24	54.57	61.70	48.79	55.03
White Icicle	42.40	35.73	44.36	40.83	6.46	9.46	6.96	7.63	63.71	71.72	61.12	65.52
SKAU-R-1	41.13	36.80	42.63	40.19	8.46	11.46	8.33	9.42	68.30	74.32	60.78	67.80
SKAU-R-2	40.80	35.66	42.40	39.62	9.33	8.43	9.43	9.07	32.98	47.84	58.60	56.48
Pusa Himani	45.6	40.70	43.43	43.27	10.40	11.46	10.66	10.84	63.14	73.25	72.75	69.72
Japanese White	45.06	43.86	44.53	44.16	11.66	13.40	14.43	13.17	89.78	100.34	99.25	96.46
Mino Early Long White	44.40	40.66	45.43	43.50	12.83	18.53	13.53	14.97	90.53	94.16	85.44	90.05
	35.53	28.76	32.43	32.24	4.53	9.43	8.56	8.51	66.70	72.40	68.23	69.11
Scarlet Globe	44.86	40.96	47.70	44.51	16.70	19.70	18.50	18.30	58.126	65.60	60.64	61.46
	40.53	37.26	42.43	40.08	12.60	16.00	14.56	14.69	9.12	77.59	75.67	74.13
SKAU-R-3	44.93	40.80	45.54	43.76	14.26	17.20	17.03	16.17	89.09	100.18	113.23	97.52
	45.73	40.60	48.30	44.88	11.20	14.20	14.53	13.31	79.89	92.64	85.83	82.79
SKAU-R-4	35.26	30.66	33.56	33.17	11.73	12.20	8.96	10.97	54.21	63.56	65.62	61.13
	38.86	33.40	35.73	36.00	14.60	12.83	13.20	13.54	72.94	89.30	92.97	85.07
SKAU-R-5	45.06	43.16	47.53	44.92	11.00	13.20	14.53	12.86	70.23	75.89	82.26	76.13
All Season	49.43	45.30	50.90	48.54	9.60	14.46	12.30	11.93	55.58	66.15	58.25	60.00
Scarlet Long	46.06	42.20	46.86	45.04	14.66	19.50	17.53	17.08	106.61	115.58	102.97	108.31
Radish Long White	43.46	40.96	44.50	42.98	11.86	12.76	13.56	12.56	74.45	76.31	83.88	78.33
Chinese Pink	44.60	40.56	45.73	43.63	11.13	11.73	11.56	11.31	64.79	68.14	66.09	66.35
Kalyanpur No.1	32.33	27.50	32.66	30.83	13.20	15.91	13.90	14.17	23.09	24.50	24.50	24.03
Hill Queen	38.40	33.66	37.66	36.58	15.93	16.89	14.96	15.80	84.18	89.15	82.45	85.25
SKAU-R-6												
SKAU-R-7	0.730	0.731	0.715	0.3234	1.240	1.060	1.363	1.294	3.187	3.871	3.697	3.271
Rapid Red White Tipped												
Early White Milano												
<i>C.D. 5%</i>												

Conti.....

Genotype/Trait	Root length (cm)				Root Diameter (cm)				Root weight (g)			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled

French Breakfast	5.70	6.33	6.00	6.01	3.40	4.40	3.80	3.87	86.70	87.81	77.56	84.03
Selection- 9	25.51	22.70	24.96	24.39	3.56	3.36	3.16	3.37	118.14	118.09	105.34	113.87
White Round	6.76	6.73	6.13	6.54	4.43	4.00	4.70	4.41	138.06	145.42	142.12	141.87
White Icicle	20.46	21.65	20.33	20.82	2.50	2.43	2.40	2.44	40.98	46.55	44.09	43.82
SKAU-R-1	14.50	15.00	16.00	15.17	3.00	2.83	3.06	2.97	130.43	132.32	124.66	129.14
SKAU-R-2	4.90	6.03	6.66	5.87	4.06	4.33	4.36	4.26	86.86	100.89	96.96	94.84
Pusa Himani	22.16	22.66	21.16	22.00	2.40	2.50	2.16	2.36	100.58	107.22	103.76	103.86
Japanese White	22.62	25.33	25.16	24.37	2.43	3.30	2.70	2.81	101.62	107.05	111.50	106.73
Mino Early Long White	23.66	24.00	23.16	23.61	2.90	3.00	3.16	3.02	116.76	108.81	117.00	114.19
	4.80	4.82	4.86	4.82	3.90	3.73	3.43	3.69	48.93	50.76	46.41	48.78
Scarlet Globe	18.39	18.83	20.00	19.08	2.20	3.03	3.00	2.74	101.21	110.84	104.25	105.49
SKAU-R-3	18.16	18.00	16.00	17.39	2.66	2.30	2.13	2.37	55.57	50.58	54.25	53.30
	24.01	24.76	27.33	26.04	2.50	2.73	2.70	2.64	102.01	104.66	102.76	103.15
SKAU-R-4	21.40	21.83	22.33	21.86	2.80	2.66	2.40	2.62	98.23	87.41	103.12	99.59
	21.17	21.53	20.66	21.11	3.63	3.60	2.80	3.34	46.71	52.83	52.10	50.54
SKAU-R-5	21.80	23.16	23.16	22.71	2.46	2.76	2.60	2.61	57.06	67.82	62.79	62.56
All Season	14.26	16.83	18.66	16.42	3.31	3.66	2.93	3.30	113.28	125.60	123.18	120.63
Scarlet Long	14.07	19.50	7.33	16.97	2.50	3.20	2.66	2.79	108.69	108.03	118.14	116.62
Radish Long White	19.39	20.50	8.662	19.52	2.45	2.66	2.31	2.48	83.54	85.92	92.24	87.23
Chinese Pink	19.27	22.16	3.66	21.70	2.45	2.75	2.61	2.61	96.18	105.83	103.15	101.72
Kalyanpur No.1	7.66	7.80	6.96	7.48	4.30	4.30	4.16	4.26	107.92	103.20	110.71	107.28
Hill Queen	5.40	5.20	4.63	5.08	4.13	3.70	3.20	3.68	47.04	49.90	50.91	49.29
SKAU-R-6	22.33	26.83	23.33	24.17	2.60	2.56	2.16	2.44	67.78	66.04	73.09	68.47
SKAU-R-7												
Rapid Red White Tipped	1.002	1.378	1.352	1.079	0.181	0.188	0.202	0.163	3.347	2.244	3.366	2.603
Early White Milano												
<i>C.D. 5%</i>												

Conti.....

<i>Genotype/Trait</i>	Shoot to root ratio								Total dry matter (%)			
	E1	Arc E1	E2	Arc E2	E3	Arc E3	Pooled	Arc pooled	E1	E2	E3	Pooled

French Breakfast	0.73	4.901	0.88	5.382	0.85	5.289	0.82	5.195	5.86	6.86	6.92	6.55
Selection- 9	0.45	3.846	0.44	3.803	0.41	3.671	0.44	3.803	4.18	4.69	4.66	4.51
White Round	0.39	3.580	0.43	3.759	0.66	4.659	0.39	3.580	6.15	6.56	6.61	6.44
White Icicle	1.55	7.151	1.62	7.312	1.31	6.572	1.49	7.011	4.26	4.40	4.56	4.41
SKAU-R-1	0.52	4.135	0.59	4.405	0.46	3.888	0.53	4.174	5.26	4.56	5.36	5.07
SKAU-R-2	0.72	4.867	0.49	4.014	0.58	4.367	0.60	4.442	5.26	5.50	5.66	5.48
Pusa Himani	0.62	4.516	0.70	4.799	0.67	4.695	0.67	4.695	5.03	5.81	6.20	5.68
Japanese White	0.88	5.362	0.90	5.443	0.93	5.534	0.91	5.474	6.46	6.96	6.73	6.72
Mino Early Long White	0.77	5.034	0.80	5.131	0.78	5.066	0.79	5.099	4.86	5.33	5.20	5.13
	1.36	6.697	1.56	7.175	1.34	6.647	1.42	6.843	5.33	5.93	5.83	5.70
Scarlet Globe	0.57	4.329	0.63	4.552	0.54	4.291	0.58	4.367	4.33	5.63	6.16	5.38
SKAU-R-3	1.24	6.393	1.42	6.843	1.51	7.058	1.39	6.770	4.56	4.60	4.90	4.69
	0.77	5.034	0.97	5.652	1.07	5.937	0.93	5.534	6.16	6.83	6.93	6.64
SKAU-R-4	0.81	5.163	0.89	5.413	0.88	5.382	0.86	5.321	4.56	5.10	5.06	4.91
	1.16	6.182	1.22	6.341	1.24	6.393	1.21	6.315	4.93	5.20	4.96	5.03
SKAU-R-5	1.36	6.697	1.41	6.819	1.37	6.721	1.35	6.672	4.23	5.26	6.06	5.19
All Sason	0.62	4.516	0.61	4.479	0.65	4.624	0.63	4.552	5.50	6.00	6.08	5.86
Scarlet Long	0.52	4.135	0.56	4.291	0.53	4.174	0.54	4.214	5.06	5.48	5.03	5.19
Radish Long White	1.27	6.470	1.25	6.419	1.22	6.341	1.25	6.419	5.40	5.70	5.53	5.54
Chinese Pink	0.77	5.034	0.73	4.901	0.79	5.099	0.76	5.001	5.93	6.43	6.56	6.31
Kalyanpur No.1	0.60	4.442	0.61	4.479	0.63	4.552	0.63	4.552	5.46	6.06	5.70	5.74
Hill Queen	0.48	3.972	0.47	3.931	0.49	4.014	0.48	3.972	3.56	4.56	3.96	4.03
SKAU-R-6	1.24	6.393	1.21	6.315	1.25	6.419	1.23	6.367	5.73	5.43	5.00	5.39
SKAU-R-7												
Rapid Red White Tipped	0.037		0.190		0.038		0.098		0.260	0.288	0.274	0.236
Early White Milano												
<i>C.D. 5%</i>												

Conti.....

Genotype/Trait	Vitamin -C (mg/100 g)				Total Soluble Solid (⁰ Brix)				Root yield qts./ha.			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled	E1	E2	E3	Pooled

French Breakfast	22.14	23.22	21.36	22.24	2.92	2.93	2.94	2.93	192.67	172.36	195.14	186.72
Selection- 9	18.39	20.53	21.06	20.00	3.13	3.93	3.66	3.51	262.64	234.08	262.42	253.04
White Round	17.29	17.41	16.74	17.15	3.40	3.90	3.80	3.70	306.78	315.83	323.78	315.46
White Icicle	19.63	20.33	20.33	20.10	3.16	3.10	4.00	3.42	91.07	97.98	103.44	97.49
SKAU-R-1	18.53	20.39	18.12	19.02	2.70	2.63	2.76	2.70	289.84	276.71	294.04	264.42
SKAU-R-2	20.76	22.74	20.89	21.47	2.90	2.96	3.06	2.98	193.01	215.46	226.72	211.73
Pusa Himani	19.58	23.86	20.33	21.26	3.20	4.83	4.83	4.29	223.52	230.59	240.27	231.46
Japanese White	20.06	22.40	20.28	20.93	4.76	4.86	5.13	4.92	225.83	247.79	237.88	237.16
Mino Early Long White	14.24	17.73	15.70	15.89	4.96	4.83	5.03	4.94	259.46	259.99	241.80	253.75
	23.18	24.89	20.23	22.72	2.83	3.16	3.36	3.12	108.73	103.14	112.84	108.23
Scarlet Globe	20.35	23.06	20.35	21.26	3.96	4.86	4.86	4.57	224.91	231.45	246.32	234.22
SKAU-R-3	22.57	24.25	22.33	23.05	4.50	5.00	5.00	4.83	123.64	120.56	111.29	118.49
	29.84	30.53	28.55	29.64	5.16	6.00	5.96	5.71	220.11	228.68	232.57	227.12
SKAU-R-4	18.13	19.46	16.92	18.17	4.50	5.63	4.10	4.74	218.29	229.18	216.46	221.31
	22.26	24.45	21.77	22.83	3.96	2.66	3.26	3.30	103.80	115.77	117.37	112.31
SKAU-R-5	16.80	18.92	16.96	17.56	4.90	5.83	6.03	5.59	126.81	139.53	150.72	139.03
All Season	25.73	27.98	24.79	26.17	4.66	4.93	5.00	4.87	256.18	273.74	278.29	269.40
Scarlet Long	21.58	27.98	24.43	24.67	3.43	4.36	3.53	3.78	234.87	262.40	240.07	245.78
Radish Long White	17.06	19.02	17.40	17.83	5.06	5.00	4.56	4.88	185.68	204.97	190.92	193.85
Chinese Pink	14.40	17.33	15.41	15.72	3.96	4.03	3.83	3.94	213.74	229.15	235.15	226.01
Kalyanpur No.1	14.90	16.90	15.32	15.71	3.96	4.06	3.53	3.86	239.83	246.02	229.32	238.39
Hill Queen	14.40	17.33	16.19	15.98	3.96	3.96	3.40	3.77	104.52	113.14	110.87	109.51
SKAU-R-6	17.77	19.10	18.32	18.40	5.63	5.26	4.80	5.23	150.61	162.43	146.76	153.26
SKAU-R-7												
Rapid Red White Tipped	0.916	1.245	0.935	0.895	0.217	0.2575	0.270	0.214	6.79	10.81	10.73	9.45
Early White Milano												
<i>C.D. 5%</i>												

Table-4: Best Five Cultivars/Genotypes in respect of Earliness Yield and Yield attributing Characters of Radish (*Raphanus sativus* L)

S.No.	Character	Best five genotypes on the basis of mean
1.	Earliness	1. Rapid Red White Tipped 2. Scarlet Globe 2. French Breakfast 4. Scarlet Long 5. Selection-9
2.	Leaf number	1. SKAU-R-3 2. Hill Queen 3. SKAU-R-5 4. Early White Milano 5. Mino Early Long White
3.	Leaf weight	1. Hill Queen 2. SKAU-R-5 3. Japanese White 4. Mino Early Long White 5. Early White Milano
4.	Root length	1. Mooly early 2. Selection-9 3. Japanese White 3. Early White Milano 5. Mino Early Long White
5.	Root diameter	1. White Round 2. SKAU-R-7 3. SKAU-R-2 4. French Breakfast 5. Scarlet Globe
6.	Root weight	1. White Round 2. SKAU-R-1 3. Chinese Pink 4. Kalyanpur No.1 5. Mino Early Long White
7.	Total dry matter	1. Japanese white 2. SKAU-R-5 3. French Breakfast 4. White Round 5. SKAU-R-6
8.	T. S. S.	1. All Season 2. Chinese pink 3. Early White Milano 4. Mino Early Long White 5. Japanese White
9.	Root yield	1. White Round 2. SKAU-R-1 3. Chinese Pink 4. Kalyanpur No.1 5. Mino Early Long White

4.1.2 Leaf number

The genotypes differed in leaf number during different sowings. During E1 Scarlet Globe was with less number of leaves (4.53) while as SKAU-R-3 showed maximum number of leaves (16.70). During E2 SKAU-R-2 showed minimum leaf number (8.43) while as Hill Queen showed maximum leaf number (19.50). During E3 White Icicle had minimum leaf number (6.96) SKAU-R-3 had maximum leaf number (18.50). The pooled data analysis showed White Icicle with less number of leaves (7.63) and SKAU-R-3 had maximum leaf number (18.30).

4.1.3 Leaf weight

The minimum leaf weight in E1, E2 and E3 sowings was shown by Rapid Red White Tipped (23.09), (24.50) and (24.50). The maximum leaf weight was shown by Hill Queen during E1, E2 (106.61) (115.58) while as during E3 the maximum leaf weight was shown by SKAU-R-5 (113.23). The pooled data analysis showed minimum leaf weight by Rapid Red White Tipped (24.03) and maximum leaf weight by Hill Queen (108.31).

4.1.4 Root length

Considerable variability was observed for root length among

the long types of radish as well as round type. Among the round type Scarlet Globe showed minimum root length during all the individual sowings as well as pooled data analysis (4.80), (4.82), (4.80) and (4.82) while as maximum root length was shown by SKAU-R-7 during E1, E2 and E3 and pooled data (7.66), (7.80), (6.96) and (7.48). Among the long types of radish the Kalyanpur No. 1 showed minimum root length during E1 sowing (14.07) and Selection-9 showed maximum root length (25.51). During E2 SKAU-R-1 showed minimum root length (15.00) and Early White Milano showed maximum root length (26.83). During E3 sowing SKAU-R-1 showed minimum root length (16.00) and SKAU-R-5 showed maximum root length (27.33). The pooled data analysis showed SKAU-R-1 with minimum root length (15.17) and SKAU-R-5 with maximum root length (26.04).

4.1.5 Root diameter

During E1 sowing the maximum root diameter was exhibited SKAU-R-3 (2.20) while as maximum root diameter was shown by White Round (4.43). During E2 sowing minimum root diameter was observed in SKAU-R-4 (2.30) and maximum was observed in French Breakfast (4.40). During E3 sowings minimum root diameter was found SKAU-R- 4 (2.13) and maximum in White Round (4.7). In pooled data analysis the minimum root diameter was observed

in Pusa Himani (2.36) and maximum root diameter in White Round (4.41).

4.1.6 Root weight

Wide variations occur among the genotypes for root weight both in individual as well as in pooled data analysis. Minimum root weight in the individual as well as pooled data analysis was shown by White Icicle (40.98, 46.55, 44.09 and 43.82). Maximum root weight in individual as well as pooled data analysis was found in White Round (138.06, 145.42, 142.12 and 141.87).

4.1.7 Shoot to root ratio

Lowest shoot to root ratio was observed in White Round for individual as well as pooled analysis (0.39, 0.43, 0.34 and 0.39). The highest shoot to root ratio during E1 and E2 was found in while Icicle (1.55) and (1.62) during E3 in SKAU-R- 4 (1.51) and for pooled data analysis in White Icicle (1.49).

4.1.8 Total dry matter

During E1 minimum dry matter was reported in Rapid Red White Tipped (3.56) and maximum in Japanese White (6.46). In E2 minimum value was observed for White Icicle (4.40) and maximum in Japanese White (6.96). During E3 minimum value was observed in Rapid Red White Tipped (3.96) and maximum in SKAU-R- 5 (6.93). The pooled data analysis showed minimum

dry matter in Rapid Red White Tipped (4.03) and maximum in Japanese White (6.72).

4.1.9 Vitamin-C

Mino Early Long White showed less vitamin-C (14.24) during E1 while as SKAU-R-5 showed maximum Vitamin-C (29.84). SKAU-R-7 showed minimum vitamin-C (16.90) during E2 while as SKAU-R-5 showed maximum vitamin-C (30.53). During E3 SKAU-R-7 showed less vitamin-C content (15.32) and SKAU-R-5 showed maximum (28.55) vitamin-C content. The pooled data analysis showed minimum vitamin-C content in SKAU-R-7 (15.71) and maximum vitamin-C content in All Season (29.64).

4.1.10 Total Soluble Solids

SKAU-R-1 showed minimum total soluble solids during E1 (2.70) while as Early White Milano showed maximum total soluble solids (5.63). During E2 minimum total soluble solids content (2.63) was observed in SKAU-R-1 and maximum total soluble solids content (6.00) was observed in SKAU-R-5. Similarly during E3 the minimum total soluble solids (2.76) was reported in SKAU-R-1 and maximum (6.03) in Radish Long White. The pooled data analysis showed minimum total soluble solids content (2.70) in SKAU-R-1 and maximum total soluble solids content (5.71) in SKAU-R-5.

4.1.11 Root yield (q/ha.)

During E1 sowing maximum root yield was shown by White Round (306.78) and minimum root yield by White Icicle (91.07). During E2 sowing maximum root yield was shown by White Round (315.38) and minimum by

White Icicle (97.08) and during E3 maximum yield was shown by White Round(323.78) and minimum by White Icicle (103.44). The pooled data analysis showed maximum root yield by White Round (315.46) and minimum by White Icicle (97.49).

4.2 Variability parameters

The character-wise estimates of mean and range of different environments and for the pooled data analysis is presented in the Table-5.

Table 5: Estimates of Mean and Range of Various Characters in Radish (*Raphanus sativus* L.)

Character/Trait	Mean				Range			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Days to maturity	41.43	37.46	42.33	40.41	32.33-49.43	27.50-45.30	32.43-48.54	30.83-48.54
Leaf number	11.48	13.50	12.55	12.37	6.46-16.70	8.43-19.70	6.96-18.50	7.63-18.30
Leaf weight (g)	68.20	74.64	72.79	71.73	23.09-106.61	24.50-115.58	24.50-113.23	24.03-108.39
Root length (cm)	16.45	17.48	17.33	17.09	4.80-26.83	4.80-26.83	4.63-27.33	4.82-26.04
Root diameter (cm)	3.07	3.21	2.98	3.09	2.30-4.40	2.30-4.40	2.13-4.70	2.36-4.44
Root weight (g)	89.19	92.18	92.73	91.37	40.98-138.06	44.09-142.12	46.55-145.42	43.89-141.87
Top to root ratio	0.84	0.89	0.86	0.91	0.39-1.55	0.43-1.62	0.33-1.51	0.39-1.83
Total dry matter	5.13	5.60	5.64	5.46	3.56-6.46	4.40-6.96	3.96-6.93	4.03-6.72
Vitamin –C (mg/100g.)	19.55	21.73	19.73	20.33	14.24-29.84	16.90-30.53	15.32-28.55	15.71-29.64
Total soluble solid (°Brix)	3.98	4.19	4.19	4.15	2.70-5.63	2.63-6.00	2.76-6.03	2.70-5.71

Days to maturity showed slight variation for all the three environments and pooled data analysis. During E1 the days to maturity ranged from 32.33 to 49.43 with a mean of 41.43, in E2 it varies from 27.50 to 45.30 with a mean of 37.46 and in E3 the character had a range of 32.43 to 48.54 with a mean value of 42.33. The pooled data analysis showed a low of 30.83, a high of 48.54 with a mean of 40.41.

The number of leaves showed a wide variation. In E1 the number of leaves ranged from 6.46n to 16.70 with a mean value of 11.48, during E2 it ranged from 8.43 to 19.70 with a mean of 13.50 and during E3 the number of leaves ranged from 6.96 to 18.50 with a mean of 12.55. The pooled data analysis showed a range of 7.63 to 18.30 with a mean value of 12.37. The leaf weight showed only a slight variation for different environments. During E1 the weight of leaves ranged from 23.09 to 106.61 with a mean of 68.20, during E2 it ranged from 24.50 to 115.58 with a mean of 74.64 and during E3 it ranged from 24.50 to 113.23 with a mean of 72.79. The pooled data analysis shows a ranged of 24.03 to 108.39 with a mean of 71.73.

The root length showed a slight variation for the different environments. During E1 root length ranged from 4.80 to 26.83 with a mean of 16.45 during E2 it ranged from 4.80 to 26.83 with a mean of 17.48 and during E3 it ranged from 4.63 to 27.33 with a mean of 17.33. The pooled data analysis showed a

ranged of 4.82 to 26.04 with a mean of 17.09.

The root diameter during E1 varied from 2.20 to 4.43 with a mean of 3.07, during E2 it showed a low of 2.30 and a high of 4.40 with a mean of 3.21 and during E3 it ranged from 2.13 to 4.70 with a mean value of 2.98. Analysis of the data pooled over the environments showed a ranged of 2.36 to 4.44 with a mean value of 3.09.

Root weight during E1 ranged from 40.98 to 138.06 with a mean value of 89.19, during E2 it ranged from 46.55 to 145.42 with a mean of 92.18 and during E3, it varied from 44.09 to 142.12 with a mean of 92.73. The analysis of pooled data of three environments showed a low of 43.89 and a high root weight of 141.87 with a mean value of 91.37.

The shoot to root ratio showed a wide range from 0.39 to 1.55 during E1 with a mean of 0.84. During E2 range varied from 0.43 to 1.62 with a mean of 0.89 and during E3 range varied from 0.33 to 1.51 with a mean of 0.91. The analysis of the pooled data showed a ranged of 0.39 to 1.83 with a mean of 0.91.

The total dry matter content showed a wide variation in the individual environments. During E1 total dry matter content ranged from 3.56 to 6.46 with a mean of 5.13, during E2 the dry matter content ranged from 4.40 to 6.96 with a mean of 5.60 and during E3 dry matter content ranged from 3.96 to 6.93

with a mean of 5.64. The pooled data showed a range of 4.03 to 6.72 with a mean of 5.46.

The vitamin-C content during E1 ranged from 14.24 to 29.84 mg/100 g with a mean value of 19.55 mg/100g, during E2 it ranges from 16.90 to 30.53 with a mean of 21.73 and during E3 it ranged from 15.32 to 28.55 mg/100 g with a mean 19.73 mg/100g weight. The pooled data over the environments showed a range of 15.71 to 29.64 mg/100g with a mean of 20.33.

The total soluble solid content ranged from 2.70 to 5.63 °Brix in E1 with a mean of 3.98°Brix, in E2 it ranged from 2.63 to 6.00 °Brix with a mean of 4.19 °Brix and during E3 it ranged from 2.76 to 6.03°Brix with a mean of 4.19°Brix. The pooled data showed a range of 2.70 to 5.71 °Brix with a mean of 4.15 °Brix.

4.3 Analysis of Variance

The estimates of the phenotypic variation was observed to be higher than the corresponding estimates of genotypic variance for individual (E1, E2, E3) environments and for the pooled data (Table-6).

The estimates of phenotypic coefficient of variation and genotypic coefficient of variation for various characters are presented in Table-7. The close correspondence between estimates of phenotypic coefficient of variation and genotypic coefficient of variation for most of the characters during different environments reveals significant

influence of environment. The highest estimate of phenotypic and genotypic coefficient of variation was revealed for root length during different environments and in the pooled data analysis. The lowest estimate was recorded for days to maturity. The magnitude of phenotypic and genotypic coefficient of variation was low (<20.0 percent) for days to maturity, total dry matter content and vitamin-C, moderate (20.0-30.0 percent) for leaf number, leaf weight, root diameter, total soluble solids where as it was high (>30.0 percent) for root length, root weight and shoot to root ratio.

4.4

Heritability and Genetic gain

The heritability estimates (broad sense) and expected genetic gain were calculated for all the characters in different environments and the pooled data (Table-8). The heritability estimates were observed to be higher for all the traits during different environments. The highest estimate of heritability during E1 was recorded for leaf weight (99.67%) and lowest for root weight (93.36). During E2 the highest estimate of heritability was recorded from shoot to root ratio (99.73) and lowest for root weight (92.84). During E3 the highest estimate of heritability was recorded for shoot to root ratio (99.71) and lowest root weight. The pooled data analysis shows a highest heritability for days to maturity (98.30) and lowest for leaf number (82.20).

The genetic advance was estimated at 5

percent selection intensity and converted into expected genetic gain (percent of mean). The estimates revealed that the expected genetic gain was high (>30%) for leaf number, leaf weight, root length, root diameter, root weight, shoot to root ratio and vitamin-C and moderate (10.0-30.0 %) for days to maturity and total dry matter during E1,E2, E3 environments and the pooled analysis.

Table 6: Estimates of Phenotypic Variance and Genotypic Variance of Various Characters in Radish (*Raphanus sativus* L.)

Character/Trait	Phenotypic Variance				Genotypic Variance			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Days to maturity	27.05	24.85	28.96	24.42	26.72	24.82	28.82	23.91
Leaf number	7.99	10.74	9.79	9.84	7.12	10.26	9.39	8.08
Leaf weight (g)	2.98.54	391.88	326.99	326.99	295.84	388.36	393.50	315.68
Root length (cm)	50.16	54.71	53.85	53.85	49.67	57.58	54.24	52.63
Root diameter (cm)	0.50	0.43	0.50	0.43	0.49	0.42	0.49	0.41
Root weight (g)	812.09	821.367	840.11	827.712	758.202	762.61	781.46	784.920
Shoot to root ratio	0.1144	0.141	0.127	0.138	0.114	0.141	0.126	0.135
Total dry matter	0.55	0.60	0.66	0.55	0.53	0.58	0.64	0.49
Vitamin –C (mg/100g)	14.38	14.47	13.44	13.37	13.98	14.25	12.25	12.54
Total soluble solid (⁰ Brix)	0.75	1.04	0.87	0.77	0.73	1.03	0.86	0.72

Table 7: Estimates of Phenotypic Coefficient of Variability and Genotypic Coefficient of Variability for Various Characters in Radish (*Raphanus sativus* L.)

Character/Trait	Phenotypic Coefficient of variability				Genotypic Coefficient of variability			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Days to maturity	12.55	13.33	12.71	12.23	12.48	13.29	12.68	12.12
Leaf number	24.63	24.26	24.93	25.36	23.28	23.71	24.42	22.99
Leaf weight (g)	25.33	26.52	27.34	25.21	25.22	26.40	27.25	24.77
Root length (cm)	43.04	42.30	43.87	42.96	42.83	42.51	43.77	42.45
Root diameter (cm)	23.15	20.44	23.69	21.36	22.94	20.79	23.49	20.66
Root weight (g)	31.95	31.09	31.25	31.48	30.87	29.95	30.14	30.66
Shoot to root ratio	40.18	42.25	41.27	42.44	40.11	42.20	41.21	40.37
Total dry matter	14.45	13.81	14.45	13.67	14.17	13.59	14.26	12.94
Vitamin –C (mg/100g)	19.39	17.50	18.58	17.99	19.12	17.37	17.75	17.42
Total soluble solid (⁰ Brix)	21.80	23.89	22.34	21.21	21.55	23.67	22.18	20.55

Table 8: Estimates of Heritability (b.s) and Genetic Gain (%) of Various Characters in Radish (*Raphanus sativus* L.)

Character/Trait	Heritability (b.s)				Genetic Gain (%)			
	E1	E2	E3	Pooled	E1	E2	E3	Pooled
Days to maturity	98.47	99.47	99.53	98.30	25.46	27.31	26.06	24.77
Leaf number	95.77	95.54	95.96	82.20	44.93	47.75	49.28	42.92
Leaf weight (g)	99.67	99.10	99.34	96.62	49.82	54.14	55.94	50.14
Root length (cm)	99.02	99.14	99.55	97.71	87.80	86.38	89.97	86.48
Root diameter (cm)	98.20	97.58	98.30	93.64	46.83	41.10	47.98	41.10
Root weight (g)	93.36	92.84	93.01	94.83	62.03	59.45	61.05	61.50
Shoot to root ratio	99.65	99.73	99.71	97.82	82.48	86.81	84.77	82.14
Total dry matter	96.12	96.76	97.37	89.09	28.62	27.54	28.99	25.27
Vitamin –C (mg/100g.)	97.22	98.44	98.14	93.75	38.84	35.50	34.71	34.77
Total soluble solid (⁰ Brix)	97.74	98.20	98.62	93.86	43.90	48.33	45.39	40.96

4.5 Estimation of phenotypic and genotypic correlation coefficients

The correlation coefficients were estimated at the phenotypic and genotypic levels among various morphological, maturity, quality yield and yield component traits in the individual environments and from the data pooled over the environments.

The genotypic correlation coefficients were by and large higher in magnitude, though similar in direction than their corresponding phenotypic correlation coefficients. The genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for the pooled data are presented in Table-9.

4.5.1 Days to maturity

The days to maturity exhibited significant positive correlation (both phenotypic and genotypic) with leaf number ($r_g=0.257$), leaf weight ($r_g=0.3652$), root length ($r_g=0.3504$) and root weight ($r_g=0.358$) and negative significant correlation with root diameter ($r_g= -0.2473$) and total dry matter ($r_g= -0.2324$). Similar results were observed in the individual environments also.

4.5.2 Leaf number

The number of leaves exhibited significant positive correlation (Genotypic and Phenotypic) coefficients with days to maturity ($r_g= 0.2571$),

Table-9: Genotypic (above diagonal) and Phenotypic (below diagonal) Correlation Coefficients between Various Characters in Radish (*Raphanus sativus* L.) for pooled data

Levels	Days to maturity	Leaf number	Leaf weight (g)	Root length (cm)	Root diameter (cm)	Root weight (g)	Shoot to root ratio	Total dry matter (%)	Vitamin-C (mg/100g)	Total soluble solids (⁰ Brix)
Days to maturity	1.000	0.2571*	0.3652**	0.3504**	-0.2473*	0.3581**	0.0842	0.2324*	0.0073	0.3101**
Leaf number	0.2558*	1.000	0.3411**	0.4516**	-0.3083**	0.4242**	0.2176	0.2354*	0.2152	0.3549**
Leaf weight	0.3638**	0.3386**	1.000	0.2775*	0.1592	0.2561	0.2639*	0.2581*	0.0135	0.3708**
Root length (cm)	0.3489**	0.4492**	0.2759*	1.000	-0.3659**	0.2857*	-0.2495*	0.2605*	0.1259	0.2853*
Root diameter (cm)	-0.2458*	-0.3065**	0.1575	-0.3601**	1.000	0.3285**	-0.2396*	-0.2315	0.0144	-0.2519*
Root weight (g)	0.3563**	0.4218**	0.2532*	0.2826*	0.3264**	1.000	-0.2321*	0.2907*	0.2215	0.2881*
Shoot to root ratio	0.0815	0.2159	0.2618*	-0.2468*	-0.2359*	-0.2301	1.000	-0.1809	0.0372	-0.3015*
Total dry matter	-0.2308	0.2338*	0.2543*	0.2589*	-0.2294	0.2884*	-0.1801	1.000	0.2154	0.1358
Vitamin –C (mg/100g)	0.0065	0.2086	0.0128	0.1208	0.0138	0.2208	0.0365	0.2139	1.000	0.2158
Total soluble solid (⁰ Brix)	0.3095**	0.3529**	0.3683**	0.2837*	-0.2512*	0.2859*	-0.3002*	0.1342	0.2149	1.000

r at 5% = 0.2319

$$1\% = 0.3017$$

leaf weight ($r_g=0.3491$) root length ($r_g=0.4516$), root weight ($r_g=0.4242$), dry matter content ($r_g=0.2354$) and total soluble solids ($r_g=0.3549$) and negative significant correlation with root diameter ($r_g=-0.3083$). Leaf number had a non significant positive correlation ($r_g=0.2152$) with vitamin-C, shoot to root ratio ($r_g=0.2176$). Similar trends were observed in the correlation coefficient of individual environments.

4.5.3 Leaf weight

The genotypic correlation coefficients exhibited by leaf weight with

other characters were higher in magnitude than corresponding phenotypic correlation coefficients, though similar in direction. Leaf weight exhibited highly significant positive correlation with days to maturity ($r_g=0.3652$), leaf number ($r_g=0.3411$) and total soluble solids ($r_g=0.3708$) and significant positive correlation with root length ($r_g=0.2775$), root weight ($r_g=0.256$), total dry matter ($r_g=0.2581$) and shoot to root ratio ($r_g=0.2639$). With root

diameter and vitamin-C, leaf weight showed non-significant

positive correlation ($r_g = 0.159$, $r_g = 0.135$).

4.5.4 Root length

Root length showed a highly significant positive correlation with days to maturity ($r_g = 0.3504$) and leaf no. ($r_g = 0.4516$) a positive significant correlation with leaf weight ($r_g = 0.277$), root wt. ($r_g = 0.2857$), total dry matter ($r_g = 0.2605$) and total soluble solid ($r_g = 0.2853$). A negative significant correlation coefficient of root length with root diameter ($r_g = -0.3659$) and shoot to root ratio ($r_g = -0.2495$) was observed. Root length showed a non-significant positive correlation with vitamin-C ($r_g = 0.1259$). Similar trends were exhibited by the correlation coefficients in the

individual environment.

4.5.5 Root diameter

Root diameter shows an over all significant negative correlation

coefficient with days to maturity ($rg = -0.2473$), leaf number ($rg = -0.3083$), root length ($g = -0.3659$), shoot to root ratio ($rg = -0.2396$), total dry matter ($rg = -0.2315$) and total soluble solids ($rg = -0.2519$) while as root weight showed a positive significant correlation coefficient ($rg=0.3285$). The quality trait vitamin-C shows no significant correlation with root diameter.

4.5.6 Root weight

Root weight shows highly significant correlation coefficient with days to maturity ($rg = 0.3581$), leaf number ($rg = 0.4242$), leaf weight ($rg=0.2561$), root length ($rg = 0.2857$), root diameter

(0.3285), total dry matter ($r_g = 0.2907$) and total soluble solid ($r_g = 0.288$). A significant negative correlation of root weight and shoot to root ratio ($r_g = -0.232$) was observed. vitamin-C had non significant but positive correlation ($r_g = 0.22515$) with root weight. Similar trends were exhibited by correlation coefficients of individual environments.

4.5.7 Shoot to root ratio

Shoot to root ratio exhibited a positive significant correlation with leaf weight ($r_g = 0.2639$) and a significant negative correlation with root length ($r_g = -0.249$), root weight ($r_g = -0.2396$) and total soluble solids ($r_g = -0.3015$). A negative non-significant correlation was exhibited with total dry matter ($r_g = -0.1809$).

4.5.8 Total dry matter

The total dry matter exhibited a significant negative correlation with days to maturity ($r_g = -0.2324$) and positive significant correlation with leaf number ($r_g = 0.2354$), leaf weight ($r_g = 0.2581$), root length ($r_g = 0.2605$), root weight ($r_g = 0.2907$). A non-significant negative correlation is exhibited with shoot to root ratio and a non-significant positive correlation with vitamin-C and total soluble solids.

4.5.9 Vitamin-C

Being a quality trait, vitamin-C does not show any

significant correlation with any character.

4.5.10 Total soluble solids

Total soluble solid shows significant correlation with the major yield contributing factors. It shows a positive significant correlation with days to maturity ($r_g = 0.3101$), leaf number ($r_g = 0.3549$), leaf weight ($r_g = 0.3708$), root length ($r_g = 0.285$), root weight ($r_g = 0.2881$) and a negative significant correlation with root diameter ($r_g = -0.2519$) and shoot to root ratio ($r_g = -0.3015$). It shows a non-significant positive correlation with total dry matter and vitamin-C.

4.6 Path coefficient analysis

Direct and indirect contribution of seven different root yield contributing traits including days to maturity, leaf number, leaf weight, root length, root diameter, total dry matter and total soluble solids were estimated through partitioning their genotypic correlation coefficients by path coefficient analysis. The results are presented in Table-10 and depicted in Fig.1.

The days to maturity showed a significant positive association with root yield. The direct effect of days to maturity on root yield was 0.2032 and was supplemented through positive indirect effect via leaf number (0.0097), leaf weight (0.0138), root length (0.0129), total soluble solids (0.0198) and negative indirect effect via root diameter (-0.0039) and total dry matter (-0.0230). Similarly leaf number exhibited significant positive correlation with root yield plant^{-1} . Its direct effect on root yield was 0.1905 and was supplemented through positive indirect effects via days to maturity (0.0075), leaf weight (0.0225), root length (0.1782), total dry matter (0.0267) and total soluble solids (0.0267) and negative indirect effects via root diameter (-0.0228).

The association between leaf weight and root yield was significant and positive and has a positive direct effect of (0.2075) on root yield. It is supplemented through positive indirect effect via days to maturity (0.0060), leaf number (0.0156), root length (0.0127) and total soluble solids (0.0155) and negative indirect effect via root diameter (-0.0597) and total dry matter (-0.0315).

The root length showed a significant positive correlation with root yield. It exhibited the maximum direct effect on root yield (0.6082) and is supplemented through positive indirect effect via days to maturity (0.0012), leaf weight (0.0281), total dry matter (0.0068) and total soluble solids (0.0055) and negative indirect effect via leaf number (-0.0808) and root diameter (-0.2833).

Similarly root diameter exhibited significant positive correlation with root yield and exhibited positive direct effect of (0.2972). It is supplemented through positive indirect effect via days to maturity (0.0021), leaf weight (0.1615), root length (0.2108) and total dry matter (0.0296) and negative indirect effect via leaf number (-0.1632) and total soluble solids (-0.2095), total dry matter also exhibited a significant positive correlation with root yield and has a positive direct effect (0.1061) and supplemented through positive indirect effect via leaf number (0.0198), leaf weight (0.0645), root length (0.1083) and root diameter (0.0645). It has a negative indirect effect via days to maturity

(-0.0071) and total soluble solids (-0.0472).

Similarly total soluble solids which has a significant positive correlation with root yield, has a direct effect on root yield (0.1005) and positive indirect effect via days to maturity (0.0082), leaf number (0.1061), leaf weight (0.0273), root length (0.1816) and total dry matter (0.0349). It exhibited a negative indirect effect via root diameter (-0.1703).

The magnitude of residual effect was worked out to be equal to 0.1539 indicating that characters included in path coefficient analysis appreciably contributed towards root yield through their direct and indirect effect.

An over all appraisal of path coefficient analysis revealed that days to maturity, leaf number, leaf weight, root length, root diameter, total dry matter and total soluble solids had positive direct effects on root yield and the correlation coefficient recorded on these characters were also positive.

Table-10: Path Coefficient Analysis at Genotypic Level Showing Direct (diagonal) and Indirect (off diagonal) Effects on Root Yield in Radish

Levels	Days to maturity	Leaf number	Leaf weight (g)	Root length (cm)	Root diameter (cm)	Total dry matter (%)	Total Soluble Solids (⁰Brix)	Genotypic Correlation Coefficient of Root yield
Days to maturity	0.2032	0.0097	0.0318	0.1205	-0.0039	-0.0230	0.0198	0.3581**
Leaf number	0.0075	0.1905	0.0225	0.1782	-0.0228	0.0267	0.0216	0.4242**
Leaf weight (g)	0.0060	0.1056	0.2075	0.0127	-0.0597	-0.0315	0.0155	0.2561*
Root length (cm)	0.0012	-0.0808	0.0281	0.6082	-0.2833	0.0068	0.0055	0.2857**
Root diameter (cm)	0.0021	-0.1632	0.1615	0.2108	0.2972	0.0296	-0.2095	0.03285**
Total dry matter	-0.0071	0.0198	0.0645	0.1083	0.0463	0.1061	-0.0472	0.2907
Total soluble solid (⁰ Brix)	0.0082	0.1061	0.0273	0.1814	-0.1703	0.0349	0.1005	0.2881*

Residual effect = 0.1539

DISCUSSION

The success of any breeding programme depends on the presence of sufficient genetic variability to pursue effective selection. It is important to assess the relative magnitude of variability in order to use such information together with other selection parameters for the improvement of plant type through adoption of effective breeding method (Johnson *et al.*, 1955, Hanson *et al.*, 1956). Genetic variability (GCV) helps to choose a particular genotype, whereas heritability (h^2) along with genetic advance (per cent of mean) are more useful in predicting the resultant effect of selection of best genotype. Root yield being a complex trait is dependent on the expression of many component characters. To bring an overall improvement in yield and its associated characters, the knowledge of association of yield with its component factors and effect of component factors on total yield becomes a prerequisite. Hence correlations and path coefficient analysis studies are important and have practical significance in selection. In the present investigation 23 genotypes of Radish, both Asiatic as well as European types were evaluated at 3 different sowing dates and the results obtained were analysed for each individual sowing as well as for pooled data.

The analysis of variance revealed highly significant differences among the genotypes for all the characters under study, thereby indicating genotypic differences among different genotypes. Analysis of quantitative characters revealed presence of significant genetic variation for all the characters. Interaction resulting from the $G \times E$ interaction was also significant for all the traits. The $G \times E$ interaction being significant shows differential behaviour of genotypes under different environments. Similar results were observed by Prasad and Prasad (1977), Vikova (1971) in radish. Mean performance of the genotypes revealed that no single genotype was superior for all the traits. Different genotypes were identified to be superior for different trait. The genotypes French Breakfast, Scarlet Globe, Rapid Red White Tipped and Scarlet Long for Days to maturity, Mino Early Long White, SKAU-R-3, SKAU-R-5, Hill Queen and Early White Milano for leaf number; Hill Queen, SKAU-R-5, Japanese White, Mino Early Long White, Radish Long White and Early White Milano for leaf weight; Selection-9, White Round, SKAU-R-7, SKAU-R-5, Radish Long White and Early White Milano for root length; White Round, SKAU-R-2, SKAU-R-7, Selection-9, White Round, Japanese White, Mino Early Long White, SKAU-R-5, Chinese Pink Kalyanpur No. 1 and SKAU-R-7 for root weight; White Round, Selection-9, SKAU-R-1, SKAU-R-2, Chinese Pink, Kalyanpur No. 1 and Rapid Red White Tipped for shoot to

root ratio; French Breakfast, White Round, Japanese White, SKAU-R-5 Chinese Pink, 40 days and Scarlet Globe for total dry matter content; SKAU-R-5, SKAU-R-4, Scarlet Globe, French Breakfast, Chinese Pink and Kalyanpur No.1 for vitamin-C content; Pusa Himani, Japanese White, Mino Early Long White, SKAU-R-5, Scarlet Globe and Early White Milano for total soluble solids; and White Round, Selection-9, SKAU-R-1 and Chinese Pink for root yield (q/ha.).

Evaluation of the cultivars over the three random environments revealed that early maturing genotypes were Scarlet Globe and Rapid Red White Tipped; maximum leaves plant⁻¹ were observed in SKAU-R-3 and Hill Queen; maximum leaf weight plant⁻¹ in Hill Queen and SKAU-R-5; maximum root length among round genotypes in White Round and SKAU-R-7 and among long type genotypes in SKAU-R-5 and Selection-9; maximum root diameter was observed among round type genotypes in SKAU-R-7 and White Round and among long genotypes in SKAU-R-5 and Selection-9 exhibited maximum root diameter; and maximum root weight plant⁻¹ in White Round , Chinese Pink and Selection-9.

Among the quality traits maximum total dry matter was observed in SKAU-R-5, Japanese White and French Breakfast; the highest vitamin-C content SKAU-R-5, Chinese Pink and Kalyanpur No. 1 and maximum total

soluble solids in SKAU-R-5, Radish Long White and Early White Milano.

Since genotypes identified for their better performance and also found superior for most of the traits could be involved in the hybridization programme for making selection of desired genotypes in the segregating generations for the yield contributing traits. Similar observations were recorded by Yousuf and Shafi (1969), Kulikova (1975) and Nieuwhof Kraai (1969) in radish. Nijjar *et al.* (1996) reported high variability for the ascorbic acid content in radish cultivars. Similarly genetic variability for different characters in turnip was reported by Murralli *et al.* (1989) and in carrot by Natrajan and Arumugam (1981) and Singh *et al.* (1987).

The range for days to maturity, leaf number, leaf weight, root weight and vitamin-C was moderate to high which suggested presence of large variations for those characters. Coefficient of variation (both phenotypic and genotypic) was moderate to high for all the traits. Highest PCV and GCV was observed for average root length, average root weight and top to root ratio whereas lowest PCV and GCV was observed for days to maturity and total dry matter content. Similar findings were reported by Rangaswami and Shanmugavelu (1980), Brar and Sukhija (1980) and Nijjar *et al.* (1996) in radish.

Further persual of data revealed that there was a close

correspondence between values of PCV and GCV. PCV in general was less than GCV indicating that most of the characters were less affected by environment and major portion of the variations was contributed by genotype, thereby suggesting that selection for these characters would be effective. Close correspondence between PCV and GCV and minor influence of environment in various root and shoot characters has been reported by Yadav (1984) and in carrot by Ahmed and Tanki (1992).

The heritable variation can be found with greater degree of accuracy when heritability in conjunction with genetic advance is studied. Johnson *et al.* (1955a) have also suggested that high heritability estimates supplemented with high genetic gain are more meaningful than heritability values alone. Heritability is a measure of genetic relationship between parents and the progeny and it is widely used for determining the degree to which a character may be transmitted from parents to off springs. In the present study, the heritability in broad sense was high for all characters suggesting that selection based on phenotype would be more effective and there is every possibility to transmit traits into the off spring. High heritability observed for various characters is probably due to presence of fixable additive gene effects and addition \times additive gene interactions which can be exploited by following

simple selection (Singh, B. D. 1994). Similar observations were recorded by Singh *et al.*, (1977), Prasad and Prasad (1978), Nijjar *et al.* (1996), Yadav (1984), Ponnuswami *et al.* (1982) and Rangaswami and Shanmugavelu (1980)

Genetic advance denotes the improvement in the genotypic value of new population when compared to original parent population. This genetic advance as percentage of mean was highest for root length (86.48%) followed by top to root ratio (82.14%) and root weight (61.50%) while it was found moderate for other characters. Johnson *et al.* (1955b) advocated that expected genetic gain is the product of the selection differential measured in terms of phenotypic standard deviation and genotypic coefficient of variability and the heritability. It was therefore concluded that high to moderate genetic gain expected for most of the characters in the present study is attributed to high heritability coupled with high to moderate GCV. High genetic gain for root and shoot characters have also been reported by Ahmed and Tanki, (1992) in turnip and Yadav, (1984); Ponnuswami *et al.* (1982) in radish.

Yield being a complex trait is influenced by many component characters each of which is under separate genetic control. For simultaneous improvement of desired characters the knowledge of association among different genotypes within a species is important. Linkage and pleiotropy are the possible reasons for correlation between two characters (Narayanan and Singh, 2000 A.D.). Since the correlation is the inter relationship of two variables and the genes effecting the phenotypes of two variables may not be completely linked. Grafius (1964)

put it as “there is no way in which yield can be changed without changing one or more components”. There can be no genes for yield which by pass the components. All changes in the components need not be expressed in changes in yield but all change in yield must be accompanied by changes in one or more of the components. Hence it is prerequisite to know the nature and magnitude of association of yield with various characters. Unfavourable association between the desired attributes under selection may result in genetic slippage (Dickerson, 1955) and limit the genetic advance. Hence a knowledge of correlation between such characters is essential for rational improvement of yield through selection programme. Correlation studies give an idea about the positive and negative associations of different characters with yield and also among themselves. However nature and extent of contribution by these characters towards yield is not obtained, which is given by path coefficient analysis –a methodology suggested by Dewey and Lu (1959) on the findings of the Wright (1921), which facilitates partitioning of correlation coefficient into direct and indirect effect of the different characters on yield or any other character and also helps in finding out how these effects influence a particular character to produce a given positive or negative correlation. The information obtained helps in giving proper weightage to the various characters during selection or other breeding programmes so that the improvement of desirable trait could be achieved effectively.

In the present study, genotypic coefficient of correlation in general was

higher in magnitude than the corresponding phenotypic coefficient of correlation, indicating that there is an inherent association among the various characters.

Similar findings in radish were also reported by Hulenicz and Hortynski (1974), Singh *et al.* (1977) and Khan *et al.* (1983).

Root weight exhibited positive and significant correlations with days to maturity, leaf number. Thumburaj (1973) also found a significant correlation of root weight and foliage weight in radish. There was a positive and significant correlation of root weight with root length, root diameter, total dry matter content and total soluble solids while it showed negative but significant correlation with shoot to root ratio. A study of cause and effect relationship showed that these characters had the maximum direct positive effect on root weight and their indirect effects on root yield via other characters were also positive. A strong positive association of yield with foliage weight, root length and root weight in radish and carrot has been reported by Khan *et al.* (1983) and Singh *et al.* (1987) respectively. A significant positive correlation of root weight with root length, number of leaves and leaf weight in radish was reported by Danu and Lal (1998). Vitamin-C content being non-significant but has positive correlation with root weight. Hence it was suggested that selection criteria based on leaf number, leaf weight, root length and root diameter could be more effective in maximizing the root yield. Days to maturity showed significant positive correlation with leaf number, leaf weight, root length, root weight and

significant negative correlation was observed with root diameter. While the path analysis showed that days to maturity had the direct positive effect on root weight as well as positive indirect effect via leaf number, leaf weight and root length and negative indirect effect via root diameter, which had a negative correlation with it. Leaf number showed significant positive correlation with major yield contributing characters except root diameter. Leaf weight was positively and significantly correlated with days to maturity, leaf number, root length, root weight and total soluble solids, while it showed positive direct and indirect effects on root yield. Root length was positively and significantly correlated with days to maturity, leaf number, leaf weight and root weight and negatively but significantly correlated with root diameter and shoot to root ratio. It had the maximum direct effect on root yield and had both positive and negative indirect effects on root yield. Root diameter showed positive and significant correlation with days to maturity, leaf number, root length and shoot to root ratio, while it showed a positive direct effect on root weight and indirect positive effect via root length, shoot to root ratio and negative indirect effect via leaf number.

Shoot to root ratio showed positive and significant correlation with leaf weight, total dry matter content and negative significant correlation with root length, root diameter and root weight. Similarly a significant positive correlation of root yield with root diameter and root dry weight in radish has been reported by Murralli *et al.* (1998).

The quality traits namely total dry matter, vitamin-C and total soluble solids generally showed a positive significant correlation among themselves suggesting that selection for any one quality trait shall simultaneously take care of the other quality traits. The path analysis showed that total dry matter and total soluble solids both exhibit a positive direct effect on root weight and both positive and negative indirect effects on root weight. The quality traits in general exhibit a positive correlation with the quantitative root and shoot characters indicating that selection for improvement of quality characters would almost certainly lead to an increase in root yield and yield associated traits and vice versa. Similar observations were recorded by Muthukrishnan and Arumugam (1977), Sharma *et al.* (1983) in radish and Bhagchandani and Chaudhary (1980) in carrot.

A comparison of correlation values and positive direct effect values for the characters clearly showed that the association between the characters was mainly due to direct effect and also due to positive indirect effect of the trait on root yield. The character which exhibited positive direct effect should be preferred while making selection for the purpose of improvement of yield and more preference should be given to the characters with greater magnitude of positive direct effect than those with smaller magnitude.

In the present studies, the value of residual effect obtained was less i.e. 0.1539 which indicates that the characters chosen for present study are the main component for yield and that the variability in yield is accounted by the characters chosen for present study to a considerable extent.

From the correlation and path coefficient studies it can be concluded that the characters such as days to maturity, leaf number, leaf weight, root length and root diameter which exhibited significant positive correlations and also most of them had either direct or indirect effect on yield proved as important components contributing to root yield and the selection primarily based on these characters may result in development of high yielding genotype in radish.

Chapter –V

SUMMARY AND CONCLUSION

The present investigation on Variability and Correlation studies in 23 diverse genotypes of Radish (*Raphanus sativus* L.) for ten characters were carried out according to RBD with three replications at the experimental fields of Division of Olericulture, S. K. University of Agricultural Sciences and Technology of Kashmir, Shalimar Srinagar during the year 2002 at three different dates viz., 22.3.2002, 24.5.2002 and 29.8.2002. The objectives of the present investigation were to study the genotypic and phenotypic variability, heritability, expected genetic advance and the correlations between important yield contributing characters.

Analysis of variance revealed highly significant variations for all the traits under study, indicating existence of genetic differences among the genotypes in both individual and pooled analysis. The overall persual of data revealed that no single genotype was superior for all the characters under study. For different characters different genotypes have been found superior. The genotypes White Round, SKAU-R-5, Chinese Pink were found superior for Root characters while as for shoot characters the genotype White Icicle and Hill Queen were found superior. Range in general was moderate to high for all the characters in both individual and pooled analysis suggesting presence of large variation in the population. The phenotypic coefficient of variation for all the characters was higher than the genotypic coefficient of variation with close relationship between PCV and GCV in both individual as well as pooled analysis. High PCV and GCV was observed in both individual and pooled analysis for root length, root weight and shoot to root ratio while as lowest PCV and GCV was observed for days to maturity, total dry matter and vit-C content in individual as well as pooled data analysis. Environmental coefficient of Variability (ECV) for all the characters was less than the GCV.

Heritability in broad sense was high for all the characters in both individual and pooled analysis. Highest genetic gain was observed for root length followed by shoot to root ratio, root weight and leaf weight while as

lowest genetic gain was observed for days to maturity and total dry matter.

Correlation studies indicated highly significant positive correlation of root weight with days to maturity, leaf number, leaf weight, root length and root diameter while as negative significant correlation was observed for shoot to root ratio. The quality traits viz. total dry matter and T. S. S. showed a significant positive correlation with root weight. Significant positive correlation existed between days to maturity and leaf weight root length and T. S. S., leaf number, leaf weight, root length and T. S. S; leaf weight and root length; root length and total dry matter.

Negative significant correlation was observed between root weight and shoot to root ratio; days to maturity and root diameter; leaf number and root diameter. This type of negative correlation indicated that these characters are a negative to each other and hence does not go together in selection programme. The path coefficient analysis at genotypic level showed that root length has the maximum direct effect on root weight followed by leaf weight and root diameter. In addition to direct effects these characters also exert indirect positive effect via various characters towards the root yield. Thus these characters prove an important components of root weight and the selection bases on these characters will have direct influence on yield and shall result in the development of superior high yielding genotypes of radish.

Conclusion

From the present study it was concluded that there were significant differences among genotypes for various characters in both individual and pooled analysis. No single genotype was found superior for all the traits. However for root and shoot characters the genotypes White Round, SKAU-R-5, Chinese Pink, White Icicle and Hill Queen have been found superior. The G×E interaction being significant in all cases revealed that genotypes behave differently in different environments. Such cases being complex require conduct of independent experiments for each location i.e. all genotypes are to be tested over a large number of years to study their behavior. Range, coefficient of variation and heritability being moderate to high in most of the characters indicated large heritable variations leading to moderate to high expected genetic gain. Further there was a strong positive association of root weight with days to maturity, leaf number, leaf weight, root length and root diameter suggesting that selection based on these traits would be more effective for improving root yield. The characters like root length, leaf weight and root diameter which showed significantly positive correlation and also had maximum direct effect on root yield, the selection based on the characters will have direct influence on yield and shall result in development of superior high yielding genotypes of radish.

ANNEXURE –I

Analysis of Variance for Various Characters of Radish (*Raphanus sativus* L.) for Different Sowing Dates and Pooled Data
Mean Squares

Source of variation	Degrees of Freedom	Days to maturity				Leaf number			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled
<i>Environments</i>	2	-	-	-	461.84	-	-	-	74.2324
Replications	2	2.3766*	1.0543	0.8039	2.7187	10.5931*	2.0804	4.8991*	25.1787
S	4	-	-	-	0.2734	-	-	-	3.5932
Replications × Environments	22	80.5733**	74.8623**	86.8933**	220.7214**	22.2284**	32.2302	29.3829	77.4021**
Treatments	44	-	-	-	4.6835**	-	-	-	4.6007**
Environments × Treatments	44	0.4133	0.3983	0.4123	-	0.8684	1.4358	1.1883	-
Error	132	-	-	-	0.4066	-	-	-	1.7531

Source of variation	Degrees of Freedom	Leaf weight (g)				Root length (cm)			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled
<i>Environments</i>	2	-	-	-	871.6875	-	-	-	21.4687
Replications	2	46.8636*	41.4974	42.4472*	46.3125	11.9454*	0.8763	4.2610*	12.4414
Replications × Environments	4	-	-	-	11.4375	-	-	-	2.3193
Treatments	22	890.1056**	1175.6461**	1188.3569**	2950.3239**	150.4916**	173.5336**	164.1400**	478.6428**
Environments × Treatments	44	-	-	-	108.3304**	-	-	-	4.7612**
Error	44	2.7056	10.5546	10.5546	-	1.4681	1.4130	0.7755	-
	132	-	-	-	7.8426	-	-	-	1.2187

Source of variation	Degrees of Freedom	Root Diameter (cm)				Shoot to root ratio			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled
<i>Environments</i>	2	-	-	-	0.9714	-	-	-	123.4423
Replications	2	0.042	0.053	0.0531	0.0685	0.054	0.0002	0.0004*	0.0259
Replications × Environments	4	-	-	-	0.0343	-	-	-	0.0229
Treatments	22	1.5157**	1.3005**	1.5015**	3.8868**	0.345**	0.4244**	0.3829**	6.3274**
Environments × Treatments	44	-	-	-	0.2154**	-	-	-	4.7078**
Error	44	0.0273	0.0314	0.0254	-	0.0036	0.0011	0.0011	-
	132	-	-	-	0.02808	-	-	-	0.0101

Source of variation	Degree of Freedom	Root weight (g)				Total dry matter (%)			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled
<i>Environments</i>	2	-	-	-	250.5625	-	-	-	5.4606
Replications	2	34.4207	0.7820	27.085**	44.5000	0.0535	0.0590	0.1085*	0.0856
Replications × Environments	4	-	-	-	9.000	-	-	-	0.0684
Treatments	22	2328.4967**	2346.602**	2403.0302**	7168.9055**	1.6547**	1.8003**	1.9943**	4.8116**
Environments × Treatments	44	-	-	-	104.6182**	-	-	-	0.3189**
Error	44	53.8890	58.750	58.6502	-	0.0642	0.0583	0.0523	-
	132	-	-	-	23.7565	-	-	-	0.0582

Source of variation	Degrees of Freedom	Vitamin-C (mg/100g)				Total Soluble Solids (^o Brix)			
		E1	E2	E3	Pooled	E1	E2	E3	Pooled
<i>Environments</i>	2	-	-	-	101.3476	-	-	-	1.6488
Replications	2	1.1243	2.5848*	0.1220	1.6601	0.0771	0.0552	0.0330	0.0875
Replications × Environments	4	-	-	-	1.0917	-	-	-	0.0389
Treatments	22	43.1450**	43.4365**	33.4371**	115.3093**	2.2654**	3.1471**	2.6364**	7.0587**
Environments × Treatments	44	-	-	-	2.3555**	-	-	-	0.4951**
Error	44	1.1977	0.6762	0.6483	-	0.0511	0.0565	0.0363	-
	132	-	-	-	0.8409	-	-	-	0.0480

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* Original not seen