

**GENETIC INVESTIGATION OF RADISH (*Raphanus sativus* L.)
GENOTYPES UNDER HILL ZONE OF KARNATAKA**

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SHIVAMOGGA**

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Thesis submitted to the

**KELADI SHIVAPPA NAYAKA
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In partial fulfillment of the requirements
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**DEPARTMENT OF VEGETABLE SCIENCE
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CERTIFICATE

This is to certify that the thesis entitled '**GENETIC INVESTIGATION OF RADISH (*Raphanus sativus* L.) GENOTYPES UNDER HILL ZONE OF KARNATAKA**' submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE) in VEGETABLE SCIENCE** to the College of Horticulture, Mudigere. Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Ms. Rakshitha, G., ID NO. MH2TBA0301** (rakshudungavath@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

**Mudigere
November, 2023**



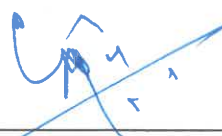

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Genetic Investigation of Radish (*Raphanus sativus* L.) Genotypes Under Hill Zone of Karnataka

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ABSTRACT

A study was undertaken on the genetic investigation of radish genotypes in the experimental block of the Department of Vegetable Science, College of Horticulture, Mudigere, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga during 2022-23. The experiment was laid out in a Randomized Complete Block Design with three replications. Analysis of variance showed highly significant differences among all the genotypes for all the characters under study. High heritability coupled with high genetic advance as a per cent of mean was recorded for plant height at 30 and 45 DAS (Days after sowing), number of leaves at 15 DAS, leaf length at 30 and 45 DAS, leaf width at 15 and 30 DAS, days to harvest, root length, root diameter, root girth, root weight, root volume, root yield per plot and root yield per hectare, suggesting that these traits can be improved through direct selection due to additive gene action. Based on D² analysis, 20 genotypes of radish were grouped into five clusters. Among the characters studied, root yield per plot contributed maximum (45.26 %), to the genetic diversity, followed by ascorbic acid (14.74 %) and leaf area index (14.00 %). Correlation studies exhibited that root yield per plot showed a highly significant and positive correlation with plant height, days to harvest, root length and root weight. Path analysis revealed that leaf length, leaf area index, days to harvest, root length and root weight had a direct and positive effect on root yield per plot. Based on the mean performance, genotypes such as Kashi Hans, Kashi Sweta and ORBI-0527 have been identified as promising for higher yield, which can be exploited for the further crop improvement programme under the hill zone of Karnataka.

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ಕರ್ನಾಟಕದ ಗುಡ್ಡಗಾಡುವಲಯದಲ್ಲಿ ಮೂಲಂಗಿ (ರಾಫನಸ್ ಸಟೈವಸ್ ಎಲ್.) ಬೆಳೆಯ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ
ಅಧ್ಯಯನ

(ರಕ್ಷಿತ, ಜಿ.)

ಸಾರಾಂಶ

ಇಪ್ಪತ್ತು ಮೂಲಂಗಿ ಬೆಳೆಯ ವಂಶವಾಹಿ ರೂಪಗಳ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ ಅಧ್ಯಯನವನ್ನು ೨೦೨೨-೨೩ ಅವಧಿಯಲ್ಲಿ ಕೆಳದಿ ಶಿವಪ್ಪ ನಾಯಕ ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ವಿಜ್ಞಾನಗಳ ವಿಶ್ವವಿದ್ಯಾಲಯದ ಅಡಿಯಲ್ಲಿ ಬರುವ ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯ ಮೂಡಿಗೆರೆಯ ತರಕಾರಿ ವಿಜ್ಞಾನ ವಿಭಾಗದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಮೂರು ಪ್ರತಿಕೃತಿಗಳೊಂದಿಗೆ ಯಾದೃಚ್ಛಿಕ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಗಿದ್ದು. ಎಲ್ಲ ವಂಶವಾಹಿ ರೂಪಗಳಲ್ಲಿ ಬೆಳವಣಿಗೆ ಹಾಗೂ ಇಳುವರಿಗೆ ಸಂಬಂಧಿಸಿದ ಗುಣಗಳಲ್ಲಿ ವೈವಿಧ್ಯಮಯ ವ್ಯತ್ಯಾಸವಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಅಧಿಕ ಅನುವಂಶಿಕತೆ ಜೊತೆಗೆ ಹೆಚ್ಚು ಅನುವಂಶಿಕ ಮುಂಗಡವನ್ನು ಸರಾಸರಿಯು ಬಿತ್ತನೆ ಮಾಡಿದ ೩೦ ಮತ್ತು ೪೫ ದಿನಗಳ ನಂತರ ಸಸ್ಯದ ಎತ್ತರ, ಬಿತ್ತನೆ ಮಾಡಿದ ೧೫ ದಿನಗಳ ನಂತರ ಎಲೆಗಳ ಸಂಖ್ಯೆ, ಬಿತ್ತನೆ ಮಾಡಿದ ೩೦ ಮತ್ತು ೪೫ ದಿನಗಳ ನಂತರ ಎಲೆಗಳ ಉದ್ದ, ಬಿತ್ತನೆ ಮಾಡಿದ ೧೫ ಮತ್ತು ೩೦ ದಿನಗಳ ನಂತರ ಎಲೆಯ ಅಗಲ, ಕೊಯ್ಲು ಮಾಡುವ ದಿನಗಳು, ಬೇರಿನ ಉದ್ದ, ಬೇರಿನ ವ್ಯಾಸ, ಬೇರಿನ ಸುತ್ತಳತೆ, ಬೇರಿನ ತೂಕ, ಬೇರಿನ ಪರಿಮಾಣ, ಪ್ರತಿ ಪ್ಲಾಟ್‌ಗೆ ಬೇರಿನ ಮತ್ತು ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ ಮೂಲ ಇಳುವರಿ ಗುಣಗಳಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಆದ್ದರಿಂದ ಈ ಮೇಲ್ಕಂಡ ಗುಣಲಕ್ಷಣಗಳು ನೇರ ಆಯ್ಕೆಗೆ ಸೂಕ್ತವಾಗಿದೆ. ಮಹಾಲನೋಬಿಸ್ ಡಿ ವಿಶ್ಲೇಷಣೆಯ ಪ್ರಕಾರ ೨೦ ಮೂಲಂಗಿಯ ತಳಿಗಳನ್ನು ೫ ಗುಂಪುಗಳಾಗಿ ವಿಂಗಡಣೆ ಮಾಡಲಾಯಿತು. ಅಧ್ಯಯನ ಮಾಡಿದ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಪ್ರತಿ ಪ್ಲಾಟ್‌ಗೆ ಬೇರಿನ ಇಳುವರಿ (ಶೇ. ೪೫.೨೬) ನಂತರ ಆಸ್ಟೋರ್ಬಿಕ್ ಆಮ್ಲ (ಶೇ. ೧೪.೭೪) ಮತ್ತು ಎಲೆ ಪ್ರದೇಶದ ಸೂಚ್ಯಂಕ (ಶೇ. ೧೪.೦೦) ಗುಣಗಳು ವೈವಿಧ್ಯತೆಗೆ ಗರಿಷ್ಠ ಕೊಡುಗೆಯನ್ನು ನೀಡಿವೆ. ಸಹಯೋಗದ ಅಧ್ಯಯನ ಫಲಿತಾಂಶದ ಪ್ರಕಾರ ಅತ್ಯಂತ ಗಮನಾರ್ಹ ಮತ್ತು ಗುಣಾತ್ಮಕ ಸಹಯೋಗವನ್ನು ಪ್ರತಿ ಪ್ಲಾಟ್‌ಗೆ ಬೇರಿನ ಇಳುವರಿ, ಸಸ್ಯದ ಎತ್ತರ, ಕೊಯ್ಲು ಮಾಡುವ ದಿನಗಳು, ಬೇರಿನ ಉದ್ದ ಮತ್ತು ಬೇರಿನ ತೂಕದಲ್ಲಿ ಕಂಡುಬಂದಿರುತ್ತದೆ. ಮಾರ್ಗ ಗುಣಾಂಕದ ಅಧ್ಯಯನದ ಪ್ರಕಾರ ಪ್ರತಿ ಪ್ಲಾಟ್‌ಗೆ ಬೇರಿನ ಇಳುವರಿ, ಎಲೆಯ ಉದ್ದ, ಎಲೆ ಪ್ರದೇಶದ ಸೂಚ್ಯಂಕ, ಕೊಯ್ಲು ಮಾಡುವ ದಿನಗಳು, ಬೇರಿನ ಉದ್ದ ಮತ್ತು ಬೇರಿನ ತೂಕದ ಗುಣಗಳ ಮೇಲೆ ನೇರ ಹಾಗೂ ಸಕಾರಾತ್ಮಕ ಪರಿಣಾಮ ಬೀರಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದ ಪ್ರಕಾರ ಕಾಶಿ ಹನ್ಸ್, ಕಾಶಿ ಶ್ವೇತ ಮತ್ತು ಓ.ಆರ್.ಬಿ.ಐ-೦೫೨೭ ತಳಿಗಳು ಹೆಚ್ಚಿನ ಇಳುವರಿಯನ್ನು ನೀಡಿದ್ದು ಇವುಗಳನ್ನು ಕರ್ನಾಟಕದ ಗುಡ್ಡಗಾಡು ವಲಯದಲ್ಲಿ ಮುಂದಿನ ಬೆಳೆಯ ಅಭಿವೃದ್ಧಿಯಲ್ಲಿ ಉಪಯೋಗಿಸಬಹುದಾಗಿದೆ.

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INTRODUCTION

I INTRODUCTION

Radish (*Raphanus sativus* L. $2n = 2x = 18$) belongs to the family Cruciferae, probably originated from Europe or Asia (Thompson and Kelly, 1957) is one of the most popular root vegetable crops, which is cultivated for its enlarged edible roots and leaves in both tropical and temperate climate. It is cultivated widely in Asia, Europe and the USA.

Radish is quick growing and short duration vegetable crop which is annual or biennial and classified broadly into two groups - European or temperate type and Asian or tropical type. Temperate types are smaller, mild in taste and mostly raised for salad. The tropical varieties adapt better to relatively higher temperature and humidity prevailing during the early sowing season. Radish is a cool season crop but Asiatic types can tolerate high temperature than temperate types. The roots develop best flavour, texture and size at a cooler temperature range of 10-15 °C (Angell and Hillyer, 1962). A long day with high temperature will result in bolting before proper root development. The roots also become hard, pithy and pungent during hot weather. The crop grown during the main season *viz.*, mid-September to early October, does not require any special technique. However, in the summer and spring season crop, the suitable cultivar should be selected and sown at proper season. Though radish can be grown on nearly all soil types, light friable loam soil is the best.

Radish has rosette of leaves, which may vary in size from 10-45 cm depending on the variety. It is a cross pollinated vegetable due to sporophytic system of self-incompatibility. The mode of pollination is entomophilous (Rubatzky and Yamaguchi, 1997). It also shows considerable amount of inbreeding depression on selfing.

Edible portion of radish is swollen root that develops from primary root and the hypocotyls. Roots are a good source of vitamin-C (ascorbic acid) containing 15-40 mg per 100 g of edible portion and supplies a variety of minerals. Trace elements in radish include aluminium, barium, lithium, manganese, silicon, titanium, fluorine and iodine. Tender leaves used as greens, are rich in vitamin-A and C besides this it also contains 3.4-6.8% carbohydrates, protein 0.7%, fat 0.2% and vitamin A 50 IU per 100 g of fresh edible portion. Pink skinned radish is generally richer in ascorbic acid than white-skinned. The characteristic pungent flavour of radish is due to volatile isothiocyanates (Bose *et al.*, 2000).

Its roots are used to prepare pickles and young leaves cooked as leafy vegetable particularly in Northern and Eastern India. Radish roots vary significantly in size, shape and other external characters as well as the length depending on cultivars. The shape varies from oblate to long tapering and exterior colours may be white or various shades of scarlet and even some of the white cultivars are white tipped.

Its consumption prevents constipation, increases appetite and helps to cure jaundice, liver disorders, and urinary complaints and piles (Brintha and Seran, 2009; Dhananjaya, 2007). In homeopathy, it is used for curing chronic diarrhoea, headache and sleeplessness. It can be used as companion plants for many other crops because their pungent odour deters insect pests such as aphids, cucumber beetles, tomato hornworms and ants.

Radish is mainly cultivated in West Bengal, Bihar, Uttar Pradesh, Karnataka, Punjab and Haryana. The area under radish in India is 209 thousand hectares, with an annual production of 3,346.71 metric tons. Radish is mainly grown in all districts of Karnataka, and the major districts are Bengaluru, Chikkaballapura, Chitradurga, Davanagere, Kolar, Ramanagara and Shivamogga. The area under radish in Karnataka is 5730 hectares, with a production of 67,900 metric tons and productivity of 11.85 tons per hectare (Anon., 2022). Therefore, the thrust is to increase the area and production of radish to meet the people's demands. To achieve this, the available genotypes, which are collected from different parts of India, are evaluated for their morphological, growth, root and quality parameters to evolve suitable high-yielding variety to local conditions.

Genetic variability is a measure of the tendency of individual genotypes in a population to vary from one another. Variability is an essential factor in evaluation, as it affects an individual's response to environmental stress and thus can lead to differential survival of organisms within a population due to natural selection of the fit variants. Genetic variability is an important factor for selecting the best genotypes for growing at an optimum period and making rapid improvement in yield and other related characteristics because most plant characteristics are polygenic in nature and are influenced by the environment. Therefore, it is necessary to work out whether the observed variability is heritable or due to the environment. Genotypic and phenotypic coefficients of variability help to assess the divergence of the characters. Realizing the significance of the crop, there is an urgent need to isolate such breeding lines with desirable horticultural traits, better quality, and high yield potential. Keeping this in view, an attempt was made to evaluate radish genotypes for cultivation under varying climatic conditions. The investigation would help to identify varieties to make radish roots available throughout the year.

Generally, diverse genotypes are expected to give high hybrid vigor (Harington, 1940). Hence, it necessitates the study of genetic divergence among different genotypes for the identification of divergent parents for the hybridization program. The information on the genetic divergence of various traits, particularly those that contribute to yield and quality, would be most useful in the proper planning of the breeding program. D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude for divergence between two genotypes under comparison. Grouping of

genotypes based on D² analysis will be useful in choosing suitable parental lines for heterosis breeding, which in turn helps the farmers to choose elite varieties.

Correlation analysis provides information on the nature and magnitude of the association of different component characters with root yield. It also helps us to understand the nature of inter-relationships among the component traits themselves. Ultimately, this analysis could help the breeder to design selection strategies to improve the yield.

Path coefficient analysis, which was developed by Wright (1921), is a standardized partial regression analysis that specifies the relative importance and measures the direct influence of one variable upon another by dividing the correlation coefficient into direct and indirect effects (Dewey and Lu, 1959). In horticulture, path analysis can help plant breeders identify traits that are useful as selection criteria to improve crop yield.

Identification of high variability and diversity for different yield-attributing traits is very important for hybridization for developing/identifying the high-yielding genotypes for the zone. Hence, the present study was undertaken to estimate the variability present in radish for quantitative and qualitative characters.

Keeping all the above-mentioned facts, the present investigation entitled "Genetic investigation of radish (*Raphanus sativus* L.) genotypes under hill zone of Karnataka" was carried out with the following objectives:

1. To know the performance of radish genotypes under hill zone of Karnataka.
2. To assess the variability and genetic diversity among radish genotypes.
3. To study the character association and path analysis for yield and its contributing traits.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Crop improvement is mainly concerned with improving the quantitative and qualitative characters of a crop. The information on quantitative and qualitative characters helps to select superior genotypes. The studies on these components increase the magnitude of success in developing an elite variety. An attempt has been made to review the literature related to the study on radish. However, the genetic investigation of different genotypes of radish will be helpful in identifying superior genotypes suitable to the hill region for future crop improvement programs. Hence, the literature related to radish and other root crops has been reviewed and presented in this chapter under the following subheadings.

2.1 Performance of radish genotypes

2.2 Genetic variability

2.3 Heritability and genetic advance over per cent of mean

2.4 Genetic diversity

2.5 Correlation studies and path coefficient analysis

2.1 Performance of radish genotypes

2.1.1 Morphological parameters

Mapari *et al.* (2009) studied twenty four diverse genotypes for different characters. They reported that plant height was from 25.97 (Hill queen) to 36.98 cm (IC-144463), number of leaves per plant at harvest ranged from 11.66 (IC-144494) to 19.53 (EXL11).

Chapagain *et al.* (2010) studied five commercial and local varieties of radish for their performance at different levels of manures and fertilizers and observed that the maximum number of leaves (20.48) in Bhetedar local.

An experiment was conducted on performance of summer carrot (*Daucus carota* L.) genotypes under temperate conditions of Kashmir valley and they found that SH-C-50 (11.66) recorded maximum number of leaves per plant followed by SH-C-33 and Chamman (10.00), SHC-130 (9.66) while minimum was recorded in SH-C-132 (7.66) (Jabeen *et al.*, 2010).

Kumar *et al.* (2012) studied variability and divergence for horticultural traits in temperate radish to develop new cultivars for commercial cultivation in Himachal Pradesh. They observed that the number of leaves was maximum (9.37) in cultivar CGN-17288 and minimum (5.93) in CGN-22078.

Ebrahimi *et al.* (2013) studied the effect of sowing dates on some qualitative and quantitative traits of three landraces of black radish. They concluded that Shiraz

had the maximum (13.10) number of leaves per plant compared to Yazd and Mashad varieties.

Panwar *et al.* (2013) found that the radish variety Century-11 produced a maximum (24.22) number of leaves per plant, which is on par with the variety Mino Early (24.08) under rainfed mid-hill conditions of Uttarakhand.

Eleven radish genotypes were evaluated by Kumari *et al.* (2016) under field conditions and low tunnel polyhouse. The results revealed that in the field and low tunnel polyhouse condition, among the genotypes, Garima recorded with maximum plant height (67.38 cm and 64.32 cm), greater leaf length (34.51 cm and 45.71 cm), maximum leaf width (12.34 cm and 9.05 cm) and maximum number of leaves per plant (20.33 and 13.91), respectively.

Mallikarjunarao *et al.* (2015) evaluated twenty four genotypes of radish and reported that the maximum number of leaves was recorded in CO-1 (17.69) and the minimum in Pusa Mridula (8.97). The maximum leaf length was observed in the genotype Pusa Mridula (35.24 cm). In contrast, the minimum leaf length was recorded in Moti Tawai Long Leaf (19.38 cm), the genotype Radish White Round recorded a maximum leaf width (13.75 cm) and the genotype Dronagiri recorded the minimum leaf width (7.92 cm).

An investigation was carried out by Dongarwar *et al.* (2018), who studied the growth parameters of various radish varieties with seven treatments and three replications in RCBD design. The growth parameter like plant height was maximum in Arka Nishant (28.29 cm) and minimum in Pusa Reshmi (23.50 cm). The maximum number of leaves was found in Japanese White (12.33). Whereas the minimum number of leaves recorded in Pusa Chetki (9.86).

Ola *et al.* (2018) conducted an experiment using twenty two varieties of radish to study their performance. The analysis of variance revealed highly significant differences among varieties for almost all the traits. The yield parameters showed that the Snow White variety showed maximum plant height (66.33 cm) and number of leaves (23.70).

Roopa *et al.* (2018) evaluated thirty genotypes of radish for genetic variability and heritability. They reported that the range of variation in the number of leaves was 8.80 (HRESB-32) to 13.80 (VRRAD-205).

Semba *et al.* (2019) conducted an experiment to assess the performance of six different varieties of radish. The maximum plant height (60.53 cm) and leaf length (32.545 cm) were observed in variety Menu Early, whereas the maximum number of leaves per plant (18.55) was observed in Local check.

Madaik (2020) evaluated twenty six radish genotypes for the performance studies. They reported that the number of leaves was found to be the maximum in the genotype RKR-Sel-IV (13.91). The minimum was recorded in UHF-SOL-RAD-5 (7.55) and the length of the leaves of radish genotypes varied from 25.65 cm (UHF-SOL-RAD-3) to 35.97 cm (RKR-6).

Assessment of the performance of eight varieties of radish viz., Vedetar Local, Miyasinge, Tokinasi, Pusa Chetki, Mino Early Long White F1, Ivory White F1, MAHY 22 F1 and All Season was carried out by Dahal *et al.* (2020). They reported the highest number of leaves per plant (20.54) in MAHY 22 F1 and the highest plant height (43.69 cm) in Tokinasi.

An experiment was conducted by Singh *et al.* (2021) to investigate the growth parameters of various radish varieties. The growth parameters like maximum plant height (56.52 cm), number of leaves per plant (19.81), leaf length (33.38 cm) and leaf width (13.04 cm) were found in Kashi Sweta.

Ashraf *et al.* (2022) evaluated the mean performance of twenty eight turnip genotypes and reported that maximum leaf length (24.43 cm) was found in Nageen and SKAU-T-15 (13.40 cm) was found superior for leaf breadth, SKAU-T-4 (55.60 cm) for plant length, SKAU-T-20 (11.33) for leaves per plant.

Singh *et al.* (2022) investigated using twenty radish genotypes to know the performance of various horticultural traits. Out of those, the maximum leaf length was recorded in the UHF-SOL-RAD-3 (35.97 cm) genotype.

Thakur *et al.* (2023) evaluated fifteen radish genotypes for high yield potential and better quality root. They reported that the maximum plant height recorded was 37.69 cm, while the minimum was 23.68 cm, and the number of leaves per plant ranged from 9.80 to 13.33. The spread of the plant (N-S) varied from 28.10 to 46.50 cm, while the spread of the plant (E-W) varied from 20.90 to 33.43 cm.

2.1.2 Growth parameters

Mapari *et al.* (2009) studied twenty four diverse genotypes for different characters. They reported that leaf area from 108.18 (Hill queen) to 153.31 cm² (EC-117074), fresh weight of leaves 93.71 (IC-144489) to 245.82 g (IC-144477), per cent dry weight of leaves 5.52 (IC-144458) to 12.34 per cent (IC-144477) and per cent dry weight of root ranged from 4.03 (EXL-11) to 8.18 per cent (IC-144459).

According to Panwar *et al.* (2013), the maximum leaf area (469.90 cm²) was recorded in radish cv. Dronagiri Local was among six varieties that were evaluated, while the minimum was recorded in Ankur Naveen (391.29 cm²).

Sivanthu *et al.* (2014) evaluated the performance of ten radish genotypes to assess yield stability across *rabi*, *summer* and *kharif* seasons. They reported that the

genotype Kumbakonam Local was stable for leaf area, followed by Kanyakumari Local 2.

Dongarwar *et al.* (2018) evaluated seven genotypes for growth, yield and qualitative parameters. The results showed that the genotype Arka Nishant had the maximum leaf area (120.92 cm²) and the minimum leaf area was observed in the genotype Pusa Himani (85.04 cm²).

Roopa *et al.* (2018) evaluated thirty genotypes of radish for genetic variability and heritability. They reported a range of variation in leaf area from 220.36 cm² (VRRAD-30) to 1800.52 cm² (HRESB-30).

An experiment was conducted to assess the performance of six different varieties of radish by Semba *et al.* (2019). The maximum fresh weight of leaves (97.61 g) was found in Menu Early, whereas the maximum fresh weight of root (160.16 g) and dry weight of root (10.96 g) was recorded in the variety Korean Cross and dry weight of the leaves (10.17 g) in Snow White variety.

Naik *et al.* (2022) conducted an experiment to investigate the impact of growth and physiological aspects of knol khol. They reported leaf area (164.50 cm²), fresh weight (215.80 g), dry weight (40.05 g), leaf area index at 25 DAT and 45 DAT (0.0257 and 0.0637), specific leaf area (102.13), specific leaf weight (0.0135) and absolute growth rate (0.816).

Thakur *et al.* (2023) evaluated fifteen genotypes of radish for high yield potential and better quality root. The results indicated that the fresh weight of leaves and roots ranged from 71.29 to 109.59 grams and 72.81 to 153.75 grams, respectively. In contrast, the dry weight of leaves and roots varied from 8 to 11 g and 9.32 to 19.68 g, respectively.

2.1.3 Root parameters

Soomro *et al.* (2006) evaluated four sugar beet cultivars under Pakistan conditions and reported that the KWS-1451 cultivar produced a maximum yield of 105.77 tonnes per hectare.

Ali *et al.* (2007) studied the performance of two carrot varieties, among them cv. NK recorded maximum yield (23.55 t/ha), whereas cv. SB gave the lowest yield (18.41 t/ha).

Ijoyah *et al.* (2008) noted yield performance of four beetroot varieties compared with the local variety under open field conditions in Seychelles. They reported that variety “Crosby” produced the maximum root length of 11.58 cm and root weight per plant of 125.50 g in addition to the best yield of 48.65 tonnes per hectare.

Alam *et al.* (2010) concluded that radish cv. SAU line-1 recorded the highest (42.2 kg) yield per plot and the lowest was in Tasakisan (37.6 kg) and Red Bombay (36.4 kg).

Jabeen *et al.* (2010) studied fifteen genotypes of carrot for performance studies. They reported maximum root yield in SH C-131 (157.00 q/ha). Genotype SH-C-131 was superior for most traits, viz., root length, root diameter and yield. Hence, it can be recommended for further evaluation.

An experimental finding of Naseeruddin *et al.* (2014) to identify the suitable radish varieties for cultivation and high yield revealed that the maximum root diameter of 5.79 cm was observed in Pusa Chetki among twenty varieties.

Datta *et al.* (2015) evaluated the performance of eleven radish genotypes. Among these, the highest root diameter was observed in the Long Chetki (4.92 cm) variety, and the maximum root length was recorded in Japanese White (16.54 cm), which was statistically at par with Long Chetki (16.40 cm) and Pusa Desi (15.77 cm).

An investigation on twelve varieties of radish was conducted by Thorat *et al.* (2015) with respect to the growth and yield and found varieties such as Indem Sweta, Ankur Naveen, Ganesh Synthetic and Pusa Reshmi had shown significantly superior performance with respect to most of the growth and yield quality attributes and found that root weight was maximum (255.33 g) in variety Ankur Naveen which was statistically at par with Radish J.W. (218.67 g) and Pune local (208.67 g) while minimum weight of root (130.67 g) was recorded in variety Solapur local. The yield of the maximum (37.75 t/ha) was recorded in variety Indem Sweta, and the minimum (17.47 t/ha) was recorded in Solapur local.

Kumari *et al.* (2016) conducted an experiment to assess the performance of eleven genotypes of radish during the winter season under field conditions and low tunnel polyhouse. The results revealed that the maximum length of the root (29.49 cm and 37.37 cm), the diameter of root (5.76 cm and 2.40 cm), weight of root (172.57 g and 93.15 g) and the whole plant weight (285.94 g and 168.72 g), respectively in variety Garima.

Ola *et al.* (2018) conducted an experiment using twenty two varieties of radish to study their performance. The analysis of variance revealed highly significant differences among varieties for almost all the traits. The root parameters showed that maximum root yield per plot and root yield per hectare were recorded in Evergreen 30.56 kg and 509.28 q, respectively. In comparison, the minimum was recorded in Pusa Mridula 15 kg and 250.05 q, respectively.

Dongarwar *et al.* (2018) investigated growth, yield and qualitative parameters of various radish varieties and they reported that values of root diameter (3.69 cm) and root yield per plot (32.34 kg/plot) were recorded maximum in Arka Nishant.

An experiment was conducted to evaluate thirty genotypes of radish by Roopa *et al.* (2018) and reported that root diameter 20.62 mm (White Icicle) to 36.71 mm (VRRAD-205), root length varied from 16.82 cm (White Icicle) to 30.46 cm (HRESB-17), root weight varied from 22.73 g (White Icicle) to 171.35 g (HRESB-8), root yield per plot ranged from 2.18 kg (White Icicle) to 16.45 kg (HRESB-8), root yield per hectare 5.08 (White Icicle) to 38.26 tonnes (HRESB-8) and days to harvest varied from 27.50 days (White Icicle) to 43.75 days (HRESB-6 and HRESB-32).

Poudel *et al.* (2018) evaluated the performance of five radish varieties and the average performance revealed that the radish genotypes HRD RAD 002 (37.91 t/ha), followed by HRD RAD 004 (28.91t/ha) were found to be promising, with better adaptability, higher root weight, root length and yield.

An experiment was conducted to assess the performance of six different radish varieties. The results indicated that the genotype Korean cross recorded the maximum root length (34.63 cm). While the minimum was recorded in Scarlet Globe (10.90 cm). The root width was observed maximum in Scarlet Globe (4.44 cm) and the genotype Long Red (2.22 cm) recorded minimum root width. The maximum root yield per hectare was observed in the genotype Korean cross (46.91 t/ha), while the minimum was recorded by Scarlet Globe (5.99 t/ha) (Semba *et al.*, 2019).

Shreshta *et al.* (2021) studied five open pollinated cultivars of radish and found that out of the five cultivars, Okura gave significantly highest root weight (326 g), root yield (53.85 t/ha), root length (25.5 cm), root diameter (53.9 mm) and days to harvest (63 days) followed by Miyasige which had root weight (259 g), root length (23.4 cm), root diameter (51.9 mm) and days to harvest (66 days).

Singh *et al.* (2021) investigated various radish varieties' growth, yield and qualitative parameters. They reported that root length (30.89 cm), root diameter (54.64 mm), root weight (165.46 g), root yield per plot (4.467 kg) and root yield per hectare (446.50 q) were found maximum in Kashi Sweta.

Makhdoomi *et al.* (2022) investigated the mean performance of carrot (*Daucus carota* L.) genotypes for yield and yield contributing characters and the results revealed that SK-C-13 performed best in terms of all the characters studied, *i.e.*, root length (16.30 cm), root diameter (2.86 cm), root weight (62.86 g) and yield (260.92 q/ha).

Thakur *et al.* (2023) evaluated fifteen genotypes of radish for high yield potential and better quality root. They reported that the root diameter varied from 3.14 to 5.65 cm, the root length ranged from 16.28 to 31.03 cm and the weight of the roots varied from 72.81 to 153.75 g.

2.1.4 Quality parameters

Five radish cultivars were evaluated by Anjanappa *et al.* (1998) and observed that leaf number did not differ significantly between cultivars. However, root shape varied from tapering (Local) to conical (Arka Nishant) and cylindrical (others) and, in the case of flesh colour pink colour flesh in Chinese Pink and white in Arka Nishant.

Langthasa and Barah (2000) analysed the performance of nine radish cultivars and found the root colour was white in all the cultivars except Crimson French Breakfast and Bombay Red, which had crimson roots and red roots with white tips, respectively. The root shape was conical in Japanese White, globular in Crimson French Breakfast, and elongated in the remaining cultivars.

Mapari *et al.* (2009) studied twenty four diverse genotypes for different characters. The results indicated that per cent forked root from 7.02 per cent (Pusa Chetki) to 22.68 per cent (IC-144456).

An investigation was carried out to assess the performance of four radish varieties by Priyanka (2015). The results indicated that minimum root forking (1.42 %) was recorded with the first fortnight of September (S4), significantly superior to the rest of the sowing dates. Maximum root forking (62.92 %) was recorded with the second fortnight of July sowing.

Singh (2020) conducted an experiment on eighteen varieties of radish. They reported that the root shape and color based on visual inspection and found that three genotypes *viz.*, R-COHF-NERI-8, R-COHF-NERI-9 and R-COHF-NERI-12 had red coloured roots and hence showed the presence of coloring pigments in them. While the majority of genotypes (15 in number), including check (Japanese White), had white coloured roots.

2.1.5 Biochemical parameters

Mapari *et al.* (2009) studied twenty four diverse genotypes for different characters. The results indicated that chlorophyll content in leaves ranged from 2.78 (IC-144490) to 3.06 mg per g (S-55) and ascorbic acid content in roots ranged from 15.30.

Jahan *et al.* (2011) screened different radish genotypes for nutrient contents and found that the variety BARI Mula-1 contained the highest amount of total sugars.

Kumar *et al.* (2012) evaluated thirty five diverse genotypes of European radishes and observed that the total sugar ranged from 0.15-1.51 per cent and the highest total sugar was found in genotype CGN-11994 (1.51 %).

Dongarwar *et al.* (2018) studied various radish varieties and found that chlorophyll content was recorded at a maximum (3.10 mg/g) in Arka Nishant.

An experiment using twenty two varieties of radish to study their performance by Ola *et al.* (2018). The results indicated that the maximum vitamin C (27.14 mg/100g) was recorded in variety Baramasi, whereas the minimum vitamin C (12.11 mg/100 g) was recorded in variety M.E.L.W.

Roopa *et al.* (2018) evaluated thirty radish genotypes for genetic variability and heritability characteristics. The results indicated a wide range of variation was observed for all the biochemical parameters; ascorbic acid ranged from 7.23 mg per 100 g (White Icicle) to 34.23 mg per 100 g (HRESB-8).

Arya *et al.* (2020) conducted an experiment on the performance of beetroot varieties for growth, yield and quality. They reported that Madhur recorded the highest total sugars (6.45 %) and non-reducing sugars (6.03 %) compared to other varieties.

Dahal *et al.* (2020) conducted an experiment using eight varieties of radish and the results revealed the highest ascorbic acid content (19.51 mg/100 g) in Ivory White F1.

Twenty eight genotypes of turnip (*Brassica rapa* var. *rapifera* L.) were evaluated for comparative performance for various quantitative and quality traits. They reported that the highest Vit. C content in SKAU-T-1 (33.00 mg/100g), total sugars in SKAU-T-14 (3.80 %), reducing sugars in SKAU-T-14 (2.70 %) and non-reducing sugar SKAU-T-24 (1.48 %) among all the varieties (Ashraf *et al.*, 2022).

2.1.6 Organoleptic test

Pujari *et al.* (1977) experimented on twelve radish cultivars under Sabour condition and studied the root qualities at the edible harvest stage. The quality of roots was assessed in terms of shape, appearance and taste of roots. It was observed that the roots were reddish to white, fusiform to cylindrical in shape and slightly pungent to sweet. The cultivars like Pusa Himani, Pusa Reshmi and Japanese white had attractive roots and agreeable taste.

An experiment was conducted by Rajagopal *et al.* (1979) on eleven varieties of radish and discussed the quality attributes of these varieties. It was observed that the colour of the roots was white in all the varieties. The pungency was low in Pusa Chetki, medium in Hissar -1, Punjab Safaid, Bombay Long and Pusa Reshmi and strong in the rest of the varieties. The shape of the roots was conical in T. 1, R.S.13 and Japanese White. The roots of Pusa Chetki were medium-long and long in the case of other varieties tested. They further reported that the varieties Pusa Chetaki and Punjab Safaid showed high-yielding potential as the roots of these varieties possess better consumer appeal. Hence, these varieties are suitable for cultivation in Tamil Nadu conditions.

Rao and Manohar (1990) studied three cultivars of radish and reported that the maximum pungency was observed in Pusa Reshmi (0.02), followed by Nerima long

(-0.19) and minimum in Pusa Chetaki (-0.67). Pungency grading was given for high 0.85, medium 0.00 and low -0.85.

Arya *et al.* (2020) conducted an experiment on the performance of beetroot for growth, yield, quality and sensory evaluation, revealing the superiority of the variety Madhur and the hybrid Red Star (Sakura) for appearance, colour, taste and overall acceptability over other varieties and hybrids.

2.2 Genetic variability

The variability studies help the plant breeder to make an effective and efficient selection of genotypes from the available material, which can be utilized for the further crop improvement programme. The success of any breeding programme mainly depends on the extent of genetic variability available in the genotypes. The phenotypic coefficient of variability (PCV) and genotypic coefficient of variability (GCV) are measured to study the genetic variability present in crop varieties. Literature on genetic variability and its components has been reviewed and cited here.

Mukhdoomi *et al.* (2007) studied genetic variability in twenty three genotypes of radish and they revealed that both phenotypic as well as genotypic coefficients of variation were high for all the characters except for days to maturity and ascorbic acid content of roots.

Mapari *et al.* (2009) conducted an experiment on twenty four genotypes of radish and the study revealed that a high genotypic coefficient of variation, as well as phenotypic coefficient of variation, was observed for the fresh weight of leaves.

Twenty five diverse genotypes of radish were evaluated by Rajput *et al.* (2009) for mean genetic variability in respect of fourteen quantitative characters. The narrowest range of variation was observed for root to leaf weight ratio and leaf shape. The genotypic and phenotypic variance was high for root weight. Root to leaf weight ratio and root weight recorded high genotypic and phenotypic coefficients of variation, which indicated the nature and genetic variability for these characters.

Murlee *et al.* (2009) studied a wide range of variability in carrot and the results revealed the PCV and GCV varied from 3.71 to 20.88 and 2.46 to 15.75 per cent, respectively.

An experiment was conducted to evaluate twenty diverse genotypes of radish for different characters. The highest genotypic coefficient of variation, as well as phenotypic coefficient of variation, was observed for root weight. Almost all the characters exhibited high heritability recorded (60.77 to 94.80 per cent). The highest range for genetic advance was also observed from 2.41 to 66.50 per cent for all the characters (Jain *et al.*, 2010).

Ullah *et al.* (2010) studied the extent of genetic variability in twenty one genotypes of radish. They reported a high genotypic coefficient of variation for root length, leaf length and root yield.

Khan *et al.* (2011) computed twenty genotypes of radish to study the genetic variability, heritability and genetic advance in radish and observed that the number of leaves, total plant weight, root yield per plant and ascorbic acid content were observed maximum genotypic as well as phenotypic coefficient of variation.

An investigation was carried out by Naseeruddin *et al.* (2011) twenty two genotypes of radish to study the genetic variability and reported that both genotypic as well as phenotypic coefficients of variation were high for the number of leaves, leaf weight, total plant weight, root yield per plant, acidity and ascorbic acid content.

Singh and Singh (2012) conducted an experiment to assess the genetic variability of seedling vigor in radish. The studies revealed that high PCV values were obtained in fresh weight (32.68 %).

Ten genotypes of radish were evaluated for variability parameters by Sivanthu *et al.* (2014). The studies revealed that the number of leaves, root diameter, fresh weight of the plant, dry weight of the plant and fresh weight of root per plant had high genetic variability. Moderate GCV and PCV were recorded by leaf length, leaf width, number of leaves and root diameter.

Jamatia *et al.* (2015) evaluated twenty rat tail radish genotypes and reported the highest genotypic and phenotypic coefficients of variation for yield per plant in comparison to other characters, indicating the presence of high amount of genetic variability for these characters.

Jabal *et al.* (2015) conducted an experiment to estimate phenotypic variances of six local genotypes of radish and observed significant differences between genotypes for diameter, length and weight of radish root.

Mallikarjunarao *et al.* (2015) reported that both genotypic and phenotypic coefficients of variation were high for the number of leaves, leaf weight, total plant weight, root yield per plant, acidity and ascorbic acid content.

Nagar *et al.* (2016) studied twenty one genotypes of radish in *rabi* season for genetic variability. They reported moderate phenotypic and genotypic coefficients of variation for ascorbic acid, shelf life without leaves, shelf life with leaves and dry matter content.

An experiment was conducted to evaluate the diverse carrot genotypes under tropical conditions for their genetic variability parameters during summer by Chaithra *et al.* (2017). The analysis of variance revealed that the genotypic coefficient

of variation (GCV) and phenotypic coefficient of variation (PCV) were high for all the traits studied, indicating the existence of variation for all the characters studied.

Teli *et al.* (2017) studied genetic variability in thirty genotypes of carrot. They reported a higher magnitude of the phenotypic coefficient of variation (PCV) than the corresponding genotypic coefficient of variation (GCV) for all the characters, which indicated the role of environment on the character expression.

A study was carried out to assess the extent of genetic variability for ninety six genotypes of carrot. The analysis of variance revealed highly significant differences among the genotypes for all the characters. PCV was higher than GCV, which indicates the role of environmental factors on the expression of various traits and traits like root weight possessed a higher value of GCV (Kulkarni *et al.*, 2019).

Singh *et al.* (2019) studied forty genotypes of European carrot and they observed high PCV for root diameter, root weight, root yield and flesh thickness, indicating additive gene action.

An experiment was conducted to assess the genetic variability of eighteen genotypes of radish by Singh (2020). The results indicated high phenotypic and genotypic coefficient of variation existed for root yield per plot, root diameter, average root weight with leaves, average root weight without leaves, ascorbic acid and number of leaves per plant. Moderate phenotypic and genotypic coefficient of variations were exhibited for root length, crown diameter, leaf length, and leaf width. The characters, like plant height and days taken to marketable maturity, showed low magnitude of phenotypic and genotypic coefficients of variation.

Mashkey *et al.* (2021) studied the genetic variability for quantitative and qualitative traits in twelve genotypes of radish in a Random Block Design with three replications. They reported that the overall values of GCV were lower than the PCV for all the traits studied, which suggests that the phenotypic expression of characters was largely influenced by the prevailing environmental conditions.

Jakhwal *et al.* (2022) evaluated twenty genotypes of Radish in RCBD with three replications during the rabi season to know the nature and magnitude of variability. They reported a higher phenotypic coefficient of variation (PCV) than the genotypic coefficient of variation (GCV) in all the attributes studied. The PCV and the GCV values were found to be high in root weight without leaves (g).

Kumar *et al.* (2022) conducted an experiment on fifteen genotypes of carrot to study the variability among the genotypes. The analysis of variance revealed a high genotypic co-efficient of variation as well as phenotypic co-efficient of variation for net root weight per five plants (kg), yield (qt. / ha.), root girth (cm) and root length (cm).

Palvi *et al.* (2022) conducted an experiment on twelve genotypes of turnip to know the extent of genetic variability. The studies revealed that leaf area, plant spread and ascorbic acid content expressed high GCV and PCV values.

Rana *et al.* (2022) evaluated twenty three genotypes of carrot to study the nature and extent of genetic variability. The study revealed that the phenotypic coefficient of variation was greater than the corresponding genotypic coefficient of variation for all the traits, indicating that the environment has a significant impact on character expression.

Eighteen diverse genotypes of Asiatic radish were evaluated by Singh *et al.* (2022) for GCV and PCV. They reported that a wide range of genetic variability was observed in all genotypes of the radish for almost all characters. Relatively high genotypic and phenotypic coefficients of variation were recorded for leaf size, leaf weight per plant, leaf length and root size.

Thakur *et al.* (2023) conducted an experiment to investigate superior radish cultivars for selection having high yield potential and better quality roots for the Bastar plateau. They reported high genotypic and phenotypic coefficient of variation for dry and fresh weights of roots, plants and leaves, diameter and length of the root, North-South and East-West spread of the plant, plant height and the number of leaves per plant.

2.3 Heritability and genetic advance over per cent of mean

The ratio of genotypic variance to the phenotypic variance or total variance is known as heritability. Thus, heritability is the heritable portion of phenotypic variance. It is a good index of the transmission of characters from parents to their offspring. Continuous variation exhibited by a quantitative character includes the heritable and non-heritable components (Fisher, 1918). A heritable component is the result of a genotype, whereas non heritable part is due to environmental factors. This knowledge of the heritability of different traits is essential for crop improvement as it is inherited from generation to generation. Wright (1921) reported that the heritability component comprised additive and non-additive portions and it was the more which responds to the selection.

While improvement in the mean genotypic value of selected plants over the parental population is known as genetic gain under selection. According to Allard (1960), the success of genetic advancement under selection depends on three main factors: genetic variability, heritability and selection intensity. Estimates of genetic advances help in understanding the type of gene action involved in the expression of various polygenic characters. Additive gene action is indicated by high values of genetic gain and low values are indicative of non-additive gene action.

However, it is not mandatory that a character showing high heritability will also exhibit high genetic advance (Johnson *et al.*, 1955). High heritability accompanied by high genetic advance indicates that the heritability might be due to additive gene effects (Panse, 1957), whereas the high heritability associated with low genetic advance might be due to non-additive gene action, which includes dominance and epistasis (Liang and Walter, 1969). Low heritability, along with high genetic advance, reveals that the character is governed by additive gene effects. The low heritability is being exhibited due to high environmental effects. Thus, selection may be ineffective in this case. The earlier studies on heritability and genetic advancement in radish are reviewed below:

An investigation was carried out to evaluate thirty two genotypes of Asiatic carrot for estimating the variability and reported high heritability estimates for average fresh root weight with leaves, plant height and leaf length. High estimates of genetic advance were recorded for root weight with leaves and average fresh root weight. The high heritability was associated with high genetic advance as per cent of the mean for average fresh root weight and root weight with leaves and was found to be the most reliable selection parameter (Singh *et al.*, 2004).

Hussain *et al.* (2005) reported that broad sense heritability was high for all characters in carrot except root diameter, which showed medium heritability. Most of the traits indicated the dominance of additive gene effects; hence, the direct selection for such traits may lead to an improvement in quality.

Singh *et al.* (2005) studied the genetic variability and character association in twenty one diverse genotypes of radish under temperate conditions in Kashmir. The traits like root yield followed by average root weight, average leaf weight, top to root ratio, root length, root diameter and number of leaves per plant had high heritability coupled with high genetic gain. This indicated that these characters had additive gene effects and therefore, these are more reliable for effective selection.

Mukhdoomi *et al.* (2007) evaluated twenty-three genotypes of radish and explained that heritability in broad sense was high for all the characters while genetic gain was maximum for root length followed by root to leaf ratio.

Mapari *et al.* (2009) assessed genetic variability among twenty-four genotypes of radish and reported that heritability was high for all characters (31.42 % - 99.58 %) while root diameter had the highest genetic advance. However, it ranged from 3.04 to 91.12 per cent for all the characters.

Jain *et al.* (2010) observed a high genotypic coefficient of variation and phenotypic coefficient of variation for root weight. Almost all characters exhibited high heritability and genetic advance over per cent mean in carrot.

Mehdi *et al.* (2010) reported high heritability estimates along with high genetic advances for characteristics like root diameter, number of leaves per plant and root yield in turnip.

Rashid *et al.* (2010) evaluated nineteen genotypes of *Brassica rapa* and reported high heritability and high to moderate genetic advance in the percentage of mean observed for plant height.

An experiment was conducted by Tanaka *et al.* (2011) on diallel analysis of root shape in Japanese radish. The root length showed high broad sense heritability, a high narrow sense heritability and incomplete dominance, while the root diameter showed high broad sense heritability and low narrow sense heritability. They reported that dominant genes for the root length root diameter had effects to elongate the root length, enlarge root diameter and increase the ratio of the root diameter to root length and increase tapering of the root, respectively.

Vieira *et al.* (2012) conducted an experiment on heritability in seventy four genotypes of radish and found that the heritability for root length ranged from 12 to 44 per cent. The other traits ranged from 3 per cent (root diameter) to 79 per cent (Leaf length).

An experiment was conducted using forty eight genotypes of Asiatic and European carrot and the results revealed high heritability estimates for plant weight, root weight, total yield and marketable yield. High estimates of genetic advance were recorded for total yield and marketable yield. The high heritability was associated with high genetic advance as a percentage of the mean for total yield, marketable yield, plant weight and root weight (Asima *et al.*, 2013).

Naseeruddin *et al.* (2014) evaluated twenty genotypes of radish and found that heritability in broad sense was high for the number of leaves, total plant weight, root weight and ascorbic acid. Genetic advance over per cent of mean was the maximum for root yield per plant followed by leaf weight.

Sivanthu *et al.* (2014) evaluated ten radish genotypes for variability parameters. The season altered the estimates of heritability and genetic advance as a percent of the mean. The number of leaves, root diameter, fresh weight of the plant, dry weight of the plant and fresh weight of root per plant had high heritability and genetic advance in all seasons.

Santhi *et al.* (2015) studied the genetic variability in sixteen varieties of carrot and concluded that high heritability was observed for root weight, the number of leaves and root diameter, whereas low heritability was observed for root length and root to top ratio during both seasons and genetic advance expressed as a percentage of mean was relatively low for the characters *viz.*, root length and root to top ratio.

Nagar *et al.* (2016) evaluated twenty genotypes of radish in the rabi season of 2014-2015 for different horticultural traits. The traits like root length and root diameter had high heritability coupled with moderate genetic gain.

Teli *et al.* (2017) studied genetic variability in thirty genotypes of carrot. The genotypes RAJC-11, RAJC-7, and HRC-1 were the best with respect to the highest total yield per hectare. Root weight per plant, root to shoot ratio and yield per hectare possessed higher values of heritability and genetic gain.

Ullah *et al.* (2017) conducted genetic variability studies in twenty one varieties of radish and stated that root length and root yield showed a high genotypic coefficient of variation and heritability with a high genetic advance in the percentage of the mean. However, root yield observed the highest genetic advance.

Thakur *et al.* (2023) conducted an experiment to investigate superior radish cultivars for selection having high yield potential and better quality roots for the Bastar plateau. They reported high heritability for root yield and fresh and dry weights of roots. Moderate heritability levels appeared for the traits, *viz.*, the plant's dry weight and the root diameter. The genetic gain resulted in a high number of characters, *viz.*, root yield and fresh and dry weights of roots.

2.4 Genetic diversity

In plant breeding, genetic diversity plays an important role because hybrids between lines of diverse origin generally display greater heterosis than those between closely related parents. Data on the level of genetic diversity of a germplasm collection also increases the efficiency of efforts to improve a species (Geleta *et al.*, 2005). The morphologic characterization, evaluation of the genetic diversity and documentation of a gene bank are essential to maintain an active basis for the exploration of genetic variability in breeding programs (Viana *et al.*, 2006 and Arriel *et al.*, 2007).

D² statistics is a numerical approach which is used for measuring genetic divergence in the germplasm. This concept was developed by Mahalanobis in 1936. The application of this technique for the assessment of genetic diversity in plant breeding was suggested by Rao (1952). D² measures the degree of diversification and determines the relative proportion of each component character to the total divergence. The forces of differentiation are measured at two levels, *i.e.*, intra-cluster and inter-cluster levels. The clusters which are separated by the largest statistical distance show the maximum divergence.

Qureshi *et al.* (2009) studied genetic divergence among indigenous germplasm of winter vegetables (Radish and Turnip). The phenogram of radish germplasm revealed five clusters at 50 per cent dissimilarity. Genetic diversity ranged from 0.45- 9.40. They observed that maximum diversity was in the germplasm collected from

three different locations of Pakistan, viz., Attock, followed by material collected from TT Singh and Lahore. This was due to the greater environmental stresses in those areas, thus representing high biodiversity.

Ivy *et al.* (2010) characterized seventy eight radish genotypes using esterase and peroxidase isoenzyme, and the result revealed that all the genotypes were classified into eight major clusters designated as I, II, III, IV, V, VI, VII, and VIII. The highest number of 21 genotypes was found under cluster number I, which represented 27 per cent of the total genotypes, followed by cluster VI contained 17 genotypes. The lowest number (4) of genotypes was found under cluster VII, followed by cluster III. The result indicated that the zymotype of higher frequency is representative of less variation. The lower frequency of the germplasm in different zymotypes indicated higher variation among the genotypes.

Singh and Ahmed (2010) evaluated twenty one genotypes of radish. All genotypes were grouped into seven clusters and it revealed that cluster 5 had maximum distance (18.73). High and low intra-cluster distances suggested that the population groups were nearly homogeneous between clusters.

An experiment was conducted to assess forty-nine local and exotic genotypes of radish, including two checks by Jatoi *et al.* (2011). A high variation in germplasm for root shape, root length, root colour (internal and external), flesh texture and root type were observed. Cluster analysis on the basis of genetic diversity for seven quantitative traits resulted in four clusters. No clustering was found on the basis of origin. On the basis of high yield and crispy root texture, some genotypes (10076, 10362, 10429, 10658, 10662 and 10667) were identified for further testing under a wide range of agro-ecological conditions.

Kumar *et al.* (2012) evaluated thirty five temperate radish genotypes at Solan, India, to study variability and divergence for horticultural traits in temperate radishes. The genotypes were grouped into four clusters. The highest inter-cluster distance was between clusters II and IV, indicating that hybridization between these clusters could be utilized for developing transgressive segregants in subsequent generations. They also made observations on different traits and observed that genotype CGN-17290 had 51 percent more yield over the check 'White Icicle' and performed better for days to marketable maturity, root-to-top ratio, root length, average root weight, and fiber content, indicating a close association between phenotype and genotypes.

Naseeruddin *et al.* (2014) evaluated twenty genotypes of radish using 19 quantitative and qualitative traits. The maximum intra-cluster divergence was observed for cluster II and the least for cluster III. However, the maximum inter-cluster divergence was observed for cluster II and cluster IV and least for cluster I and cluster

III. They revealed that genotypes falling in cluster II having maximum divergence might be used in hybridization programmes for further crop improvement.

Kumar *et al.* (2014) conducted an experiment using D² analysis to study the genetic variability in twenty nine genotypes of radish. The genotypes in cluster III recorded maximum intra-cluster distance. Maximum inter-cluster distance between clusters I and II suggested a wide diversity between the groups. Highest gross root weight, net root weight, root length, root diameter, and yield were recorded in cluster II. The results revealed that clusters II, VI and IV might be employed for further breeding programmes in temperate carrots.

Ashraf *et al.* (2022) conducted an experiment on twenty eight turnip genotypes for diversity studies. The genotypes were grouped into five clusters. Cluster I had the maximum number of genotypes (17), followed by cluster II with six genotypes, cluster III with three genotypes and cluster IV and V with one genotype each. Maximum intra-cluster distance was recorded in cluster II (179.19), followed by cluster III (177.92). Maximum inter-cluster distance was observed between cluster IV and V (1518.63), followed by inter-cluster distance between cluster III and V (996.20). Maximum contribution towards total divergence was shown by total root weight (33.86 %) followed by leaf area (26.23 %).

Manisha *et al.* (2022) evaluated eighty accessions in RBD with three replications. The Mahalanobis' D² analysis grouped these accessions into seven clusters. Cluster I was the largest with sixty nine genotypes, followed by cluster III, comprising six genotypes, while clusters II, IV, V, VI, and VII contained one genotype each. Among the traits studied, yield contributed maximum (38.04 %) towards diversity, followed by root weight (26.58 %), root colour (9.18 %) and plant height (6.7 %). Diversity analysis has given an indication of the genetic variation among the carrot accessions, which will prove useful in the selection of diverse parents in the crop improvement programme.

Singh *et al.* (2022) evaluated 81 genotypes of carrot for genetic diversity. The divergence analysis grouped all 81 genotypes into ten clusters, and cluster VI was the biggest, comprising 30 genotypes. Cluster X exhibited a high mean value for root weight and anthocyanin content, cluster III showed a high value for days to first root harvest and root girth, and Cluster V for dry matter content, total sugar content, and carotene content, respectively. The maximum distance between clusters was recorded among II and X clusters (43,678.5) followed by I and X (43,199.7), and it indicated that genotypes from these far away clusters could be used efficiently in breeding programs to obtain superior hybrids.

2.5 Correlation studies and Path coefficient analysis

Correlation is a measure of association between two traits working at the same time (Hayes *et al.*, 1955). Correlation is used to find out the degree and direction of the relationship between two or more variables. Yield is a complex trait that is polygenically controlled, and its expression depends on the performance of a number of component traits. Hence, the selection of superior genotypes based on yield performance is usually ineffective.

For selecting superior genotypes, the breeder has to choose the material on the basis of phenotypic expression. As most of the traits of economic importance are complex, involving several related traits, the knowledge of the correlation between these traits is essential (Robinson *et al.*, 1951). The association between two variables that can be directly observed is termed a phenotypic correlation. Phenotypic correlation fails to give the true picture of the relationship between two characters because, along with genetic value, it is also influenced by the environment. Therefore, genotypic correlation is essential for studying the natural genetic variation in different characters and the manner in which environmental variation affects the expression of such variation. The genetic improvement in dependent traits can be achieved by applying strong selection to a character that is genetically correlated with the dependent character. This is called correlated response. Correlation studies provide a better understanding of yield components that help the plant breeder during selection (Johnson *et al.*, 1955).

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

Zhao *et al.* (2008) conducted an experiment on the nutritional quality of forty-two Chinese radish cultivars, and they reported that dry matter content was positively correlated with the content of vitamin C and protein. While, the vitamin C content of radish showed a positive correlation with the protein content.

Research findings of Mapari *et al.* (2009) on correlation studies in twenty four genotypes of radish showed that root yield per plant was closely associated with the number of leaves per plant at harvest, fresh weight of leaves, root length, total plant weight and days required to harvest.

Kumar *et al.* (2009) conducted a correlation study with European radish genotypes and revealed that the average root weight, seed germination, number of leaves, leaf length, leaf width, root top ratio, root length and root diameter had a positive correlation with root yield. These characters largely contributed to yield, and thus, selection for these characters will effectively improve the yield.

Meena *et al.* (2010) conducted an experiment on correlation in thirty genotypes of cabbage. They concluded that days to maturity (-0.135) and leaf width (- 0.121) had a direct negative effect, but correlation with yield is positive except days to maturity owing to indirect through all the characters.

Rashid *et al.* (2010) evaluated nineteen genotypes of *Brassica rapa* to analyze the correlation and path coefficient in the traits. The correlation and path coefficient analysis studies suggested that more emphasis should be given to plant height during selection.

Association studies revealed that root yield in turnip exhibited a significant positive correlation with root diameter and leaf length at genotypic levels and the number of leaves per plant at both genotypic and phenotypic levels, while leaf yield has a significant positive correlation with leaf length and number of leaves per plant in turnip conducted by (Mehdi *et al.*, 2010).

Ullah *et al.* (2010) conducted an experiment involving twenty one radish varieties for correlation and path coefficient analysis of yield and yield contributing traits. They reported that leaf length was negatively associated with root diameter.

Naseeruddin *et al.* (2011) evaluated twenty radish genotypes to assess the correlation and path coefficient analyses. Root yield per plant was positively correlated with plant height 40, 50, 60 and 70 days after sowing, the number of leaves 40, 50, 60 and 70 days after sowing, total plant height after harvesting, total plant weight and leaf weight. The maximum positive direct effects on root yield per plant were observed by the number of leaves 70 days after sowing followed by plant height 70 days after sowing.

Jatoi *et al.* (2011) experimented on forty nine local and exotic radish genotypes to assess the correlation and path coefficient analysis. For local germplasm, they reported a negative correlation between root length and root diameter and a negative correlation between root length and root width.

Sivanthu *et al.* (2014) evaluated ten genotypes for fourteen characters to determine character association. They concluded that root length and root diameter exhibited a direct and positive correlation with root yield in all seasons.

Mallikarjunarao *et al.* (2015) evaluated yield and its components in radish. Correlation studies revealed that root weight was positively and significantly correlated with leaf number, leaf weight, root length, root diameter, yield per plant and vitamin C while negatively and significantly correlated with shoot to root ratio at both phenotypic and genotypic levels.

Jabal *et al.* (2015) conducted an experiment to estimate phenotypic variances and to determine the correlation of yield components of six local genotypes of radish.

The correlation analysis revealed that root weight was positively and significantly correlated with both yield and root diameter. Yield was positively and significantly correlated with root diameter. Root length was positively and significantly correlated with plant height and number of leaves per plant.

An experiment was carried out to study twenty genotypes of European carrot for the genetic parameters. At the phenotypic level, root length, biological yield per plant, root diameter, days taken to marketable maturity, leaf length, total sugar content and number of leaves per plant had direct positive effects on marketable root yield per plot. At the genotypic level, root diameter, leaf length, days taken to marketable maturity, total sugar content, and number of leaves per plant had direct positive effects. Correlation and path analysis revealed that root diameter, leaf length, total soluble solids and total content could be used as selection indices for the improvement of temperate carrot (Thakur and Jamwal, 2015).

Nagar *et al.* (2016) evaluated twenty one genotypes of radish for different horticultural traits. Correlation and path analysis revealed that significant and negative correlations were observed with root diameter.

Kaur *et al.* (2017) studied the correlation for yield and its contributing traits in radish, including seventeen radish genotypes. They reported that character association analysis was highly significant and showed a positive correlation between root yield and marketable yield, root weight, plant weight, root diameter, root length and root plant ratio. An increase in root mass also leads to an increase in vitamin C content in the roots.

Chakraborty *et al.* (2017) conducted an experiment including fifteen germplasm of carrot. The analysis for correlation was carried out to study leaf length (cm), leaf width (cm), root diameter (cm), days to root harvest, root weight (g) and yield (t/ha) for the identification of appropriate selection indices. Phenotypic and Genotypic correlation coefficient analysis revealed that root weight, days to root harvest, root length, leaf width, leaf length and root diameter had significant positive correlation with marketable yield.

Ola *et al.* (2018) evaluated twenty two varieties of radish for yield potential and suitability under valley condition of Garhwal Hills. The correlation studies revealed that ascorbic acid was negatively associated with root yield.

Roopa *et al.* (2018) evaluated thirty genotypes of radish to assess the correlation. Root yield per hectare had significant and positive correlations with leaf area, root diameter, root length, and root weight both at genotypic and phenotypic levels. The trait root diameter was significantly and positively correlated with root length, root weight, and root yield per hectare, whereas root length had a positive and

significant correlation with root to leaf ratio, root weight, and root yield per hectare at both genotypic and phenotypic levels.

Singh *et al.* (2022) evaluated eighteen diverse genotypes of Asiatic radish for heritability and expected genetic advance of root weight. The correlation studies revealed that root weight was positively and significantly correlated with plant height, leaf length, leaf size, root length, root thickness, root size and leaf. The characters, *viz.*, leaf length and root length, showed strong positive direct effects while the number of leaves/plant and leaf size had less direct effects.

Esho and Alhuseein (2022) evaluated seven genotypes of radish to assess the correlation. Results indicated that the total root yield had phenotypic and genetics positively correlated with each of the root diameter, total chlorophyll content and root weight. Root weight characteristics had positively correlated with phenotypic and genetically significant both with the root diameter characteristic and the total chlorophyll content and amounted to the phenotypic correlation.

Thakur *et al.* (2023) reported that the fresh weight of roots had the maximum positive direct effect on root yield in the genotypic path, followed by the dry weight of roots and the plant, the East-West spread of the plant and the diameter of the root in radish.

2.5.1 Path coefficient analysis

Wright (1921) developed the concept of path analysis originally but the technique was first used in plant selection by Dewey and Lu (1959). Path analysis is a potent source and efficient technique in selection because correlation coefficient alone when considered as the criteria of selection for high yield, may provide misleading information as such a character may not be directly correlated with yield but might exert its influence via other characters. The path coefficient splits the correlation coefficient into the measures of direct and indirect effects. In other words, it measures the direct and indirect contribution of various independent characters on dependent characters.

If the correlation between yield and a character is due to the direct effect of a character, it reveals a true relationship between them, and direct selection for this trait will be rewarding for yield improvement. In plant breeding, it is very difficult to have complete knowledge of all component traits of yield. The residual effect measures the role of other possible independent variables that were not included in the study on the dependent variable.

Singh *et al.* (2005) evaluated twenty one diverse genotypes of radish under temperate conditions of Kashmir and found that root yield could be successfully improved upon by making selection for greater average root weight, root diameter and root length. The characters like root diameter, root length and average gross weight were identified to have direct positive effects on root yield, whereas the number of

leaves per plant, leaf length and top to root ratio exerted a negative direct effect on root yield.

An experiment by Kumar *et al.* (2009) on path analysis in thirty five diverse genotypes of European radish introduced from the Crop genetic resources, Netherlands, reported that a highly significant and positive correlation for average root weight was with number of leaves, leaf length, leaf width, root to top ratio, root length and root diameter. The results of path analysis also showed a maximum direct effect on average root weight.

Mapari *et al.* (2009) investigated path analysis in twenty four genotypes of radish. They found that a positive direct effect on root yield was through root length, days to harvest and number of leaves per plant at harvest.

Meena *et al.* (2010) conducted an experiment on correlation and path analysis for yield components in cabbage and concluded that characters like gross weight (0.519) had the highest positive direct effect on yield, followed by the number of non-wrapper leaves (0.141).

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

Jatoi *et al.* (2011) conducted an experiment on 49 local exotic genotypes of radish and results indicated that the leaf width had shown a direct negative effect on root yield and also an indirect negative effect on the number of leaves, leaf length, root length and root weight.

Vieira *et al.* (2012) conducted an experiment on path analysis in seventy four genotypes of radish with root length as the dependent variable and observed that positive direct relationship between root length and root weight, whereas root diameter displayed a negative direct effect on root length.

Mallikarjunarao *et al.* (2015) conducted path coefficient analysis in radish and reported that leaf weight, leaf number, root length and root diameter showed maximum direct effects on average root weight. Hence, while selecting genotypes for root yield improvement, these traits should be given more emphasis.

An experiment was conducted to evaluate twenty genotypes of radish in *the rabi* season of 2014-2015 for different horticultural traits. The path coefficient analysis revealed that the maximum positive direct effect towards root yield per plant was contributed by root weight without leaf, root weight with leaf, and number of leaves, thereby indicating the importance of these traits for yield improvement in radish through direct or indirect selection (Nagar *et al.*, 2016).

Kaur *et al.* (2017) studied the path analysis for yield and its contributing traits in radishes, which includes seventeen radish genotypes, and the results of path coefficient analysis, both at phenotypic and genotypic levels, revealed a strongly positive direct effect of marketable yield, root weight, and foliage weight on the total root yield. Greater emphasis on direct and desirable selection for traits such as root diameter, root length and higher root: plant ratio would be effective in increasing the overall root yield and quality.

Ullah *et al.* (2017) conducted path coefficient analysis in twenty one varieties of radish and revealed that the maximum positive direct effect on root yield was shown by plant height followed by root diameter and days to harvest.

Naseeruddin *et al.* (2018) studied path coefficient analysis in twenty genotypes of radish and the results indicated that the number of leaves 60 days after sowing, total plant height after harvesting, total plant weight and root length had a negative direct effect.

Roopa *et al.* (2018) evaluated thirty genotypes of radish to assess the path analysis. The results indicated that leaf area index was significantly and positively correlated with root diameter, root length, root weight and root yield per hectare.

Esho and Alhuseein (2022) conducted path coefficient analysis in seven genotypes of radish. The results indicated that a positive direct effect between plant height, length, diameter and root weight directly impacted the total yield of radish, which amounted to 0.2581, 0.283, 0.0486 and 1.391, respectively.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The present investigation on “Genetic investigation of radish (*Raphanus sativus* L.) genotypes under hill zone of Karnataka” was carried out in the experimental field, Department of Vegetable Science, College of Horticulture, Mudigere, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, during the period from January 2023 to March 2023. The details of the material used and methods adopted during the investigation are presented below.

3.1 Geographical location of the experimental site

Mudigere is situated in the Western Ghats and represents the typical Hilly region (Zone -9) of Western Ghats in Karnataka state at 13°25' N latitude and 75° 57' E longitude of 982 m above mean sea level.

3.2 Climatic condition

Mudigere weather was cool and pleasant throughout the year. The area received a total annual rainfall of 1150 mm during the experimental year 2022-23, mainly distributed over six to eight months, with the peak period of rainfall from June to August. The average annual maximum temperature was 33.11°C and the minimum temperature was 12.35°C. The average annual maximum relative humidity was 99.57 per cent, and the minimum relative humidity was 50.07 per cent. The meteorological data for the period of experimentation was obtained from the meteorological observatory of Krishi Vigyan Kendra (KVK), Mudigere and the same is presented in Appendix I.

3.3 Soil characteristics of the experimental site

The soil of the experimental site has a pH of 5.39. The composite soil samples were collected from the experimental site up to a depth of 30 cm and analyzed for chemical properties in Appendix – II.

3.4 Experimental details

3.4.1 Design and layout of the experiment

The experiment involved 20 treatments and was laid out in the open field with Randomized Complete Block Design (RCBD) and was replicated thrice. The treatments in each replication were imposed randomly based on a random number table. The plan of the layout of the experiment is given in Figure 1 and the general view of the experimental plot is shown in Plate 1.

3.4.2 The experimental details

Crop	: Radish (<i>Raphanus sativus</i> L.)
Location	: College of Horticulture, Mudigere
Design	: Randomized Complete Block Design (RCBD)
Spacing	: 30 cm × 10 cm
Treatments	: 20 (Genotypes)
Number of replications	: 3
Gross plot	: 1.5 m ² (1.5 m × 1.0 m)
Net plot	: 0.72 m ² (0.9 m × 0.8 m)
Number of plants per plot	: 50
Planting method	: Ridges and furrows
Check	: Pusa Chetki

3.4.3 Treatment details

Twenty genotypes procured from different sources have been used for investigation. The list of genotypes used for the experiment and their sources of collection are furnished in the Table 1 and Plate 2.

T ₁ - Kashi Hans	T ₁₁ - Arka Nishant
T ₂ - Kashi Sweta	T ₁₂ - White Sparkle Tip
T ₃ - Kashi Mooli – 40	T ₁₃ - Chinese Pink
T ₄ - Kashi Aardra	T ₁₄ - Palak Patta
T ₅ - VRRAD – 4	T ₁₅ - White Star
T ₆ - VRRAD – 91	T ₁₆ - VBGH – 507
T ₇ - VRRAD – 199	T ₁₇ - ORBI- 0527
T ₈ - VRRAD – 131	T ₁₈ - Scarlet Globe
T ₉ - VRRAD – 200	T ₁₉ - Red Radish
T ₁₀ - VRRAD – 11	T ₂₀ - Pusa Chetki

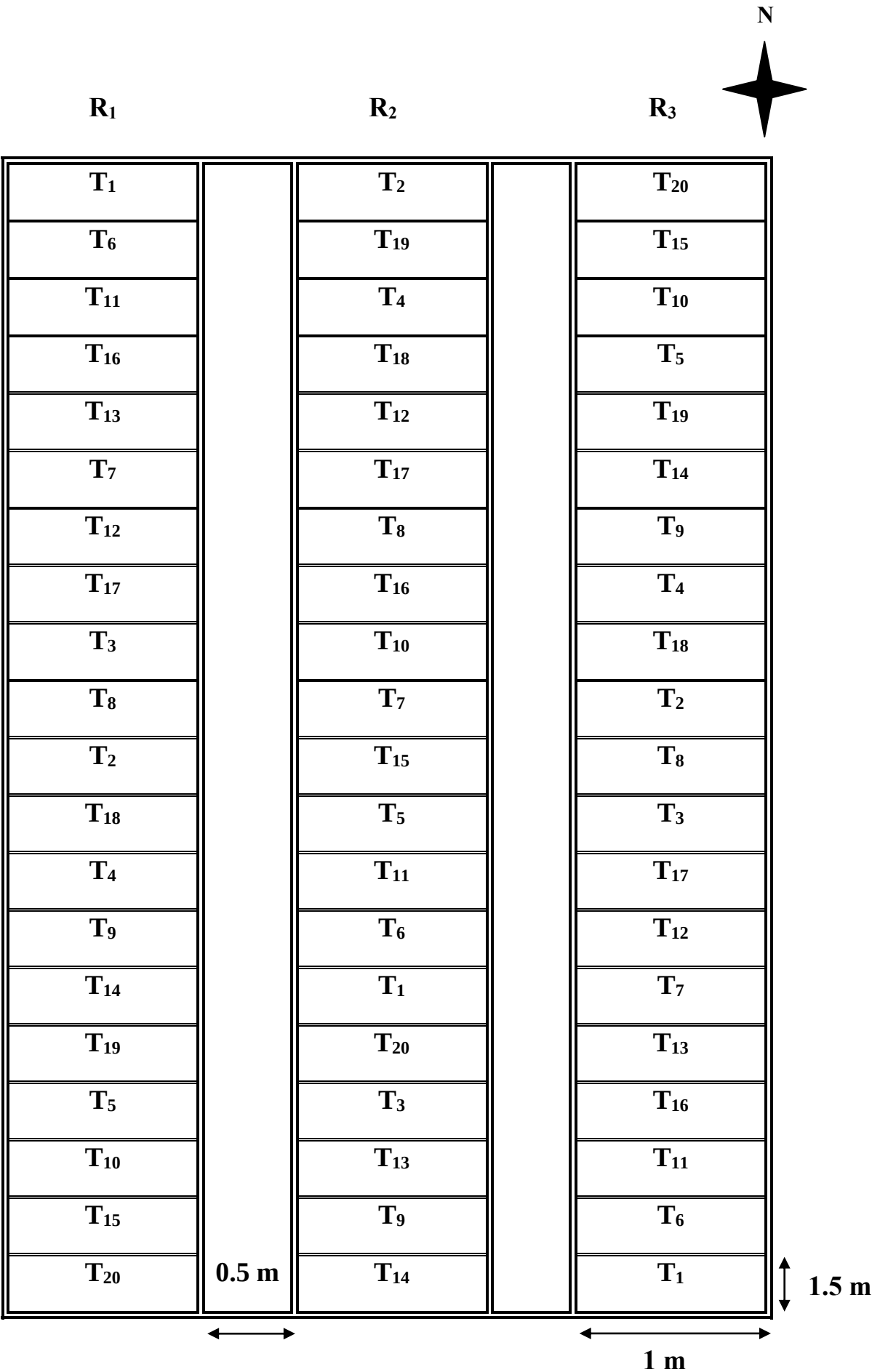


Figure 1. Plan and layout of the experimental plot



Plate 1. General view of the experimental plot



Plate 2. Radish genotypes used for the experiment



Plate 2. Radish genotypes used for the experiment



Plate 2. Radish genotypes used for the experiment



Plate 2. Radish genotypes used for the experiment

Table 1. List of radish genotypes used in the experiment

Sl. No.	Name of the genotype	Source of collection	Sl. No.	Name of the genotype	Source of collection
1	Kashi Hans	ICAR-IIVR, Varanasi	11	Arka Nishant	ICAR-IIHR, Bengaluru
2	Kashi Sweta	ICAR-IIVR, Varanasi	12	White Sparkle Tip	Gennext seeds, Bengaluru
3	Kashi Mooli – 40	ICAR-IIVR, Varanasi	13	Chinese Pink	Sungro seeds, New Delhi
4	Kashi Aardra	ICAR-IIVR, Varanasi	14	Palak Patta	Abhi seeds, Hubli
5	VRRAD – 4	ICAR-IIVR, Varanasi	15	White Star	Orbi seeds, Bengaluru
6	VRRAD – 91	ICAR-IIVR, Varanasi	16	VBGH – 507	Orbi seeds, Bengaluru
7	VRRAD – 199	ICAR-IIVR, Varanasi	17	ORBI- 0527	Orbi seeds, Bengaluru
8	VRRAD – 131	ICAR-IIVR, Varanasi	18	Scarlet Globe	Tokai seeds co. New Delhi
9	VRRAD – 200	ICAR-IIVR, Varanasi	19	Red Radish	Kraft seeds, New Delhi
10	VRRAD – 11	ICAR-IIVR, Varanasi	20	Pusa Chetki	ICAR-IARI, New Delhi

Where,

IIVR- Indian Institute of Vegetable Research

IIHR- Indian Institute of Horticultural Research

IARI- Indian Agricultural Research Institute

3.5 Cultural operations

3.5.1 Preparation of experimental site

The land was ploughed deeply, weeds, stubbles, stones etc., were completely removed, and the soil was brought to fine tilth by repeated harrowing. After levelling the entire field, required size micro plots were prepared as per the plan of work.

3.5.2 Fertilizer application

Recommended levels of nitrogen, phosphorus and potassium were applied for each plot in every replication in the form of urea, single super phosphate and murate of potash, respectively. Entire SSP, MOP and 50 per cent urea were applied as a basal dose at the time of sowing and the remaining 50 per cent nitrogen was applied 20 days after sowing. The package of practice recommendations of fertilizer (50: 100: 50 kg NPK/ha) was used for the study.

3.5.3 Sowing

Sowing was done during the month of January. Seeds were hand dibbled at a depth of about 2 cm in the soil. The seeds were sown on one side of the ridge according to the recommended spacing (30 cm × 10 cm). Thinning was done at ten days after sowing by retaining one seedling per hill to maintain proper spacing and to facilitate the development of roots.

3.5.4 Intercultivation

The crop needs earthing-up at least twice and this operation is sufficient to keep out weeds. In order to keep the soil pores and also free from weeds, regular inter cultivation operations were carried out at frequent intervals. Hand weeding was done as and when the weeds were noticed to keep the plot clean and free from weeds competition.

3.5.5 Irrigation

Protective irrigations were given at 3 to 5 days interval throughout the cropping period of root production.

3.5.6 Plant protection chemicals

To control the pest and diseases, necessary plant protection measures were taken up as per the recommended package of practices for radish. Insects, pests such as, diamond back moth, mustard sawfly and aphids were observed during the crop growth period. These pests were managed by spraying of Chloropyriphos @ 2 ml per litre, Imidacloprid @ 0.3 ml per litre and Quinalphos @ 2 ml per litre.

3.5.7 Harvesting

The roots were harvested at an interval of 15, 30 and 45 DAS. The harvested roots from each treatment and replication were washed separately for recording observations and were kept in a hot air oven for recording dry weight observations.

3.6 Collection of experimental data

3.6.1 Selection of plants

Five plants were selected randomly from each plot and tagged for recording the observations on growth and root yield parameters as mentioned below.

3.6.2 Morphological parameters

Observations on growth parameters such as plant height, number of leaves, leaf length, leaf width, spread of the plant, stem diameter, fresh weight and dry weight of leaves, stem and roots were recorded at 15, 30 and 45 days after sowing.

3.6.2.1 Plant height (cm)

From randomly selected five plants, height was recorded from base of the plant to the top of the plant and average plant height worked out and average was expressed in centimetres.

3.6.2.2 Number of leaves

The numbers of leaves in tagged plants were counted and the average value was worked out.

3.6.2.3 Leaf length (cm)

Length of leaves was measured from base to the tip of the leaves and the leaf length average was expressed in centimetres.

3.6.2.4 Leaf width (cm)

The width of randomly selected five leaves from each tagged plant was recorded by measuring the horizontal distance exactly at the centre of the leaves and average was worked out and expressed in centimetres.

3.6.2.5 Spread of the plant (cm)

The plant spread was measured in both East-West and North-South directions and the mean was expressed in centimetres.

3.6.3 Growth parameters

3.6.3.1 Leaf area (cm²/plant)

The leaves from five selected plants from each treatment were used for the estimation of leaf area. Leaf area was computed by using leaf area meter and was expressed as square centimetres per plant.

3.6.3.2 Leaf area index (LAI)

The LAI was calculated by dividing the leaf area per plant by the land area occupied by the plant (Sestak *et al.*, 1971).

$$LAI = \frac{\text{Leaf area } \left(\frac{\text{cm}^2}{\text{plant}}\right)}{\text{Land area } \left(\frac{\text{cm}^2}{\text{plant}}\right)}$$

3.6.3.3 Fresh weight of leaves (g/plant)

The fresh weight of leaves was taken from each of tagged plant in each replication and the average fresh weight of leaves was then expressed in grams per plant.

3.6.3.4 Dry weight of leaves (g/plant)

The leaves of the tagged plants were collected and it was dried in a hot air oven at 65 °C for 48 hours till it reaches constant weight. The dry weight was recorded and the average was expressed in grams per plant.

3.6.3.5 Fresh weight of root (g/plant)

The roots from five randomly selected plants in each replication were harvested and their weight was recorded using electronic digital balance. The average fresh weight of root was expressed in grams per plant.

3.6.3.6 Dry weight of root (g/plant)

The roots from five randomly selected plants in each replication were collected and it was dried in a hot air oven at 65 °C for 48 hours till it reaches constant weight. The dry weight was recorded and the average was expressed in grams per plant.

3.6.3.7 Total dry matter (g/plant)

Total dry matter of the plant was found out by weighing the whole dried plant parts like leaves and root, and it is expressed in grams.

3.6.3.8 Absolute growth rate (AGR)

It is the rate of dry matter production per plant per unit time (g/plant/day). The absolute growth rate (AGR) was calculated by the formula suggested by Watson (1952).

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where,

W_1 – Dry weight of the plant (g/m²) at time t_1

W_2 – Dry weight of the plant (g/m²) at time t_2

$t_2 - t_1$ – time interval between two stages (days)

3.6.3.9 Crop growth rate (CGR)

Crop growth rate is defined as the rate of dry matter production per unit ground area per unit time (Watson, 1952) and it was calculated by using the following formula and expressed in g per m² per day.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where, W_1 – Dry weight of the plant (g/m²) at time t_1

W_2 – Dry weight of the plant (g/m²) at time t_2

$t_2 - t_1$ – time interval between two stages (days)

A – Unit land area

3.6.3.10 Net assimilation rate (NAR)

The NAR is the rate of increase in dry weight per unit leaf area per unit time. It was calculated by following the formula of Radford (1967) and expressed as g per dm² per day.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log L_2 - \log L_1)}{(L_2 - L_1)}$$

Where,

$\log_e$ – Logarithm to the base e

L_1 and W_1 – Leaf area (cm²) and total dry weight of the plant (g) respectively at time t_1

L_2 and W_2 – Leaf area (cm²) and total dry weight of the plant (g) respectively at time t_2

$t_2 - t_1$ – time interval between two stages (days)

3.6.3.11 Specific leaf area (SLA)

It is the ratio of the leaf area to its dry weight. It was calculated by using the following formula and was expressed in cm² per g.

$$SLA = \frac{\text{Leaf area per plant}}{\text{Leaf dry weight per plant}}$$

3.6.3.12 Specific leaf weight (SLW)

It is the ratio of the leaf dry weight to the leaf area. It was determined by the method suggested by Radford (1967) and was expressed as g per cm².

$$SLW = \frac{\text{Leaf dry weight per plant}}{\text{Leaf area per plant}}$$

3.6.4 Root parameters

3.6.4.1 Days to harvest

The number of days required for maturity of root from the time of sowing to harvest was calculated for five randomly selected plants and the average number of days was recorded

3.6.4.2 Root length (cm)

The length of the root was measured in five randomly selected plants at 45 DAS from the base of the root to top of the root and average root length was expressed in centimetres.

3.6.4.3 Root diameter (mm)

Roots from five tagged plants in each plot were collected at harvest. The root diameter was measured by using digital vernier callipers and average root diameter was calculated and expressed in millimetres.

3.6.4.4 Root weight (g/plant)

Fresh weight of the roots of five tagged plants are measured by using an electronic balance at the time of harvest and average root weight was calculated and expressed in grams per plant.

3.6.4.5 Root girth (cm)

The girth of five roots selected randomly at 45 DAS was recorded at the basal portion of the root with the help of thread and scale and the average root girth was expressed in centimetres.

3.6.4.6 Root volume (cc)

The volume of root was measured by the water displacement method. A measuring cylinder of one litre capacity was employed for measuring root volume in which known amount of water was added. Five roots were selected randomly from each treatment and individual roots were placed in measuring cylinder. Then amount of water displaced by each root was measured by taking the difference between initial volume and final volume. The volume of the root was expressed in cubic centimetres (cc).

3.6.4.7 Root yield (kg/plot)

The root yield per net plot was recorded by pooling the root yield of all the plants in each treatment of each replication separately and expressed in kilograms.

3.6.4.8 Root yield (t/ha)

The weight of root was recorded treatment wise from each net plot and from each replication. Radish crop utilized only 80 per cent of the land and the remaining

20 per cent of the land was used for irrigation channels and bund. Keeping this in mind, the total yield per hectare in tonnes was calculated using the formula,

$$\text{Yield (t/ha)} = \frac{\text{Yield per net plot (kg)}}{\text{Net area of the plot (m}^2\text{)}} \times \frac{10000}{1000}$$

3.6.5 Quality parameters

3.6.5.1 Root shape

Shapes of five tagged roots were taken at marketable root harvest stage on the basis DUS of character. The leaf characteristics of the genotypes is represented in the Appendix- III.

3.6.5.2 Root colour

The colour (external) of the roots were recorded at marketable root harvest stage on the basis of visual observation.

3.6.5.3 Forking (%)

The incidence of forking was calculated after the harvesting and expressed in percentage.

$$\text{Forking (\%)} = \frac{\text{Number of plants forked}}{\text{Total number of plants in plot}} \times 100$$

3.6.6 Biochemical parameters

3.6.6.1 Chlorophyll content in leaves (mg/g of fresh weight)

The chlorophyll content of leaf was analyzed by collecting the healthy, fully matured leaves from randomly selected plant at peak growth stage. Chlorophyll-‘a’, Chlorophyll-‘b’ and total chlorophyll content of leaf tissue were determined by using dimethyl sulfoxide (DMSO) method as suggested by Shoaf and Lium (1976). Fresh leaf tissue (100 mg) was cut in to small pieces and incubated in 10 ml of dimethyl sulfoxide in dark for 24 hours. Later the absorbance of the extract was measured at 645 nm and 663 nm using DMSO as blank in spectrophotometer (Model- VISISCAN-167).

The chlorophyll-‘a’, chlorophyll-‘b’ and total chlorophyll, contents were calculated by using the formulae given below and expressed in mg per g fresh weight.

$$\text{Chlorophyll-a} = 12.7 (A_{663}) - 2.69 (A_{645}) \times \frac{V}{1000 \times W \times a}$$

$$\text{Chlorophyll-b} = 22.9 (A_{645}) - 4.68 (A_{663}) \times \frac{V}{1000 \times W \times a}$$

$$\text{Total chlorophyll} = 20.2 (A_{645}) + 8.02 (A_{663}) \times \frac{V}{1000 \times W \times a}$$

Where,

A= Absorbance at specific wave lengths (645 nm and 663 nm)

V= Final volume of the extract (10 ml)

W= Fresh weight of the sample (100 mg)

a = Path length of light in the cuvette (1 cm)

3.6.6.2 Total sugars (%)

Total sugars in the radish samples were estimated by the anthrone reagent method and was expressed in percentage (Ranganna, 1979). 1 ml of sample aliquot and different concentrations (0, 0.2, 0.4, 0.6, 0.8 and 1.0 ml) of standard glucose solution was pipette out in different test tubes and volume was made up the to 2.5 ml each with distilled and all the test tubes are kept in an ice bath, and 5 ml of anthrone reagent was added slowly and the contents were stirred gently with a glass rod. Then the contents were heated on boiling water bath exactly for 7.5 minutes and cooled immediately in an ice bath. After cooling, the absorbance of the solutions was measured at 630 nm against the blank. Then the total sugar content was calculated through a standard glucose curve.

$$\text{Total sugars(\%)} = \frac{\text{Glucose (mg) in a sample from standard curve}}{\text{Aliquot taken (ml) for test}} \times \frac{\text{Vol. made after hydrolysis (ml)}}{\text{Vol. taken for alcohol hydrolysis (ml)}} \times \frac{\text{Vol. made after alcohol evaporation (ml)}}{\text{Vol. taken for evaporation (ml)}} \times \frac{\text{Vol. made after sample extraction (ml)}}{\text{sample taken for extraction (ml)}} \times 100$$

3.6.6.3 Reducing sugars (%)

Reducing sugars present in the radish samples were estimated by DNSA reagent method and was expressed in percentage (Ranganna, 1978).

1. DNSA reagent: 40 % Rochelle salt + solution (sodium-potassium tartarate solution)
2. DNSA solution: Dissolved simultaneously 1 g DNSA, 200 mg of crystalline phenol and 50 mg of sodium sulphite in 100 ml of 1 per cent NaOH solution by stirring. The reagent was stored in a stopper bottle at 4 °C.

The clean and dried test tubes were taken from which reducing sugars were estimated by the DNSA reagent method and was expressed in percentage. The test tubes were taken to which 0.2, 0.4, 0.6, 0.8 and 1ml of prepared standard glucose were added. This was made up to 1ml using distilled water and 1 ml of DNSA reagent was added. The test tubes were closed with aluminium foil and were kept in a boiling water bath for a few minutes and then the test tubes were cooled down and 4 ml of distilled water was added to it. The test tubes were vortexed and optical density was measured at

540 nm. Similarly, 0.25 ml of prepared sample were taken, volume was made up to 1 ml using distilled water and DNSA reagent was added. These test tubes were kept in a water bath, then it is cooled and optical density was measured at 540nm. The amount of reducing sugar present in the sample was calculated using a standard graph (Ranganna,1978).

$$\text{Reducing sugars (\%)} = \frac{\text{Glucose (mg) in sample from standard curve}}{\text{Aliquot taken for test (ml)}} \times \frac{\text{Vol. made (ml) after alcohol evaporation}}{\text{Vol. taken for alcohol evaporation (ml)}} \times \frac{\text{Vol. made (ml) after sample extraction}}{\text{Sample taken for extraction (mg)}} \times 100$$

3.6.6.4 Non-reducing sugars (%)

Non-reducing sugars was estimated by subtracting reducing sugars from total sugars content of the sample.

$$\text{Non-reducing sugars (\%)} = \text{Total sugars (\%)} - \text{Reducing sugars (\%)}$$

3.6.6.5 Ascorbic acid (mg/100 g)

The ascorbic acid content in radish roots was determined by volumetric method as suggested by Sadasivam and Manickam (2009) using 2, 6- dichloro phenol indophenol dye.

Dye solution: 42 mg of sodium bicarbonate was weighed and dissolved in small volume of distilled water and 52 mg of 2,6 dichlorophenol indophenol was dissolved in it and volume was made up to 200 ml with distilled water.

Standard stock solution: Stock solution was prepared by dissolving 100 mg ascorbic acid in 100 ml of 4 per cent oxalic acid solution (1 mg/ ml).

Working standard: 10 ml of stock solution was diluted to 100 ml with 4 per cent oxalic acid, to get the working standard concentration of 100 µg per ml.

Procedure

Five ml of the working standard solution was pipetted into a 100 ml of conical flask to which 10 ml of 4 per cent oxalic acid was added and the contents were titrated against the dye (V₁ ml) to get pink end point which persisted for a few minutes. The radish root sample of (10 ml) was extracted in 4 per cent oxalic acid and the volume was made to 100 ml and the contents were centrifuged. 5 ml of this supernatant was pipetted out, to which 10 ml of 4 per cent oxalic acid was added and titrated against the dye (V₂ ml). The ascorbic acid content was calculated by using the formula as given below and expressed in (mg / 100 g).

$$\text{Ascorbic acid (mg/100 g)} = \frac{0.5 \text{ mg}}{V_1 \text{ ml}} \times \frac{V_2}{5 \text{ ml}} \times \frac{100 \text{ ml}}{\text{Weight of the sample}} \times 100$$

3.6.6.6 Sensory evaluation (5 point hedonic scale)

Organoleptic evaluation of radish with respect to pungency, texture and overall acceptability was adjudged on a 5 point hedonic scale (Ranganna, 1986) by a panel of 21 untrained judges.

Parameter	5	4	3	2	1
Pungency	Highly pungent	Moderately pungent	Pungent	Slightly pungent	Non pungent
Texture	Highly crisp	Moderately crisp	Brittle crisp	Lightly crisp	Not crisp

Overall acceptance score is based on treatment obtained highest score in above all parameters.

3.7 Statistical analysis

The details of the statistical procedure adopted for analysis of the data recorded on different genotypes of radish to get an idea of the nature of magnitude of variation, the association of characters and direct and indirect effects of characters on fruit yield are presented below.

3.7.1. Mean

Mean is the sum of all observations in a sample divided by the number of observations (n).

$$\text{Mean} = \sum \frac{x_i}{n}$$

Where,

X_i = i^{th} observation of a population

n = Number of observations

3.7.2. Range

The range is the minimum and maximum values of the observations in a sample of a genotype.

3.7.3. Analysis of variance

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F _{cal}
Treatment	(t-1)	S_t	$M_t = S_t / (t-1)$	M_t / M_e
Replications	(r-1)	S_r	$M_r = S_r / (r-1)$	M_r / M_e
Error	(r-1) (t-1)	S_e	$M_e = S_e / (r-1) (t-1)$	
Total	(tr-1)	S_T		

The data on various biometric observations collected during the study were subjected to statistical analysis using Fischer's method of analysis of variance technique as given by Panse and Sukhatme (1957). The significance of treatment mean squares and replication mean squares were tested by comparing with error mean squares referring to "F" table values at 5 per cent level of probabilities.

Where,

r	=	Number of replications
t	=	Number of treatments
S _r	=	Sum of squares due to replications
S _t	=	Sum of squares due to treatments
S _e	=	Sum of squares due to error
S _T	=	Total sum of squares
M _r	=	Mean sum of squares due to replications
M _t	=	Mean sum of squares due to treatments
M _e	=	Mean sum of squares due to error

The replication and entries mean sum of squares was tested against error mean squares by the 'F' test at (r-1), (r-1) (t-1), and (t-1) degree of freedom for RCBD at a 5 per cent level of significance.

3.7.4. Standard error

It is the measure of uncontrolled variation present in a sample which was estimated by dividing the standard deviation (SD) by the square root of the number of observations (n) in the sample and was denoted by SE.

$$SE = \frac{SD}{\sqrt{n}}$$

3.7.5. Critical difference

Critical difference (CD) was calculated by multiplying the SE with table 't' value at 5 per cent and 1 per cent of probabilities for error degrees of freedom. The critical difference was calculated as,

$$CD = \sqrt{2 \times S.Em \times t(\alpha, df)}$$

Where,

α - the level of significance (5 and 1 %)

df - degrees of freedom.

3.7.6. Variance

Variance is defined as the average of the standard deviations of individual observation from the mean. It is expressed as the sum of squares of the deviations of all observations of a sample from its mean and divided by (n-1), where 'n' is the number of observations. It is estimated by the following formula:

$$\text{Variance} = \frac{\sum x_i^2 - (\sum x)^2/n}{(n - 1)}$$

Where,

x_i = i^{th} observation of a population

n = number of observations

3.7.7. Standard deviation (SD)

The Standard deviation was calculated

as,

$$SD = \sqrt{\text{Variance}}$$

3.7.8. Estimation of genetic variability parameters

The variability for different quantitative and qualitative traits in radish was estimated in the genotypes as detailed below.

Variance due to genotype, phenotype, and environment were computed as follows.

- Genotypic variance (σ^2_g) = $\frac{\text{Treatment MSS} - \text{Error MSS}}{r}$
- Environmental variance (σ^2_e) = Error mean sum of squares
- Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$

Where, 'r' is the number of replications.

3.7.8.1. Phenotypic and genotypic coefficient of variation

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all the characters were calculated according to the formula provided by Burton and Devane (1953).

- Phenotypic coefficient of variation (PCV%) = $\frac{\sigma^2_p}{\bar{X}} \times 100$
- Genotypic coefficient of variation (GCV%) = $\frac{\sigma^2_g}{\bar{X}} \times 100$

Where,

σ^2_p = Phenotypic variance

σ^2_g = Genotypic variance

$\bar{X}$ = Mean

PCV and GCV were classified as shown below following the method suggested by Robinson *et al.* (1949)

0-10 % = Low

>10-20 % = Moderate

>20 % = High

3.7.8.2. Heritability (h^2 broad sense)

Broad-sense heritability was estimated for all the traits using the following formula of Johnson *et al.* (1955).

$$h^2 (\%) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

h^2 (b) = Heritability (broad sense) expressed in per cent

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

The heritability percentage was categorized as low, moderate and high as suggested by Robinson *et al.* (1949) and is given below.

0-30 % = Low

>30-60 % = Moderate

>60 % = High

3.7.8.3. Genetic advance (GA)

The extent of genetic advance was estimated by using the following formula of Johnson *et al.* (1955).

$$GA = h^2 \times K \times \sigma_p$$

Where,

h^2 = Heritability estimate

K = Selection differential at given intensity (which is equal to 2.06 at 5 per cent intensity of selection)

σ_p = Phenotypic standard deviation

3.7.8.4. Genetic advance as per cent over mean (GAM)

Genetic advance as per cent over mean was assessed by using the following formula.

$$\text{Genetic advance as per cent over mean} = \frac{\text{GA}}{\text{Grand Mean}} \times 100$$

Genetic advance as per cent over mean was grouped into low, moderate and high as given below following the method of Johnson *et al.* (1955).

0 to 10 % = Low

>10 to 20 % = Moderate

>20 % = High

3.7.8.5. Correlation coefficient analysis

The correlation coefficient among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated employing formula (Al-Jibouri *et al.* 1958).

$$r_p(xy) = \frac{\text{Cov}_p(xy)}{\sqrt{\sigma_p^2(x) + \sigma_p^2(y)}}$$

Where,

$r_p(xy)$ = phenotypic correlation coefficient between characters 'x' and 'y'

$\text{Cov}_p(xy)$ = phenotypic covariance of character 'x' and 'y'

$\sigma_p^2(x)$ = phenotypic variance of character 'x'

$\sigma_p^2(y)$ = phenotypic variance of character 'y'

The calculated 'r' value was compared with table 'r' value at (n-2) degrees of freedom for significance at 0.05 and 0.01 probability levels, where 'n' refers to the number of pairs of observations.

3.7.8.6. Path coefficient analysis

Path coefficient analysis was carried out in advanced breeding lines using the simple correlation coefficient to know the direct and indirect effects of the yield components as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

The equations were as follows,

$$r_{1y} = a + r_{12}b + r_{13}c + \dots + r_{1I}i$$

$$r_{2y} = a + r_{21}a + b + r_{23}c + \dots + r_{2I}i$$

$$r_{3y} = r_{31}a + r_{32}b + c + \dots + r_{3I}i$$

$$r_{ly} = r_{l1}a + r_{l2}b + r_{l3}c + \dots + r_{lI}i$$

Where,

r_{ly} to r_{Iy} = Coefficient of correlation between causal factors 1 to I with dependent characters y.

r_{12} to r_{II} = Coefficient of correlation among causal factors a, b, c.....

i = Direct effects of characters 'a' to 'I' on the dependent character 'y'.

Residual effect (R) was computed as follows.

$$\text{Residual effect (R)} = 1 - \sqrt{a^2 + b^2 + c^2 \dots i^2 + 2abc_{12} + 2acr_{13} \dots}$$

3.7.8.7 Genetic divergence

Mahalanobis (1936) D^2 statistic was used for assessing the genetic divergence between different populations. The D^2 analysis was carried out using the data recorded on germplasm. Mahalanobis generalized distance (D^2) between any two populations is given by the formulas,

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

Where, D^2 = Square of generalized distance

λ_{ij} = Reciprocal of the common dispersal index

$$\sigma_j = \mu_{j1} - \mu_{j2}$$

μ = General formula

Since the formula for computation requires the inversion of higher-order determinants, the transformation of the original correlated unstandardized character means (Xs) to standardize uncorrelated variable (Ys) was done to simplify the computational procedure. The D^2 values were obtained as the corresponding uncorrelated (Ys) values of any two uncorrelated genotypes. (Rao, 1952).

3.7.8.8 Clustering D^2 values

All the $n(n-1)/2$ D^2 values were clustered using Tocher's method (Rao, 1952).

3.7.8.9 Intra and inter- cluster distance

The intra and inter-cluster distances were calculated by following the formula described by Singh and Choudhary (1977).

$$\text{Square of intracluster distance} = (\sum D_i^2) / (N)$$

Where,

$\sum D_i^2$ = Sum of distances between all possible combination of the entries included in the cluster

N = Number of all possible combinations

$$\text{Square of inter – cluster distance} = \frac{\sum D_{ij}^2}{n_i n_j}$$

Where,

$\sum D_{ij}^2$ = Sum of distances between all possible combinations ($n_i n_j$) of the entries included in the cluster.

n_i = Number of entries in the cluster i

n_j = Number of entries in the cluster j

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The present investigation was carried out with twenty genotypes of radish at the College of Horticulture, Mudigere of Chikkamagaluru district of Karnataka, to assess the nature and extent of genetic variability for growth, yield and quality parameters, correlation, path analysis and divergence under hill zone. The results of the experiment are presented in this chapter under the following headings.

4.1 Analysis of variance

4.2 Performance of radish genotypes

4.3 Genetic components of variation

4.4 Genetic divergence

4.5 Correlation coefficient analysis

4.6 Path coefficient analysis

4.1 Analysis of variance

Analysis of variance for morphological, growth, root and biochemical parameters showed highly significant differences for all the traits under study (Tables 2, 3 and 4). The morphological parameters viz., plant height at 15, 30 and 45 DAS, number of leaves at 15, 30 and 45 DAS, leaf length at 15, 30 and 45 DAS, leaf width at 15, 30 and 45 DAS, spread of the plant (N-S) and (E-W) at 15, 30 and 45 DAS exhibited significant differences among the genotypes (Table 2).

Growth, root and biochemical parameters viz., leaf area, leaf area index, fresh weight of leaves, fresh weight of roots, dry weight of leaves, dry weight of roots, specific leaf area, specific leaf weight, absolute growth rate, crop growth rate, net assimilation rate, days to harvest, root length, root diameter, root girth, root volume, root weight, root yield per plot, root yield per hectare, reducing sugars, non-reducing sugars, total sugars and ascorbic acid content showed significant differences among the genotypes which indicated the presence of high variability among the genotypes. (Table 3 and 4).

4.2 Performance of radish genotypes

The mean performance of nineteen radish genotypes, along with one check for growth and yield characters, were presented in Tables 5 to 19.

4.2.1 Morphological parameters

4.2.1.1 Plant height (cm) at 15 DAS

Plant height at 15 DAS ranged from 4.16 to 7.33 cm, with an average mean value of 6.32 cm. The genotype Kashi Hans had recorded the maximum plant height of 7.33 cm, which was on par with White Star (7.26 cm), ORBI- 0527 (7.13 cm),

Table 2. Analysis of variance for morphological parameters in radish genotypes

Sl. No.	Source of variation/character	Replication	Treatment (genotypes)	Error	S.Em. ±	CD at 5%	CD at 1%
	Degrees of freedom	2	19	38			
1	Plant height (cm) at						
	15 DAS	0.15	1.64**	0.16	0.23	0.66	0.88
	30 DAS	0.45	54.08**	0.20	0.26	0.75	1.01
	45 DAS	0.31	52.79**	0.57	0.44	1.25	1.68
2	Number of leaves at						
	15 DAS	0.00	0.65**	0.00	0.06	0.16	0.21
	30 DAS	0.77	1.41**	0.53	0.42	1.21	1.61
	45 DAS	0.25	2.64**	0.42	0.37	1.07	1.43
3	Leaf length (cm) at						
	15 DAS	0.04	0.36**	0.09	0.18	0.51	0.68
	30 DAS	0.34	89.35**	0.25	0.29	0.84	1.12
	45 DAS	0.02	40.19**	0.26	0.30	0.86	1.14
4	Leaf width (cm) at						
	15 DAS	0.04	1.26**	0.03	0.11	0.31	0.41
	30 DAS	0.04	3.00**	0.03	0.11	0.32	0.43
	45 DAS	0.01	2.21**	0.05	0.14	0.40	0.53
5	Plant spread (North to South) (cm) at						
	15 DAS	0.046	6.47**	0.16	0.23	0.67	0.89
	30 DAS	0.286	8.84**	0.27	0.30	0.87	1.16
	45 DAS	0.368	13.49**	0.91	0.55	1.58	2.11
6	Plant spread (East to west) (cm) at						
	15 DAS	0.20	3.28**	0.13	0.21	0.60	0.80
	30 DAS	0.38	22.06**	0.36	0.35	1.00	1.34
	45 DAS	1.23	36.57**	0.82	0.53	1.50	2.01

** Significant @ 1 % DAS- Days after sowing

Table 3. Analysis of variance for growth parameters and chlorophyll content in radish genotypes

Sl. No	Source of variation/ character	Replication	Treatments (genotypes)	Error	S.Em. ±	CD at 5%	CD at 1%
	Degrees of freedom	2	19	38			
1	Leaf area (cm ²) at						
	15 DAS	0.01	111.48**	0.63	0.46	1.32	1.76
	30 DAS	10.21	4728.84**	17.90	2.44	6.99	9.36
	45 DAS	86.57	13852.25**	57.68	4.39	12.55	16.81
2	Leaf area index at						
	15 DAS	0.0001	0.02**	0.0003	0.001	0.004	0.09
	30 DAS	0.00001	1.02**	0.0002	0.007	0.020	0.03
	45 DAS	0.01000	2.94**	0.0009	0.020	0.057	0.07
3	Fresh weight of leaves (g/plant) at						
	15 DAS	0.08	65.72**	0.06	0.15	0.43	0.58
	30 DAS	61.25	315.08**	25.09	2.89	8.28	11.09
	45 DAS	0.44	970.19**	2.95	0.99	2.84	3.80
4	Dry weight of leaves (g/plant) at						
	15 DAS	0.0004	0.68**	0.002	0.02	0.06	0.07
	30 DAS	3.7000	1.42**	0.380	0.36	1.02	1.36
	45 DAS	0.9800	6.95**	0.410	0.37	1.06	1.42
5	Fresh weight of roots (g/plant) at						
	15 DAS	0.0020	45.95**	0.001	0.02	0.05	0.06
	30 DAS	0.2200	68.33**	0.350	0.34	0.98	1.31
	45 DAS	18.6700	2110.57**	14.940	2.23	6.39	8.55
6	Dry weight of roots (g/plant) at						
	15 DAS	0.0001	0.23**	0.0001	0.003	0.01	0.01
	30 DAS	0.0004	1.63**	0.0037	0.033	0.09	0.12
	45 DAS	0.0400	16.15**	0.01	0.067	0.19	0.26
7	Total dry matter (g/plant) at						
	15 DAS	0.002	0.74**	0.002	0.03	0.06	0.08
	30 DAS	0.0200	2.44**	0.02	0.07	0.21	1.36
	45 DAS	0.0500	316.78**	1.34	0.11	0.31	1.46
8	Specific leaf area (cm ² /g) at						
	15 DAS	1.42	743.83**	1.16	0.61	1.74	2.39
	30 DAS	1.07	1234.30**	2.61	0.94	2.70	3.57
	45 DAS	27.04	2758.89**	17.30	1.69	4.82	9.21
9	Specific leaf weight (g/cm ²) at						
	15 DAS	0.000002	0.001**	0.00001	0.0006	0.0016	0.004
	30 DAS	0.0000003	0.00013**	0.0000004	0.0003	0.0007	0.002
	45 DAS	0.00000009	0.0001**	0.0000001	0.0002	0.0005	0.004
10	Absolute growth rate (g/plant/day) at						
	15-30 DAS	0.000002	0.011**	0.00017	0.003	0.009	0.009
	30-45 DAS	0.000058	0.051**	0.00005	0.005	0.014	0.028
11	Crop growth rate (g/m ² /day) at						

Continued	15-30 DAS	0.02	18.29**	0.02	0.106	0.303	0.36
	30-45 DAS	0.02	24.15**	0.04	0.147	0.422	0.44
12	Net assimilation rate (g/dm ² /day) at						
	15-30 DAS	0.00000001	0.000002**	0.00000001	0.00006	0.0002	0.000
	30-45 DAS	0.00	0.114**	0.00	0.000014	0.000042	0.019
13	Chlorophyll 'a' (mg/g) of fresh weight						
	30 DAS	0.00003	0.047**	0.00019	0.01	0.02	0.03
	45 DAS	0.00450	0.257**	0.00099	0.02	0.06	0.05
14	Chlorophyll 'b' (mg/g) of fresh weight						
	30 DAS	0.00003	0.046**	0.00017	0.01	0.02	0.03
	45 DAS	0.00054	0.11**	0.00067	0.01	0.03	0.05
15	Total chlorophyll (mg/g) of fresh weight						
	30 DAS	0.00218	0.13**	0.00062	0.01	0.05	0.06
	45 DAS	0.00053	0.63**	0.00456	0.02	0.12	0.16

** Significant @ 1 % DAS- Days after sowing

Table 4. Analysis of variance for root and quality parameters in radish genotypes

Sl. No.	Source of variation/character	Replication	Treatment (genotypes)	Error	S.E.m. $\pm$	CD at 5%	CD at 1%
	Degrees of freedom	2	19	38			
1	Days to harvest	3.61	101.16**	1.36	0.67	1.91	2.55
2	Root length (cm)	0.11	49.16**	0.23	0.28	0.79	1.06
3	Root diameter (mm)	0.36	42.58**	4.76	1.26	3.60	4.83
4	Root girth (cm)	0.02	7.23**	0.05	0.14	0.40	0.53
5	Root weight (g)	18.69	2110.66**	14.95	2.23	6.39	8.56
6	Root volume (cc)	3.84	1397.94**	3.82	1.13	3.23	4.33
7	Root yield per plot (kg)	0.06	5.31**	0.02	0.09	0.24	0.32
8	Root yield per hectare (t)	0.85	187.18**	0.96	0.57	1.62	2.18
9	Ascorbic acid (mg/100g)	0.32	39.09**	0.30	0.32	0.90	1.21
10	Reducing sugars (%)	0.06	0.91**	0.07	0.16	0.45	0.60
11	Non-reducing sugars (%)	0.00002	0.27**	0.000 24	0.01	0.03	0.03
12	Total sugars (%)	0.05	1.38**	0.07	0.16	0.44	0.60

** Significant @ 1 %

VRRAD- 131 (6.80 cm) and VRRAD- 4 (6.70 cm). Whereas the genotype Scarlet Globe recorded the minimum plant height (4.16 cm) as presented in Table 5.

4.2.1.2 Plant height (cm) at 30 DAS

Plant height at 30 DAS in genotypes of radish ranged from 12.65 to 27.81 cm with an average mean value of 20.42 cm. The genotype Kashi Mooli- 40 recorded the maximum plant height (27.81 cm), which was on par with ORBI- 0527 (27.57 cm). Whereas the genotype Scarlet Globe recorded the minimum plant height (12.65 cm) as presented in Table 5.

4.2.1.3 Plant height (cm) at 45 DAS

Plant height at 45 DAS ranged from 15.29 to 31.61 cm, with an average mean value of 27.72 cm. The genotype VRRAD-131 recorded the maximum plant height (31.61 cm), which was on par with Kashi Hans (31.57 cm), VRRAD- 199 (31.36 cm), Arka Nishant (31.29 cm) and Kashi Sweta (31.01 cm). Whereas the genotype Scarlet Globe recorded the minimum plant height (15.29 cm) as presented in Table 5.

4.2.1.4 Number of leaves at 15 DAS

The number of leaves at 15 DAS ranged from 4.80 to 2.99, with an average mean value of 3.70. Among the different genotypes, the genotype Kashi Hans (4.80) recorded the highest number of leaves, followed by Kashi Aardra (4.40) and the genotype VBGH- 507 recorded the minimum number of leaves (2.99), as presented in Table 5.

4.2.1.5 Number of leaves at 30 DAS

The number of leaves at 30 DAS in radish genotypes ranged from 8.07 to 5.53, with an average mean value of 7.09. The genotype Kashi Aardra (8.07) recorded the highest number of leaves, which was on par with Palak Patta (7.90), Kashi Mooli- 40 (7.80), VRRAD- 200 (7.80), and the minimum number of leaves at 30 DAS was recorded by the genotype Scarlet Globe (5.53) as presented in Table 5.

4.2.1.6 Number of leaves at 45 DAS

The number of leaves at 45 DAS in genotypes of radish ranged from 11.46 to 7.73, with an average mean value of 9.58. Among the different genotypes, the genotype Kashi Aardra (11.46) recorded the highest number of leaves, which was on par with Kashi Mooli- 40 (11.13), Chinese Pink (10.60), White Star (10.46) and the genotype Scarlet Globe (7.73) recorded the minimum number of leaves as presented in Table 5.

4.2.1.7 Leaf length (cm) at 15 DAS

Leaf length at 15 DAS ranged from 3.81 to 2.26 cm, with an average mean value of 3.5 cm. The genotype Kashi Hans (3.81 cm) recorded the maximum leaf length, which was on par with Kashi Sweta (3.78 cm), VRRAD- 4 (3.80 cm),

Table 5. Performance of radish genotypes for plant height and number of leaves at different stages of crop growth

Genotypes	Plant height (cm)			Number of leaves		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	7.33	23.67	31.57	4.80	7.13	10.26
Kashi Sweta	6.23	22.29	31.01	4.19	7.06	9.33
Kashi Mooli 40	6.13	27.81	30.85	4.19	7.80	11.13
Kashi Aardra	5.23	18.83	25.91	4.40	8.07	11.46
VRRAD- 4	6.70	16.55	22.70	3.20	6.73	10.00
VRRAD- 91	5.83	17.35	24.46	4.20	7.66	9.73
VRRAD- 199	6.33	21.21	31.36	3.60	7.06	9.80
VRRAD- 131	6.80	24.61	31.61	3.80	7.66	9.60
VRRAD- 200	6.50	22.23	29.39	3.60	7.80	9.33
VRRAD- 11	6.16	15.84	28.87	4.00	6.33	9.40
Arka Nishant	6.00	26.19	31.29	3.20	5.80	8.40
White Sparkle Tip	6.60	18.51	27.27	3.60	6.86	8.13
Palak Patta	6.53	20.95	23.10	3.19	7.90	9.40
White Star	7.26	17.49	27.53	3.60	7.00	10.46
Chinese Pink	6.43	19.77	29.75	3.40	6.66	10.60
VBGH- 507	5.56	16.73	29.11	2.99	7.66	9.80
ORBI- 0527	7.13	27.57	30.16	3.39	7.26	9.33
Scarlet Globe	4.16	12.65	15.29	3.40	5.53	7.73
Red Radish	7.00	15.19	23.13	3.60	7.00	9.00
Pusa Chetki	6.45	22.85	30.04	3.60	6.73	8.73
Mean	6.32	20.42	27.72	3.70	7.09	9.58
S.Em. $\pm$	0.23	0.26	0.44	0.06	0.42	0.37
CD at 5 %	0.66	0.75	1.26	0.16	1.21	1.07

DAS: Days after sowing

White Star (3.72 cm) and the minimum leaf length was recorded in the genotype Scarlet Globe (2.26 cm) as presented in Table 6.

4.2.1.8 Leaf length (cm) at 30 DAS

Leaf length at 30 DAS in radish genotypes ranged from 22.72 to 9.52 cm with an average mean value of 17.48 cm. The genotype Kashi Hans (22.72 cm) recorded the maximum leaf length, which was on par with Kashi Sweta (21.46 cm). Whereas the genotype Scarlet Globe (9.52 cm) recorded the minimum leaf length as presented in Table 6.

4.2.1.9 Leaf length (cm) at 45 DAS

Leaf length at 45 DAS in genotypes of radish ranged from 29.80 to 12.80 cm with an average mean value of 20.72 cm. The genotype Kashi Hans (35.80 cm) recorded the maximum leaf length, which was followed by Kashi Sweta (25.17 cm) and the minimum leaf length was recorded in the genotype Scarlet Globe (12.80 cm) as presented in Table 6.

4.2.1.10 Leaf width (cm) at 15 DAS

Leaf width at 15 DAS ranged from 4.05 to 1.24 cm with an average mean value of 2.51 cm. The genotype Pusa Chetki (4.05 cm) recorded the maximum leaf width, which was on par with Kashi Hans (3.60 cm) and the minimum leaf length was recorded in the genotype VRRAD- 11 (1.24 cm) as presented in Table 6.

4.2.1.11 Leaf width (cm) at 30 DAS

Leaf width at 30 DAS ranged from 7.91 to 4.48 cm with an average mean value of 6.43 cm. Among the different genotypes, the genotype Kashi Hans (7.91 cm) recorded the maximum leaf width, which was on par with Kashi Sweta (7.70 cm) and the minimum leaf width was recorded in the genotype VRRAD- 4 (4.48 cm) as presented in Table 6.

4.2.1.12 Leaf width (cm) at 45 DAS

Leaf width at 45 DAS ranged from 9.68 to 6.66 cm with an average mean value of 8.27 cm. The genotype Kashi Hans (9.68 cm) recorded the maximum leaf width which was followed by Kashi Sweta (9.19 cm) and the genotype Scarlet Globe (6.66 cm) recorded the minimum leaf width at 45 DAS, as presented in Table 6.

4.2.1.13 Spread of the plant (N-S) (cm) at 15 DAS

Spread of plant at 15 DAS in radish genotypes ranged from 17.44 to 12.10 cm with an average mean value of 14.70 cm. The genotype Pusa Chetki (17.44 cm) recorded the maximum plant spread (N-S), which was followed by VRRAD- 4 (16.60 cm) and the minimum spread of the plant was recorded in the genotype VRRAD- 131 (12.10 cm) as presented in Table 7.

Table 6. Performance of radish genotypes for leaf length and leaf width at different stages of crop growth

Genotypes	Leaf length (cm)			Leaf width (cm)		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	3.81	22.72	29.80	3.60	7.91	9.68
Kashi Sweta	3.78	21.46	25.17	2.86	7.70	9.19
Kashi Mooli 40	3.55	18.62	21.98	2.41	6.84	8.68
Kashi Aardra	3.02	16.56	19.96	2.18	6.34	7.78
VRRAD- 4	3.80	12.88	20.94	1.66	4.48	7.22
VRRAD- 91	3.57	13.9	20.32	2.90	6.63	7.90
VRRAD- 199	3.54	17.28	23.12	2.96	7.20	8.77
VRRAD- 131	3.57	19.94	22.59	2.72	7.48	8.84
VRRAD- 200	3.42	17.25	17.24	2.01	7.02	8.04
VRRAD- 11	3.47	13.44	23.42	1.24	4.64	6.80
Arka Nishant	3.70	20.00	24.48	2.38	6.36	8.72
White Sparkle Tip	3.41	15.38	17.18	2.78	6.82	8.86
Palak Patta	3.71	16.34	18.26	3.06	7.36	9.18
White Star	3.72	14.64	21.16	2.10	6.00	8.06
Chinese Pink	3.49	16.14	24.46	2.08	5.56	7.76
VBGH- 507	3.30	20.18	22.32	1.98	5.78	8.02
ORBI- 0527	3.48	19.92	22.52	2.54	7.18	8.78
Scarlet Globe	2.26	9.52	12.80	2.58	5.14	6.66
Red Radish	3.70	11.51	18.16	2.04	5.37	7.36
Pusa Chetki	3.66	16.2	22.14	4.05	6.82	9.14
Mean	3.50	17.48	20.72	2.51	6.43	8.27
S. Em ±	0.18	0.29	0.30	0.11	0.11	0.14
CD at 5%	0.51	0.84	0.86	0.31	0.32	0.40

DAS: Days after sowing

4.2.1.14 Spread of the plant (N-S) (cm) at 30 DAS

The Spread of the plant at 30 DAS ranged from 29.23 to 23.60 cm with an average mean value of 25.90 cm. Among the different genotypes, the genotype Chinese Pink (29.23 cm) recorded the maximum plant spread (N-S), which was on par with Pusa Chetki (29.04 cm), VRRAD- 4 (28.34 cm) and the minimum spread of the plant was recorded in the genotype VRRAD- 131 (23.60 cm) as presented in Table 7.

4.2.1.15 Spread of the plant (N-S) (cm) at 45 DAS

Spread of plant at 45 DAS in radish genotypes ranged from 35.99 to 28.61 cm with an average mean value of 32.03 cm. Among the different genotypes, the genotype Pusa Chetki (35.99 cm) had recorded the maximum plant spread, which was on par with Kashi Mooli- 40 (34.95 cm) and the minimum spread of the plant was recorded in the genotype Scarlet Globe (28.61 cm) as presented in Table 7.

4.2.1.16 Spread of the plant (E-W) (cm) at 15 DAS

The Spread of the plant (E-W) at 15 DAS ranged from 17.20 to 12.78 cm with an average mean value of 15.08 cm. The genotype VRRAD- 131 (17.20 cm) recorded the maximum plant spread, which was followed by VRRAD- 4 (16.25 cm). Whereas the minimum plant spread was recorded in the genotype Scarlet Globe (12.78 cm) as presented in Table 7.

4.2.1.17 Spread of the plant (E-W) (cm) at 30 DAS

Spread of plant (E-W) at 30 DAS in radish genotypes ranged from 32.15 to 20.15 cm with an average mean value of 23.90 cm. Among the different genotypes, the genotype Kashi Mooli- 40 (32.15 cm) recorded the maximum plant spread, which was followed by Pusa Chetki (27.27 cm) and the genotype ORBI- 0527 (20.15 cm) recorded the minimum plant spread as presented in Table 7.

4.2.1.18 Spread of the plant (E-W) (cm) at 45 DAS

The Spread of the plant (E-W) at 45 DAS ranged from 40.28 to 25.74 cm with an average mean value of 32.24 cm. The maximum spread of the plant was recorded in the genotype Red Radish (40.28 cm), which was followed by Kashi Hans (36.14 cm), and the genotype ORBI- 0527 (25.74 cm), recorded the minimum plant spread (E-W) as presented in Table 7.

4.2.2 Growth parameters

4.2.2.1 Leaf area (cm²) at 15 DAS

Leaf area at 15 DAS in radish genotypes ranged from 45.81 to 25.99 cm² with an average mean value of 31.72 cm². The maximum leaf area was recorded in Pusa Chetki (45.81 cm²), which was followed by Kashi Hans (42.66 cm²) and the genotype Palak Patta (25.99 cm²) recorded the minimum leaf area as presented in Table 8.

Table 7. Performance of radish genotypes for spread of the plant North to South and East to West at different stages of crop growth

Genotypes	Spread of the plant (cm) (N-S)			Spread of the plant (cm) (E-W)		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	14.76	26.91	31.07	15.93	26.61	36.14
Kashi Sweta	14.49	25.22	31.32	14.85	24.46	33.40
Kashi Mooli 40	12.61	25.60	34.95	15.52	32.15	31.50
Kashi Aardra	13.86	23.68	32.90	15.49	22.06	32.04
VRRAD- 4	16.60	28.34	33.87	16.25	22.69	30.71
VRRAD- 91	14.76	25.81	30.30	15.21	21.10	29.16
VRRAD- 199	15.40	24.24	32.50	15.87	23.52	31.55
VRRAD- 131	12.10	23.60	29.20	17.20	24.82	32.82
VRRAD- 200	13.67	24.24	32.82	15.98	24.48	33.42
VRRAD- 11	15.08	26.46	31.20	14.71	21.89	29.62
Arka Nishant	13.21	24.06	29.26	14.95	22.48	31.70
White Sparkle Tip	15.26	24.33	28.68	14.68	26.63	34.27
Palak Patta	16.12	25.70	33.42	14.82	24.23	32.18
White Star	12.88	26.19	31.96	14.85	22.58	30.46
Chinese Pink	16.34	29.23	33.72	13.59	21.59	29.10
VBGH- 507	14.84	26.56	31.06	14.03	23.23	30.26
ORBI- 0527	16.08	27.98	33.89	15.14	20.15	25.74
Scarlet Globe	12.90	25.20	28.61	12.78	22.04	30.33
Red Radish	15.52	26.41	33.87	13.58	23.96	40.28
Pusa Chetki	17.44	29.04	35.99	16.09	27.27	40.10
Mean	14.7	25.94	32.03	15.08	23.90	32.24
S. Em ±	0.23	0.30	0.55	0.21	0.35	0.53
CD at 5%	0.67	0.87	1.58	0.60	1.00	1.50

DAS: Days after sowing

4.2.2.2 Leaf area (cm²) at 30 DAS

Leaf area at 30 DAS ranged from 215.04 to 69.38 cm² with an average mean value of 149.35 cm². Among the different genotypes, the genotype Kashi Hans (215.04 cm²) recorded maximum leaf area, which was followed by Kashi Sweta (196.82 cm²). Whereas the minimum leaf area was recorded in the Scarlet Globe (69.38 cm²) genotype as presented in Table 8.

4.2.2.3 Leaf area (cm²) at 45 DAS

Leaf area at 45 DAS in radish genotypes ranged from 497.86 to 269.68 cm² with an average mean value of 359.61 cm². The maximum leaf area was recorded in the genotype Kashi Hans (497.86 cm²), which was on par with Kashi Sweta (493.81 cm²). Whereas the minimum leaf area was recorded in the Scarlet Globe (269.68 cm²) genotype as presented in Table 8.

4.2.2.4 Leaf area index at 15 DAS

The leaf area index at 15 DAS in radish genotypes ranged from 0.15 to 0.08, with an average mean value of 0.11. The maximum leaf area index was recorded in the genotype Pusa Chetki (0.15), which was followed by Kashi Hans (0.14). Whereas the minimum leaf area index was recorded in the Kashi Mooli- 40 (0.08) genotype as presented in Table 8.

4.2.2.5 Leaf area index at 30 DAS

The leaf area index at 30 DAS ranged from 0.72 to 0.23, with an average mean value of 0.50. The genotype Kashi Hans (0.72) recorded the maximum leaf area index, followed by Kashi Sweta (0.65) and the genotype Scarlet Globe (0.23) recorded the minimum leaf area index as presented in Table 8.

4.2.2.6 Leaf area index at 45 DAS

The leaf area index at 45 DAS among different radish genotypes ranged from 1.71 to 0.89, with an average mean value of 1.21. The maximum leaf area was recorded in the genotype Kashi Hans (1.71), which was on par with Kashi Sweta (1.65), and the minimum leaf area index was recorded in the Scarlet Globe (0.90) genotype, as presented in Table 8.

4.2.2.7 Fresh weight of leaves (g/plant) at 15 DAS

The fresh weight of leaves at 15 DAS ranged from 18.42 to 0.27 g, with an average mean value of 8.98 g. The genotype Kashi Hans (18.42 g) recorded the maximum fresh weight of leaves, which was followed by VRRAD- 200 (16.82 g) and the minimum fresh weight of leaves was recorded in VRRAD- 11 (0.27 g) genotype as presented in Table 9.

Table 8. Performance of radish genotypes for leaf area and leaf area index at different stages of crop growth

Genotypes	Leaf area (cm ²)			Leaf area index		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	42.66	215.04	497.86	0.14	0.72	1.66
Kashi Sweta	37.09	196.82	493.81	0.12	0.66	1.65
Kashi Mooli 40	26.42	103.36	325.38	0.08	0.34	1.08
Kashi Aardra	31.20	164.57	444.23	0.10	0.55	1.48
VRRAD- 4	29.42	81.58	363.04	0.10	0.27	1.21
VRRAD- 91	26.87	195.34	293.90	0.09	0.65	0.98
VRRAD- 199	28.44	175.60	385.84	0.09	0.59	1.29
VRRAD- 131	33.47	194.82	382.74	0.11	0.65	1.28
VRRAD- 200	26.87	147.46	431.20	0.09	0.49	1.44
VRRAD- 11	38.66	159.58	353.04	0.13	0.53	1.18
Arka Nishant	26.25	120.65	273.02	0.09	0.40	0.91
White Sparkle Tip	27.53	144.76	293.87	0.09	0.48	0.98
Palak Patta	25.99	138.66	290.62	0.09	0.46	0.97
White Star	26.74	98.42	341.92	0.09	0.33	1.14
Chinese Pink	39.42	137.78	335.54	0.13	0.46	1.12
VBGH- 507	36.15	147.31	325.18	0.12	0.49	1.08
ORBI- 0527	27.89	183.52	419.77	0.09	0.61	1.40
Scarlet Globe	28.85	69.38	269.68	0.10	0.23	0.90
Red Radish	28.60	163.72	340.60	0.10	0.55	1.14
Pusa Chetki	45.81	148.60	330.85	0.15	0.50	1.10
Mean	31.72	149.35	359.61	0.11	0.50	1.20
S. Em ±	0.46	2.44	4.39	0.001	0.007	0.020
CD at 5%	1.32	6.99	12.55	0.004	0.020	0.057

DAS: Days after sowing

4.2.2.8 Fresh weight of leaves (g/plant) at 30 DAS

The fresh weight of leaves at 30 DAS in radish genotypes ranged from 48.62 to 6.58 g, with an average mean value of 34.07 g. The maximum fresh weight of leaves was recorded in genotype Kashi Hans (48.62 g), which was on par with Kashi Sweta (45.19 g), Kashi Hans (43.78 g), VRRAD- 4 (42.76 g), VBGH- 507 (43.73 g), Palak Patta (42.83 g) and the minimum fresh weight of leaves was recorded in genotype Scarlet Globe (6.58 g) as presented in Table 9.

4.2.2.9 Fresh weight of leaves (g/plant) at 45 DAS

The fresh weight of leaves at 45 DAS ranged from 85.72 to 12.43 g, with an average mean value of 60.48 g. Among the different genotypes, the maximum fresh weight of leaves was recorded in genotype Kashi Hans (85.72 g), which was on par with Kashi Sweta (83.6 g), and the genotype Scarlet Globe (12.43 g) recorded minimum fresh weight of leaves at 45 DAS as presented in Table 9.

4.2.2.10 Dry weight of leaves (g/plant) at 15 DAS

The dry weight of leaves at 15 DAS in radish genotypes ranged from 1.92 to 0.39 g, with an average mean value of 1.28 g. The maximum dry weight of leaves was recorded in genotype VBGH- 507 (1.92 g), which was on par with Chinese Pink (1.88 g) and Pusa Chetki (1.86 g) and the minimum dry weight of leaves was recorded in the genotype VRRAD- 200 (0.39 g) at 15 DAS as presented in Table 9.

4.2.2.11 Dry weight of leaves (g/plant) at 30 DAS

The dry weight of leaves at 30 DAS ranged from 4.10 to 1.23 g, with an average mean value of 2.85 g. Among the different genotypes, the genotype White Sparkle Tip (4.10 g) recorded the maximum dry weight of leaves, which was on par with Kashi Aardra (3.97 g), and the minimum dry weight of leaves was recorded in the genotype Scarlet Globe (1.23 g) at 30 DAS as presented in Table 9.

4.2.2.12 Dry weight of leaves (g/plant) at 45 DAS

The dry weight of leaves at 45 DAS ranged from 7.46 to 1.33 g, with an average mean value of 4.67 g. The genotype Pusa Chetki (7.46 g) recorded the maximum dry weight of leaves, which was on par with Kashi Hans (7.05 g) and the minimum dry weight of leaves was recorded in the genotype Scarlet Globe (1.33 g) at 45 DAS as presented in Table 9.

4.2.2.13 Fresh weight of roots (g/plant) at 15 DAS

The fresh weight of roots at 15 DAS in radish genotypes ranged from 4.38 to 0.35 g, with an average mean value of 1.08 g. Among the different genotypes, the genotype Kashi Hans (4.38 g) recorded the maximum fresh weight of roots, which was

Table 9. Performance of radish genotypes for fresh weight and dry weight of leaves at different stages of crop growth

Genotypes	Fresh weight of leaves (g/plant)			Dry weight of leaves (g/plant)		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	18.42	48.62	85.72	1.18	2.60	7.05
Kashi Sweta	13.84	45.19	83.60	1.07	3.65	3.97
Kashi Mooli- 40	10.93	24.64	80.99	1.20	2.09	7.02
Kashi Aardra	8.02	43.78	72.75	0.81	3.97	5.32
VRRAD- 4	5.72	42.76	61.51	1.71	3.04	3.16
VRRAD- 91	8.55	29.17	77.16	1.82	3.07	3.89
VRRAD- 199	6.73	33.73	69.58	1.21	2.76	5.65
VRRAD- 131	13.10	31.17	65.56	0.70	2.25	3.81
VRRAD- 200	16.82	34.45	55.01	0.39	2.59	3.88
VRRAD- 11	0.27	30.72	66.54	1.08	3.14	6.18
Arka Nishant	9.98	24.53	40.79	1.52	3.06	4.93
White Sparkle Tip	5.99	17.69	29.72	1.44	2.06	3.81
Palak Patta	12.48	42.83	60.53	1.43	4.10	4.69
White Star	8.09	38.54	59.65	0.79	3.03	5.00
Chinese Pink	7.76	30.55	57.45	1.88	2.79	3.15
VBGH- 507	13.05	43.47	44.16	1.92	2.68	4.93
ORBI- 0527	7.96	38.11	64.72	1.44	3.20	3.69
Scarlet Globe	1.40	6.58	12.43	1.72	1.23	1.33
Red Radish	4.82	35.60	63.10	0.42	2.39	4.92
Pusa Chetki	5.55	39.19	58.67	1.86	2.72	7.46
Mean	8.98	34.07	60.48	1.28	2.85	4.67
S. Em ±	0.15	2.89	0.99	0.02	0.36	0.37
CD at 5%	0.43	8.28	2.84	0.06	1.02	1.06

DAS: Days after sowing

followed by Scarlet Globe (1.79 g). Whereas the minimum fresh weight of roots was recorded in the VRRAD- 4 (0.35 g) genotype at 15 DAS as presented in Table 10.

4.2.2.14 Fresh weight of roots (g/plant) at 30 DAS

The fresh weight of roots at 30 DAS ranged from 33.37 to 13.13 g, with an average mean value of 20.91 g. The genotype Kashi Hans (33.37 g) recorded the maximum fresh weight of roots, which was followed by Kashi Sweta (25.60 g) and the minimum fresh weight of roots was recorded in the White Sparkle Tip (13.13 g) genotype at 30 DAS as presented in Table 10.

4.2.2.15 Fresh weight of roots (g/plant) at 45 DAS

The fresh weight of roots at 45 DAS ranged from 155.67 to 47.61 g with an average mean value of 105.1 g. Among the different genotypes, the genotype Kashi Hans (155.67 g) recorded maximum fresh weight of roots which was followed by Kashi Sweta (137.17 g), ORBI- 0527 (136.63 g). Whereas, the genotype Scarlet Globe (47.61 g) recorded minimum fresh weight of roots at 45 DAS as presented in Table 10.

4.2.2.16 Dry weight of roots (g/plant) at 15 DAS

The dry weight of roots at 30 DAS ranged from 1.10 to 0.04 g, with an average mean value of 0.19 g. The genotype Kashi Aardra (1.10 g) recorded maximum dry weight of roots which was followed by Kashi Hans (0.85 g) and the minimum dry weight of roots was recorded in White sparkle tip and VRRAD- 4 (0.04 g) at 15 DAS as presented in Table 10.

4.2.2.17 Dry weight of roots (g/plant) at 30 DAS

The dry weight of roots at 30 DAS ranged from 3.80 to 0.78 g, with an average mean value of 1.99 g. The genotype Kashi Hans (3.80 g) recorded maximum dry weight of roots which was followed by White Sparkle Tip (3.43 g) and the minimum dry weight of roots was recorded in the Chinese Pink (0.78 g) at 30 DAS as presented in Table 10.

4.2.2.18 Dry weight of roots (g/plant) at 45 DAS

Dry weight of roots at 45 DAS in radish genotypes ranged from 7.12 to 1.83 g with average mean value of 3.71 g. Among the different genotypes, the genotype VRRAD- 91 (7.38 g) recorded maximum dry weight of roots which was followed by Kashi Sweta (7.12 g) and the genotype VRRAD- 131 (1.83 g) recorded minimum dry weight of roots as presented in Table 10.

4.2.2.19 Total dry matter (g/plant) at 15, 30 and 45 DAS

Total dry matter content ranged from 0.47 (Red radish and VRRAD- 200 each) to 2.03 g (Kashi Hans), 2.69 (Scarlet Globe) to 6.40 g (Kashi Hans) and 3.89 (Scarlet

Table 10. Performance of radish genotypes for fresh weight and dry weight of roots at different stages of crop growth

Genotypes	Fresh weight of roots (g/plant)			Dry weight of roots (g/plant)		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	4.38	33.37	155.67	0.85	3.80	5.36
Kashi Sweta	1.68	25.60	137.17	0.13	1.98	7.12
Kashi Mooli 40	0.46	14.15	99.10	0.05	1.75	2.23
Kashi Aardra	0.72	24.42	114.96	1.10	1.06	4.03
VRRAD- 4	0.35	16.98	102.10	0.07	2.58	2.57
VRRAD- 91	0.55	19.65	109.17	0.14	2.66	7.38
VRRAD- 199	1.65	21.48	103.62	0.15	2.62	4.36
VRRAD- 131	1.41	16.99	101.52	0.10	1.78	1.83
VRRAD- 200	0.78	23.06	102.88	0.08	1.64	2.29
VRRAD- 11	1.21	17.89	102.71	0.04	1.57	3.79
Arka Nishant	0.97	21.53	108.15	0.19	1.60	4.23
White Sparkle Tip	0.57	13.13	59.62	0.04	3.43	2.41
Palak Patta	1.33	24.42	127.08	0.24	1.83	5.25
White Star	0.77	24.78	122.06	0.24	1.28	1.94
Chinese Pink	0.77	17.19	75.89	0.08	0.78	3.08
VBGH- 507	0.81	24.03	114.97	0.05	1.77	4.31
ORBI- 0527	0.51	19.71	136.63	0.05	1.96	1.98
Scarlet Globe	1.79	15.51	47.61	0.07	1.46	2.56
Red Radish	0.44	20.50	67.62	0.05	1.96	4.63
Pusa Chetki	0.48	23.81	112.77	0.13	2.19	2.75
Mean	1.08	20.91	105.10	0.19	1.99	3.71
S. Em ±	0.02	0.34	2.23	0.003	0.033	0.067
CD at 5 %	0.05	0.98	6.39	0.010	0.090	0.191

DAS: Days after sowing

Table 11. Performance of radish genotypes for total dry matter at different stages of crop growth

Genotypes	Total dry matter (g/plant)		
	15 DAS	30 DAS	45 DAS
Kashi Hans	2.03	6.40	12.41
Kashi Sweta	1.20	5.63	11.09
Kashi Mooli 40	1.25	3.84	9.25
Kashi Aardra	1.91	5.03	9.35
VRRAD- 4	1.78	5.62	5.73
VRRAD- 91	1.96	5.73	11.27
VRRAD- 199	1.36	5.38	10.01
VRRAD- 131	0.80	4.03	5.64
VRRAD- 200	0.47	4.23	6.17
VRRAD- 11	1.12	4.71	9.97
Arka Nishant	1.71	4.66	9.16
White Sparkle Tip	1.48	5.49	6.22
Palak Patta	1.67	5.93	9.94
White Star	1.03	4.31	6.94
Chinese Pink	1.96	3.57	6.23
VBGH- 507	1.97	4.45	9.24
ORBI- 0527	1.49	5.16	5.67
Scarlet Globe	1.79	2.69	3.89
Red Radish	0.47	4.35	9.55
Pusa Chetki	1.99	4.91	10.21
Mean	1.47	4.80	9.01
S.Em. $\pm$	0.02	0.35	0.38
CD at 5 %	0.06	1.01	1.09

DAS: Days after sowing

Globe) to 12.41 g (Kashi Hans) with an average mean of 1.47, 4.80 and 8.39 at 15, 30 and 45 DAS, respectively as presented in Table 11.

4.2.2.20 Specific leaf area (cm^2/g) at 15, 30 and 45 DAS

Specific leaf area ranged from 14.76 (VRRAD- 91) to 68.89 (VRRAD- 200), 26.83 (VRRAD- 4) to 86.58 (VRRAD- 131) and 44.34 (Pusa Chetki) to 202.76 (Scarlet Globe) with an average mean of 29.84, 54.28 and 86.75 at 15, 30 and 45 DAS, respectively as presented in Table 12.

4.2.2.21 Specific leaf weight (g/cm^2) at 15, 30 and 45 DAS

Specific leaf weight ranged from 0.0145 (VRRAD- 200) to 0.0677 (VRRAD- 91), 0.0115 (VRRAD- 131) to 0.0372 (VRRAD- 4) and 0.0049 (Scarlet Globe) to 0.0225 (Pusa Chetki) with an average mean of 0.004, 0.020 and 0.010 at 15, 30 and 45 DAS, respectively as presented in Table 12.

4.2.2.22 Absolute growth rate ($\text{g}/\text{plant}/\text{day}$) at 15, 30 and 45 DAS

Absolute growth rate ranged from 0.060 (Scarlet Globe) to 0.295 (Kashi Sweta) and 0.007 (VRRAD- 4) to 0.400 (Kashi Hans) with mean value of 0.22 and 0.24 at 15-30 and 30-45 DAS, respectively as presented in Table 13.

4.2.2.23 Crop growth rate ($\text{g}/\text{m}^2/\text{day}$) at 15, 30 and 45 DAS

Crop growth rate ranged from 1.999 (Scarlet Globe) to 9.832 (Kashi Sweta) and 0.233 (VRRAD- 4) to 13.332 (Kashi Hans) with an average mean of 7.400 and 7.970 at 15-30 and 30-45 DAS, respectively as presented in Table 13.

4.2.2.24 Net assimilation rate ($\text{g}/\text{cm}^2/\text{day}$) at 15, 30 and 45 DAS

Net assimilation rate ranged from 0.0013 (Scarlet Globe and Chinese Pink) to 0.0050 (VRRAD-4) and 0.0001 (ORBI- 0527) to 0.0018 (Kashi Mooli- 40) with an average mean of 0.0030 and 0.0010 at 15-30 and 30-45 DAS, respectively as presented in Table 13.

4.2.3 Root parameters

4.2.3.1 Days to harvest

Days to harvest from the date of sowing were recorded, and they ranged from 24.33 to 45.67 days, with an overall mean of 36.12 days. The earliest harvest was observed for Scarlet Globe (24.33 days) which was followed by White Sparkle Tip (27.33 days). Whereas, the maximum number of days to harvest was noted in Pusa Chetki (45.67 days) as presented in Table 14.

4.2.3.2 Root length (cm)

Root length in genotypes of radish varied from 9.96 to 25.01 cm with overall mean of 18.88 cm. The maximum root length was found in Kashi Hans (25.01 cm)

Table 12. Performance of radish genotypes for specific leaf area and specific leaf weight at different stages of crop growth

Genotypes	Specific leaf area (cm ² / g)			Specific leaf weight (g/ cm ²)		
	15 DAS	30 DAS	45 DAS	15 DAS	30 DAS	45 DAS
Kashi Hans	36.15	82.70	70.61	0.0276	0.0120	0.0141
Kashi Sweta	34.66	53.92	124.38	0.0288	0.0185	0.0080
Kashi Mooli 40	22.07	49.45	46.35	0.0454	0.0202	0.0215
Kashi Aardra	38.51	41.45	83.50	0.0259	0.0241	0.0119
VRRAD- 4	17.20	26.83	114.88	0.0581	0.0372	0.0087
VRRAD- 91	14.76	63.62	75.55	0.0677	0.0157	0.0132
VRRAD- 199	23.50	63.62	68.29	0.0425	0.0157	0.0146
VRRAD- 131	47.81	86.58	100.45	0.0209	0.0115	0.0099
VRRAD- 200	68.89	56.93	111.13	0.0145	0.0175	0.0089
VRRAD- 11	35.79	50.82	57.12	0.0279	0.0196	0.0175
Arka Nishant	17.26	39.42	55.37	0.0579	0.0253	0.0180
White Sparkle Tip	19.11	70.27	77.13	0.0523	0.0142	0.0129
Palak Patta	18.17	33.81	61.96	0.0550	0.0295	0.0161
White Star	33.84	32.48	68.38	0.0295	0.0307	0.0146
Chinese Pink	20.96	49.38	106.52	0.0476	0.0202	0.0093
VBGH- 507	18.82	54.96	65.95	0.0531	0.0181	0.0151
ORBI- 0527	19.36	49.73	131.17	0.0516	0.0201	0.0076
Scarlet Globe	16.77	56.40	202.76	0.0596	0.0177	0.0049
Red Radish	68.09	68.50	69.22	0.0146	0.0145	0.0144
Pusa Chetki	25.03	54.63	44.34	0.0406	0.0183	0.0225
Mean	29.84	54.28	86.75	0.004	0.020	0.010
S. Em ±	0.61	0.94	1.69	0.0006	0.0003	0.0002
CD at 5 %	1.74	2.70	4.82	0.0016	0.0007	0.0005

DAS: Days after sowing

Table 13. Performance of radish genotypes for absolute growth rate, crop growth rate and net assimilation rate at different stages of crop growth

Genotypes	Absolute growth rate (g/ plant/day)		Crop growth rate (g/m ² /day)		Net assimilation rate (g/dm ² /day)	
	15-30 DAS	30-45 DAS	15-30 DAS	30-45 DAS	15-30 DAS	30-45 DAS
Kashi Hans	0.291	0.400	9.699	13.332	0.0027	0.0011
Kashi Sweta	0.295	0.364	9.832	12.132	0.0030	0.0011
Kashi Mooli 40	0.172	0.360	5.732	11.998	0.0030	0.0018
Kashi Aardra	0.208	0.288	6.932	9.599	0.0025	0.0010
VRRAD- 4	0.256	0.007	8.532	0.233	0.0050	0.0003
VRRAD- 91	0.251	0.369	8.365	12.298	0.0029	0.0015
VRRAD- 199	0.268	0.308	8.932	10.265	0.0033	0.0011
VRRAD- 131	0.215	0.107	7.165	3.566	0.0023	0.0003
VRRAD- 200	0.250	0.129	8.332	4.299	0.0035	0.0004
VRRAD- 11	0.239	0.350	7.965	11.665	0.0028	0.0014
Arka Nishant	0.196	0.300	6.532	9.999	0.0031	0.0016
White Sparkle Tip	0.267	0.048	8.899	1.599	0.0037	0.0002
Palak Patta	0.284	0.267	9.465	8.899	0.0042	0.0013
White Star	0.218	0.175	7.265	5.832	0.0039	0.0008
Chinese Pink	0.107	0.177	3.566	5.899	0.0013	0.0007
VBGH- 507	0.165	0.319	5.499	10.632	0.0020	0.0014
ORBI- 0527	0.244	0.034	8.132	1.133	0.0029	0.0001
Scarlet Globe	0.060	0.080	1.999	2.666	0.0013	0.0005
Red Radish	0.258	0.346	8.599	11.532	0.0033	0.0014
Pusa Chetki	0.194	0.353	6.466	11.765	0.0022	0.0015
Mean	0.220	0.240	7.400	7.970	0.0030	0.0010
S. Em ±	0.003	0.005	0.106	0.147	0.0005	0.00002
CD at 5 %	0.009	0.014	0.303	0.422	0.0002	0.00004

DAS: Days after sowing

which was followed by Kashi Sweta (22.56 cm), while the minimum root length was observed in Scarlet Globe (9.96 cm) as presented in Table 14.

4.2.3.3 Root diameter (mm)

Root diameter in genotypes of radish varied from 32.22 to 19.29 mm, with an overall mean of 23.93 mm. The maximum root diameter was found in Scarlet Globe (32.22 mm) which was on par with White sparkle tip (30.90 mm), Kashi Hans (28.64 mm). While, the minimum root diameter was observed in VRRAD- 11 (19.29 mm), as presented in Table 14.

4.2.3.4 Root girth (cm)

Root girth in genotypes of radish varied from 11.76 to 6.72 cm with an overall mean of 9.29 cm. The maximum root girth was found in Scarlet Globe (11.76 cm) which was on par with Kashi Hans (11.26 cm). While, the minimum root girth was observed in Kashi Aardra (6.72 cm) as presented in Table 14.

4.2.3.5 Root volume (cc)

Root volume in genotypes of radish varied from 103.00 to 25.60 cc with an overall mean of 72.11 cc. The maximum root volume was found in Kashi Hans (103.00 cc), which was followed by Kashi Sweta (97.00 cc). While the minimum root volume was observed in Scarlet Globe (25.60 cc), as presented in Table 14.

4.2.3.6 Root weight (g)

The root weight varied from 155.67 to 47.60 g, with an overall mean of 105.10 g. The highest root weight was observed in Kashi Hans (155.67 g) followed by Kashi Sweta (137.71 g), while the lowest root weight was observed in Scarlet Globe (47.60 g), as presented in Table 15.

4.2.3.7 Root yield (kg/plot)

Root yield per plot in genotypes of radish ranged from 7.59 to 2.40 kg with an average mean of 5.17 kg. Among the different genotypes, the line Kashi Hans (7.59 kg) recorded maximum root yield per plot which was followed by Kashi Sweta (6.82 kg), ORBI- 0527 (6.27 kg). Whereas, the genotype Scarlet Globe (2.40 kg) recorded the minimum root yield per plot as presented in Table 15.

4.2.3.8 Root yield (t/ha)

Root yield per hectare in genotypes of radish ranged from 43.67 to 16.31 tonnes per hectare with the average mean 33.75 tonnes per hectare. Among the different genotypes, Kashi Hans (43.67 t/ha) recorded the maximum root yield per hectare followed by Kashi Sweta (41.58 t/ha). Whereas the genotype Scarlet Globe (16.31 t/ha) recorded the minimum root yield per hectare as presented in Table 15.

Table 14. Performance of radish genotypes for days to harvest, root length, root diameter, root girth and root volume

Genotypes	Days to harvest	Root length (cm)	Root diameter (mm)	Root girth (cm)	Root volume (cc)
Kashi Hans	31.33	25.01	28.64	11.26	103.00
Kashi Sweta	36.00	22.56	27.32	11.12	97.00
Kashi Mooli 40	44.33	21.48	19.30	8.04	64.00
Kashi Aardra	45.66	20.90	21.93	6.72	86.00
VRRAD- 4	37.66	18.40	21.48	6.74	72.80
VRRAD- 91	39.33	20.48	20.14	8.54	81.00
VRRAD- 199	34.66	18.98	25.68	10.16	72.80
VRRAD- 131	38.00	18.00	21.05	8.42	75.60
VRRAD- 200	37.66	20.58	25.24	8.54	75.60
VRRAD- 11	34.66	22.26	19.29	9.78	73.20
Arka Nishant	41.66	19.10	22.05	9.00	74.00
White Sparkle Tip	27.33	11.10	30.90	10.26	31.00
Palak Patta	38.33	22.06	26.39	10.06	97.60
White Star	37.33	16.16	22.28	8.36	80.20
Chinese Pink	29.66	9.96	25.53	7.34	42.40
VBGH- 507	34.66	20.38	20.29	9.06	75.20
ORBI- 0527	34.66	21.30	24.86	11.46	92.00
Scarlet Globe	24.33	11.34	32.22	11.76	25.60
Red Radish	29.33	16.69	22.99	10.92	41.00
Pusa Chetki	45.67	20.90	20.95	8.18	83.00
Mean	36.12	18.88	23.93	9.29	72.11
S.Em. $\pm$	0.67	0.28	1.26	0.14	1.13
CD at 5 %	1.91	0.8	3.61	0.40	3.23

Table 15. Performance of radish genotypes for root weight, root yield per plot and root yield per hectare

Genotypes	Root weight (g)	Root yield (kg/plot)	Root yield (t/ha)
Kashi Hans	155.67	7.59	43.67
Kashi Sweta	137.71	6.82	41.58
Kashi Mooli 40	99.10	4.98	33.21
Kashi Aardra	114.96	5.98	39.86
VRRAD- 4	102.10	5.06	33.81
VRRAD- 91	109.17	5.11	34.12
VRRAD- 199	103.62	5.34	35.66
VRRAD- 131	101.52	5.07	33.85
VRRAD- 200	102.89	5.00	33.34
VRRAD- 11	102.71	5.64	37.53
Arka Nishant	108.15	5.50	35.92
White Sparkle Tip	59.62	3.12	20.94
Palak Patta	127.08	6.19	40.43
White Star	122.06	5.63	37.56
Chinese Pink	75.89	2.78	18.59
VBGH- 507	114.96	5.54	36.98
ORBI- 0527	136.63	6.27	41.20
Scarlet Globe	47.60	2.40	16.31
Red Radish	67.63	3.38	22.56
Pusa Chetki	112.77	5.97	37.84
Mean	105.10	5.17	33.75
S.Em. $\pm$	2.23	0.09	0.57
CD at 5 %	6.39	0.24	1.63

4.2.4 Quality parameters

The root quality parameters viz., colour and shape were recorded for radish genotypes on the DUS character and visual observation basis and is presented in Table 16.

Radish genotypes varied in the shape of their root, which was categorised into narrow triangular, oblong, acicular, cylindrical, narrow elliptic and globular. Genotypes of radish showed a range of colours, including white, purple, red and Pink.

The per cent incidence of forking in roots of radish genotypes is presented in Table 17. The genotype VRRAD- 4 (20.33 %) recorded the highest incidence of forking and the least in Kashi Hans, Kashi Sweta, ORBI- 0527, Palak Patta and Pusa Chetki (0.00 %).

4.2.5 Biochemical parameters

4.2.5.1 Reducing sugars (%)

Reducing sugar content in radish genotypes varied from 1.22 to 2.99 per cent, with an average mean of 1.93 per cent. Among the different genotypes, the genotype ORBI- 0527 (2.99 %) recorded the maximum reducing sugars which was on par with Kashi Sweta (2.86 %) and Kashi Hans (2.80 %). Whereas, the genotype VRRAD- 131 (1.22 %) recorded the minimum reducing sugars content as presented in Table 18.

4.2.5.2 Non- reducing sugars (%)

Non reducing sugars content in radish genotypes varied from 0.32 to 1.32 per cent with the average mean of 0.61 per cent. The genotype Pusa Chetki (1.32 %) recorded the maximum non-reducing sugars, which was followed by Palak Patta (0.95 %), and the genotype White Sparkle Tip (0.32 %) recorded the minimum non-reducing sugars content, as presented in Table 18.

4.2.5.3 Total sugars (%)

Total sugar content in radish genotypes varied from 1.65 to 4.20 per cent, with an average mean of 2.56 per cent. Among the different genotypes, the genotype ORBI- 0527 (4.20 %) recorded the maximum total sugars which was followed by Kashi Hans (3.62 %) and the genotype VRRAD- 131 (1.65 %) recorded the minimum total sugars content as presented in Table 18.

4.2.5.4 Ascorbic acid (mg/ 100g)

The ascorbic acid content in the genotypes of radish ranged from 28.30 to 12.32 per cent with the average mean value of 18.46 per cent. The maximum ascorbic acid content was found in VRRAD- 131 (28.30 %), which was followed by Red Radish (22.69 %). Whereas the genotype Kashi Aardra (12.32 %) recorded the minimum ascorbic acid content as presented in Table 18.

Table 16. Variability for root shape and colour in radish genotypes

Genotypes	Root shape	Root colour
Kashi Hans	Narrow triangular	White
Kashi Sweta	Oblong	White
Kashi Mooli 40	Acicular	White
Kashi Aardra	Acicular	White
VRRAD- 4	Cylindrical	White
VRRAD- 91	Narrow triangular	White
VRRAD- 199	Narrow triangular	White
VRRAD- 131	Narrow triangular	Purple
VRRAD- 200	Cylindrical	White
VRRAD- 11	Narrow triangular	White
Arka Nishant	Narrow triangular	White
White Sparkle Tip	Medium oblate	Purplish white
Palak Patta	Oblong	White
White Star	Acicular	White
Chinese Pink	Narrow elliptic	Pink
VBGH- 507	Oblong	White
ORBI- 0527	Oblong	White
Scarlet Globe	Globular	Red
Red Radish	Cylindrical	Red
Pusa Chetki	Cylindrical	White

Table 17. Incidence of forking per cent in radish genotypes

Genotypes	Forking %
Kashi Hans	0.00
Kashi Sweta	0.00
Kashi Mooli - 40	6.18
Kashi Aardra	10.00
VRRAD- 4	20.33
VRRAD- 91	8.00
VRRAD- 199	22.00
VRRAD- 131	16.00
VRRAD- 200	12.00
VRRAD- 11	14.00
Arka Nishant	12.00
White Sparkle Tip	20.00
Palak Patta	0.00
White Star	12.00
Chinese Pink	18.00
VBGH- 507	12.24
ORBI- 0527	0.00
Scarlet Globe	12.00
Red Radish	12.00
Pusa Chetki	0.00
Mean	9.74
S.Em. $\pm$	0.19
CD at 5 %	0.53

4.2.5.5 Chlorophyll 'a' (mg/g) content at 30 and 45 DAS

Chlorophyll-a content in radish genotypes varied from 0.83 (VRRAD- 199) to 0.32 mg (VRRAD- 91) and 1.87 (VRRAD- 11) to 0.65 (VRRAD- 91) mg with an overall mean of 0.58 and 1.48 mg at 30 and 45 DAS, respectively as presented in Table 19.

4.2.5.6 Chlorophyll 'b' (mg/g) content at 30 and 45 DAS

Chlorophyll-b content in radish genotypes varied from 0.74 (White sparkle tip) to 0.14 mg (VRRAD- 91) and 1.09 (VRRAD- 199) to 0.36 (VRRAD- 91) mg with an overall mean of 0.45 and 0.80 mg at 30 and 45 DAS, respectively as presented in Table 19.

4.2.5.7 Total chlorophyll (mg/g) content at 30 and 45 DAS

Total chlorophyll content in radish genotypes varied from 1.33 (Red radish) to 0.46 mg (VRRAD- 91) and 2.93 (Red radish) to 1.01 (VRRAD- 91) mg with an overall mean of 1.03 and 2.28 mg at 30 and 45 DAS, respectively as presented in Table 19.

4.2.6 Organoleptic evaluation

The radish genotypes showed significant differences in their organoleptic qualities, such as pungency, texture and overall acceptability, presented in Figure 2.

Data obtained of the pungency differed significantly for the genotypes. The maximum pungency score (4.5) was observed in Kashi Sweta, followed by Kashi Mooli- 40 (4.25). Whereas the minimum score was recorded in the genotype Palak Patta (2.00).

The data obtained for the texture revealed that the genotypes VRRAD- 4 and VRRAD-131 had maximum scores of 4.5 each, while the minimum score was observed in the White Sparkle Tip (2.5).

The results for the overall acceptability showed maximum by the Kashi Hans (4.25) genotype followed by VRRAD- 131 (3.8). Whereas the minimum score was recorded by White Sparkle Tip (2.25).

4.3 Genetic components of variation

4.3.1 Variability, Heritability and Genetic Advance for radish genotypes

The range, mean, phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad-sense heritability (h^2), genetic advance (GA), and genetic advance as per cent of mean (GAM) were calculated in order to determine the degree to which the observed variations are caused by genetic factors. The data showed that the researched features had a wide range of variability, heritability, and genetic advancement, which is provided in Tables 20 to 23 and Plate 3.

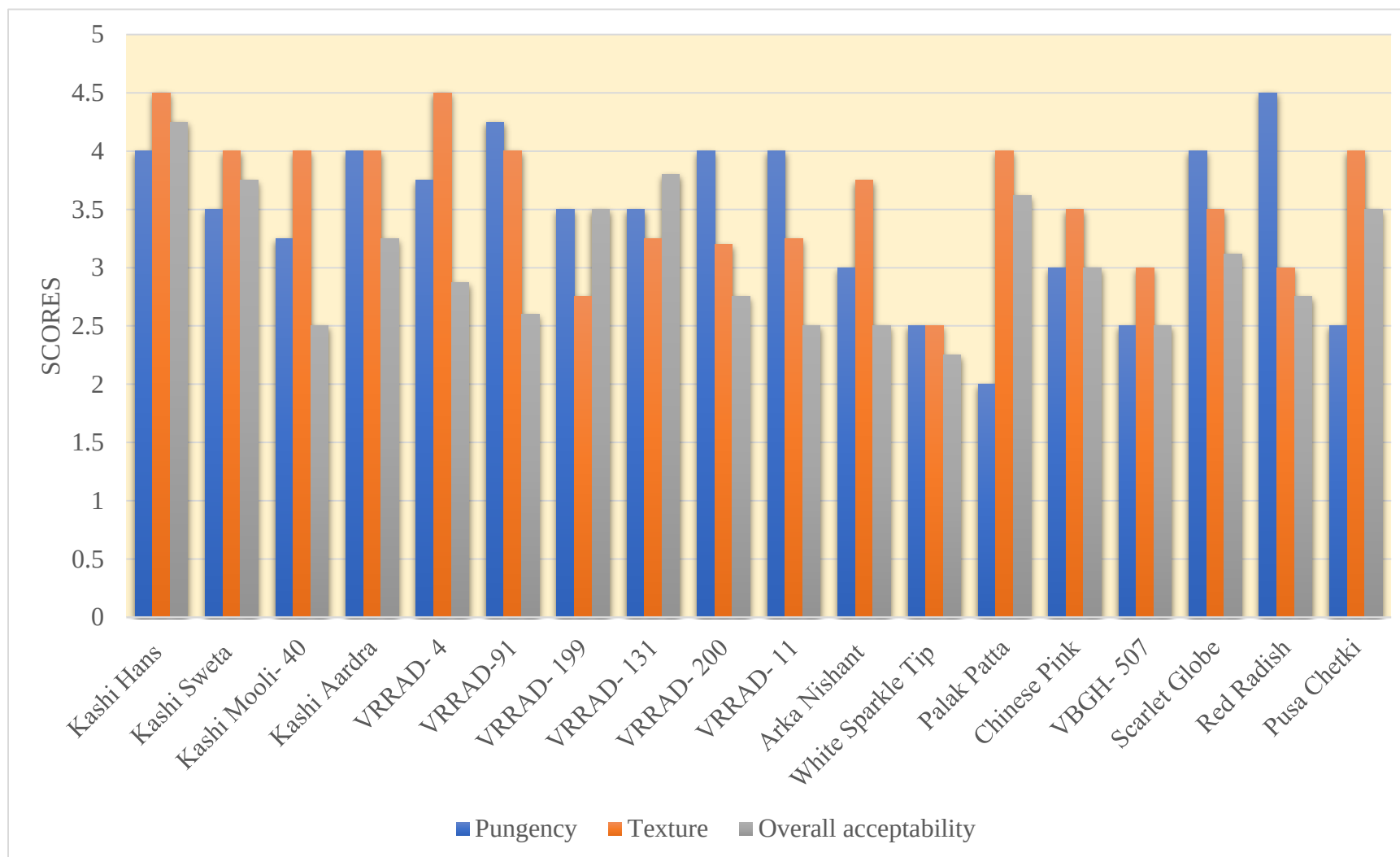


Fig 2. Organoleptic evaluation of radish genotypes

Table 18. Performance for biochemical parameters in radish genotypes

Genotypes	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)	Ascorbic acid (mg/100 g)
Kashi Hans	2.80	0.82	3.62	17.32
Kashi Sweta	2.86	0.51	3.37	17.83
Kashi Mooli 40	2.47	0.63	3.10	18.02
Kashi Aardra	1.71	0.41	2.12	12.32
VRRAD- 4	1.99	0.44	2.43	17.42
VRRAD- 91	1.28	0.33	1.61	18.88
VRRAD- 199	1.57	0.42	1.99	20.61
VRRAD- 131	1.22	0.43	1.65	28.30
VRRAD- 200	2.17	0.35	2.52	21.23
VRRAD- 11	1.39	0.42	1.81	17.52
Arka Nishant	1.89	0.51	2.40	17.67
White Sparkle Tip	1.65	0.32	1.97	22.02
Palak Patta	1.80	0.95	2.75	16.52
White Star	2.16	1.02	3.18	18.37
Chinese Pink	2.33	0.33	2.66	19.51
VBGH- 507	2.08	0.42	2.50	12.64
ORBI- 0527	2.99	1.21	4.20	15.42
Scarlet Globe	1.27	0.69	1.96	20.28
Red Radish	1.25	0.62	1.87	22.69
Pusa Chetki	1.69	1.32	3.01	14.68
Mean	1.93	0.61	2.56	18.46
S.Em. $\pm$	0.16	0.01	0.03	0.32
CD at 5 %	0.45	0.03	0.10	0.91

Table 19. Performance of radish genotypes for chlorophyll content (mg/g of fresh weight) at different stages of crop growth

Genotypes	Chlorophyll 'a'		Chlorophyll 'b'		Total chlorophyll	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
Kashi Hans	0.68	1.67	0.55	1.06	1.24	2.73
Kashi Sweta	0.47	1.36	0.46	0.71	0.94	2.0
Kashi Mooli 40	0.67	1.72	0.54	0.95	1.21	2.67
Kashi Aardra	0.50	1.10	0.35	0.52	0.73	1.62
VRRAD- 4	0.63	1.66	0.52	0.89	1.16	2.56
VRRAD- 91	0.32	0.65	0.14	0.36	0.46	1.01
VRRAD- 199	0.83	1.82	0.49	1.09	1.32	2.91
VRRAD- 131	0.63	1.62	0.45	0.78	1.09	2.40
VRRAD- 200	0.50	1.34	0.37	0.59	0.88	1.94
VRRAD- 11	0.72	1.87	0.45	0.72	1.18	2.59
Arka Nishant	0.64	1.41	0.33	0.73	0.97	2.15
White Sparkle Tip	0.42	1.63	0.74	0.93	1.17	2.57
Palak Patta	0.36	1.20	0.36	0.61	0.83	1.82
White Star	0.57	1.56	0.53	0.88	1.11	2.44
Chinese Pink	0.65	1.44	0.40	0.89	1.06	2.34
VBGH- 507	0.55	1.33	0.35	0.66	0.90	1.99
ORBI- 0527	0.59	1.31	0.40	0.89	1.00	2.21
Scarlet Globe	0.51	1.49	0.48	0.78	1.03	2.27
Red Radish	0.71	1.84	0.61	1.08	1.33	2.93
Pusa Chetki	0.59	1.49	0.40	0.71	1.00	2.20
Mean	0.58	1.48	0.45	0.80	1.03	2.28
S.Em. $\pm$	0.01	0.02	0.01	0.01	0.01	0.02
CD at 5 %	0.02	0.06	0.02	0.03	0.05	0.12

DAS: Days after sowing

4.3.1.1 Plant height (cm) (15, 30 and 45 DAS)

Plant height varied from 4.16 to 7.33 cm, 12.65 to 27.81 cm and 15.29 to 31.61 cm with an average mean of 6.32, 20.42 and 27.72 cm at 15, 30 and 45 DAS, respectively. The GV and PV were (0.49 and 0.65), (17.96 and 18.16) and (17.40 and 17.98) at 15, 30 and 45 DAS, respectively. A moderate estimate of GCV (11.12 %) and PCV (12.80 %) at 15 DAS, a high estimate of GCV (20.76 %) and PCV (20.88 %) at 30 DAS and moderate estimate of GCV (15.05 %) and PCV (15.30 %) at 45 DAS was recorded along with low genetic advance (1.25, 8.68 and 8.45) at 15, 30 and 45 DAS, respectively. High heritability (75.46 %, 98.85 % and 96.78 %) at 15, 30 and 45 DAS. Moderate genetic advance as per cent of mean (19.89 %) and high genetic advance as per cent of mean (42.51 % and 30.49 %) was observed at 15, 30 and 45 DAS (Table 20).

4.3.1.2 Number of leaves (15, 30 and 45 DAS)

Number of leaves varied from 2.99 to 4.80, 5.53 to 8.07 and 7.73 to 11.46, with an average mean of 3.70, 7.09 and 9.58 at 15, 30 and 45 DAS, respectively. The GV and PV were (0.21 and 0.22), (0.29 and 0.82) and (0.74 and 1.16) at 15, 30 and 45 DAS, respectively. Moderate GCV (12.51 %) and PCV (12.77 %) at 15 DAS and low estimate of GCV and moderate estimate of PCV (7.65 % and 12.82 %) and (8.99 % and 11.25 %) along with low genetic advance (0.93, 0.66 and 1.41) was observed at 30 and 45 DAS, respectively. The trait showed high heritability (95.87 % and 63.88 %) at 15 and 45 DAS, whereas moderate heritability (35.60 %) was observed at 30 DAS. High genetic advance as per cent of mean (24.33 %) and, low genetic advance as per cent of mean (9.40 %) and moderate genetic advance as per cent of mean (14.80 %) was observed at 15, 30 and 45 DAS, respectively (Table 20).

4.3.1.3 Leaf length (cm) (15, 30 and 45 DAS)

Leaf length varied from 2.26 to 3.81 cm, 9.52 to 22.72 cm and 12.80 to 29.80 cm with an average mean of 3.5, 17.48 and 20.72 cm at 15, 30 and 45 DAS, respectively. GV and PV were (0.08, 0.18), (29.70, 29.95) and (13.31, 13.57) at 15, 30 and 45 DAS, respectively. Low estimate of GCV (8.52 %) and a moderate estimate of PCV (12.23 %) at 15 DAS, a high estimate of GCV and PCV (31.18 % and 31.32 %) and a moderate estimate of GCV and PCV (17.61 % and 17.78 %) at 30 and 45 DAS, respectively. Low genetic advance (0.42, 7.44) and moderate genetic advance (11.17) at 15, 45 and 30 DAS, respectively. Moderate heritability (48.50 %) along with moderate genetic advance as per cent of mean (12.22 %) was observed at 15 DAS, whereas high heritability (99.14 % and 98.02 %) coupled with high genetic advance as a per cent of mean (63.95 % and 35.90 %) was recorded at 30 and 45 DAS, respectively (Table 20).

4.3.1.4 Leaf width (cm) (15, 30 and 45 DAS)

Leaf width varied from 1.24 to 4.05 cm, 4.48 to 7.91 cm and 6.66 to 9.68 cm with an average mean of 2.51, 6.43 and 8.27 cm at 15, 30 and 45 DAS, respectively. GV and PV were (0.41, 0.44), (0.98, 1.02) and (0.69, 0.74) at 15, 30 and 45 DAS, respectively. The high estimate of GCV (25.56 %) and PCV (26.65 %) was observed at 15 DAS, whereas the moderate estimate of GCV (15.45 % and 10.04 %) and PCV (15.75 % and 10.46 %) was recorded at 30 and 45 DAS, respectively. High heritability (91.97%, 96.23 %) and coupled with high genetic advance as a per cent of mean (50.48 %, 31.22 %) was observed at 15 and 30 DAS and high heritability (92.22 %) coupled with moderate genetic advance as a per cent of mean (19.86 %) was recorded at 45 DAS. The low genetic advance of 1.26, 2.00 and 1.64 were noticed at 15, 30 and 45 DAS, respectively (Table 20).

4.3.1.5 Spread of the plant (cm) (N-S) (15, 30 and 45 DAS)

Spread of the plant North to South ranged from 12.10 to 17.44 cm, 23.60 to 29.23 cm and 28.61 to 35.99 cm with an average mean of 14.70, 25.94 and 32.03 cm at 15, 30 and 45 DAS, respectively. GV and PV were (2.10, 2.27), (2.85, 3.13) and (4.19, 5.10) at 15, 30 and 45 DAS, respectively. The trait had moderate GCV and PCV (10.01 % and 10.25 %) and low GCV (6.51 % and 6.39 %) and PCV (6.82 % and 7.05 %) was observed at 15, 30 and 45 DAS, respectively. High heritability (92.74 %, 91.15 % and 82.17 %) and coupled with moderate genetic advance as a per cent of mean (19.58 %, 12.80 % and 11.94 %) were recorded at 15, 30 and 45 DAS, respectively. Whereas, low genetic advance (2.87, 3.23 and 3.82) was observed at 15, 30 and 45 DAS respectively (Table 20).

4.3.1.6 Spread of the plant (cm) (E-W) (15, 30 and 45 DAS)

Spread of the plant East to West ranged from 12.78 to 17.20 cm, 20.15 to 32.15 cm and 25.74 to 40.28 cm with mean value of 15.08, 23.90 and 32.24 cm at 15, 30 and 45 DAS, respectively. The GV and PV were (1.05 and 1.18, 7.23 and 7.60, 11.91 and 12.74) at 15, 30 and 45 DAS, respectively. Low GCV and PCV (6.80 % and 7.21 %) at 15 DAS, moderate GCV (11.25 % and 10.70 %) and PCV (11.53 % and 11.07 %) at 30 and 45 DAS were observed. The trait showed high heritability (88.78 %) coupled with moderate genetic advance as a per cent of mean (13.19 %) at 15 DAS, whereas high heritability (95.15 % and 93.50 %) along with high genetic advance as a per cent of mean (22.60 % and 21.32 %) at 30 and 45 DAS and low genetic advance of 1.98, 5.40 and 6.87 were recorded at 15, 30 and 45 DAS respectively (Table 20).

4.3.1.7 Leaf area (cm²) at 15, 30 and 45 DAS

Leaf area ranged from 25.99 to 45.81 cm², 69.38 to 215.04 cm² and 269.68 to 497.86 cm² with an average value of 31.72, 149.35 and 359.61 at 15, 30 and 45 DAS,

Table 20. Mean, range and genetic components for morphological parameters in radish

Characters	Mean ±S.Em.	Range		GV	PV	GCV (%)	PCV (%)	h ² (%)	GA	GAM (%)
		Min.	Max.							
Plant height (cm) at 15 DAS	6.32 ± 0.23	4.16	7.33	0.49	0.65	11.12	12.80	75.46	1.25	19.89
Plant height (cm) at 30 DAS	20.42 ± 0.26	12.65	27.81	17.96	18.16	20.76	20.88	98.85	8.68	42.51
Plant height (cm) at 45 DAS	27.72 ± 0.44	15.29	31.61	17.40	17.98	15.05	15.30	96.78	8.45	30.49
Number of leaves at 15 DAS	3.70 ± 0.08	2.99	4.80	0.21	0.22	12.51	12.77	95.87	0.93	24.33
Number of leaves at 30 DAS	7.09 ± 0.42	5.53	8.07	0.29	0.82	7.65	12.82	35.60	0.66	9.40
Number of leaves at 45 DAS	9.58 ± 0.37	7.73	11.46	0.74	1.16	8.99	11.25	63.88	1.41	14.80
Leaf length (cm) at 15 DAS	3.5 ± 0.18	2.26	3.81	0.08	0.18	8.52	12.23	48.50	0.42	12.22
Leaf length (cm) at 30 DAS	17.48 ± 0.29	9.52	22.72	29.70	29.95	31.18	31.32	99.14	11.17	63.95
Leaf length (cm) at 45 DAS	20.72 ± 0.3	12.80	35.80	13.31	13.57	17.61	17.78	98.02	7.44	35.90
Leaf width (cm) at 15 DAS	2.51 ± 0.11	1.24	4.05	0.41	0.44	25.56	26.65	91.97	1.26	50.48
Leaf width (cm) at 30 DAS	6.43 ± 0.11	4.48	7.91	0.98	1.02	15.45	15.75	96.23	2.00	31.22
Leaf width (cm) at 45 DAS	8.27 ± 0.14	6.66	9.68	0.69	0.74	10.04	10.46	92.22	1.64	19.86
Plant spread North to South (cm) at 15 DAS	14.70 ± 0.23	12.10	17.44	2.10	2.27	10.01	10.25	92.74	2.87	19.58
Plant spread North to South (cm) at 30 DAS	25.94 ± 0.30	23.60	29.23	2.85	3.13	6.51	6.82	91.15	3.32	12.80
Plant spread North to South (cm) at 45 DAS	32.03 ± 0.55	28.61	35.99	4.19	5.10	6.39	7.05	82.17	3.82	11.94
Plant spread East to West (cm) at 15 DAS	15.08 ± 0.21	12.78	17.20	1.05	1.18	6.80	7.21	88.78	1.98	13.19
Plant spread East to West (cm) at 30 DAS	23.90 ± 0.35	20.15	32.15	7.23	7.60	11.25	11.53	95.15	5.40	22.60
Plant spread East to West (cm) at 45 DAS	32.24 ± 0.53	25.74	40.28	11.91	12.74	10.70	11.07	93.50	6.87	21.32

DAS - Days after sowing

PV - Phenotypic variance

GCV - Genotypic coefficient of variation

h² - Broad sense heritability

GV - Genotypic variance

PCV - Phenotypic coefficient of variation

GA- Genetic advance

GAM- Genetic advance as per cent of mean

respectively. GV and PV were (36.95 and 37.58, 1570.31 and 1588.22, 4598.18 and 4655.87) at 15, 30 and 45 DAS, respectively. Moderate GCV and PCV (19.16 % and 19.33 %) and (18.86 % and 18.97 %) were observed at 15 and 45 DAS, respectively. Whereas high GCV and PCV were (26.53 % and 26.68 %) was recorded at 30 DAS. High heritability (98.30 %, 98.87 % and 98.76 %) coupled with high genetic advance as a per cent of mean (39.14 %, 54.34 % and 38.60 %) at 15, 30 and 45 DAS, respectively. The genetic advance of 12.41, 81.17 and 138.82 were noticed at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.8 Leaf area index (15, 30 and 45 DAS)

Leaf area index varied from 0.08 to 0.15, 0.23 to 0.72 and 0.89 to 1.71 with mean average values of 0.11, 0.50 and 1.21 at 15, 30 and 45 DAS, respectively. The GV and PV values were (0.00 and 0.00, 0.01 and 0.01, 0.05 and 0.05) at 15, 30 and 45 DAS, respectively. Moderate GCV and PCV (19.08 % and 19.48 %) and (19.53 % and 19.73 %) were observed at 15 and 45 DAS, respectively. While high GCV and PCV were (26.54 % and 26.71 %) was recorded at 30 DAS. High heritability (95.84 %, 98.75 % and 97.97 %) coupled with high genetic advance as a per cent of mean (38.47 %, 54.33 % and 39.82 %) at 15, 30 and 45 DAS, respectively. The genetic advance of 0.04, 0.27 and 0.48 were recorded at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.9 Fresh weight of leaves (g/plant) (15, 30 and 45 DAS)

GV and PV were (21.88 and 21.95), (96.66 and 121.75) and (322.41 and 325.36) at 15, 30 and 45 DAS, respectively, for the fresh weight of leaves and it ranged from 0.27 to 18.42 g, 6.58 to 48.62 g and 12.43 to 85.72 g with a mean value of 8.98, 34.07 and 60.48 g at 15, 30 and 45 DAS, respectively. High GCV (52.11 %, 28.86 % and 29.69 %) and PCV (52.19 %, 32.39 % and 29.82 %) were noticed at 15, 30 and 45 DAS, respectively. High heritability (99.68 %, 79.38 % and 99.09 %) coupled with high genetic advance as a per cent of mean (107.17 %, 52.96 % and 60.87 %) were observed at 15, 30 and 45 DAS, respectively. The genetic advance of 9.62, 18.04 and 36.82 were noticed at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.10 Dry weight of leaves (g/plant) (15, 30 and 45 DAS)

GV and PV for a dry weight of leaves were 0.22 and 0.23, 0.34 and 0.72, 2.17 and 2.59 at 15, 30 and 45 DAS, respectively. The dry weight of leaves ranged from 0.39 to 1.92 g, 1.23 to 4.10 g and 1.33 to 7.46 g with a mean value of 1.28, 2.85 and 4.67 g at 15, 30 and 45 DAS and at harvest, respectively. The high estimates of GCV and PCV (37.33 % and 37.43 %, 20.70 % and 29.95 %, 31.62 % and 34.50 %) were observed at 15, 30 and 45 DAS, respectively. The trait showed high heritability (99.44 % and 84.04 %) at 15 and 45 DAS, respectively, whereas moderate heritability of (47.74 %) was noticed at 30 DAS along with high genetic advance as per cent of

mean (76.68 %, 29.45 % and 59.72%) and low genetic advance of 0.98, 0.83 and 2.78 were observed at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.11 Fresh weight of roots (g/plant) (15, 30 and 45 DAS)

Fresh weight of roots ranged from 0.35 to 4.38 g, 13.13 to 33.37 g and 47.61 to 155.67 g with a mean value of 1.08, 20.91 and 105.10 g at 15, 30 and 45 DAS, respectively. GV and PV were (0.80, 0.80), (22.66, 23.01) and (698.54, 713.49) at 15, 30 and 45 DAS, respectively. The trait had high GCV and PCV (82.82 % and 82.86%, 22.76 % and 22.94 %, 25.15 % and 25.42 %) at 15, 30 and 45 DAS, respectively. The trait showed high heritability (99.90 %, 98.47 % and 97.90 %) coupled with high genetic advance as a per cent of mean (170.53 %, 46.52 % and 51.26 %) at 15, 30 and 45 DAS, respectively. Low genetic advance of 1.84 and 9.73 were noticed at 15 and 30 DAS, whereas a high genetic advance of 53.87 was observed at 45 DAS (Table 21).

4.3.1.12 Dry weight of roots (g/plant) at 15, 30 and 45 DAS

The dry weight of roots ranged from 0.04 to 1.10 g, 0.78 to 3.80 g and 1.83 to 7.12 g with a mean value of 0.19, 1.99 and 3.71 g at 15, 30 and 45 DAS, respectively. GV and PV were (0.08, 0.08), (0.54, 0.54) and (2.72, 2.73) at 15, 30 and 45 DAS, respectively. The trait had high GCV and PCV (58.58 % and 58.72 %), (38.64 % and 38.73 %), (53.37 % and 53.44 %) at 15, 30 and 45 DAS, respectively. The high heritability (99.91 %, 99.60 % and 99.70 %) along with high genetic advance as a per cent of mean at (296.91 %, 76.30 % and 91.53 %) 15, 30 and 45 DAS, respectively. Low genetic advance of 0.57, 1.51 and 3.39 were noticed at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.13 Total dry matter (g/plant) (15, 30 and 45 DAS)

Total dry matter content ranged from 0.47 to 2.03 g, 2.69 to 6.40 g and 3.89 to 12.41 g with an average mean of 1.47, 4.80 and 8.39 at 15, 30 and 45 DAS, respectively. GV and PV were (0.25, 0.25), (0.81, 0.83) and (5.54, 5.59) at 15, 30 and 45 DAS, respectively. High GCV and PCV (33.77 %, 33.85 %) and (28.03 %, 28.17 %) were noticed at 15 and 45 DAS, respectively. Whereas a moderate estimate of GCV and PCV (18.71 %, 18.90 %) was observed at 30 DAS. The high heritability (99.50 %, 97.95 % and 99.04 %) along with high genetic advance as a per cent of mean (69.39 %, 38.14 % and 57.46 %) at 15, 30 and 45 DAS, respectively. The low genetic advance of 1.02, 1.83 and 4.83 were observed at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.14 Specific leaf area (cm²/g) (15, 30 and 45 DAS)

The average mean value of specific leaf area was 29.84, 54.28 and 86.75, with a range of 14.76 to 68.89, 26.83 to 86.58 and 44.34 to 202.76 at 15, 30 and 45 DAS, respectively. The GV and PV were (257.74, 258.50), (410.56 and 413.17) and (1400.16, 1403.91), at 15, 30 and 45 DAS, respectively. High GCV and PCV (53.81 % and

53.89 %), (39.70 % and 39.83 %) and (43.13 % and 43.19 %) at 15, 30 and 45 DAS, respectively. The trait showed high heritability (99.71 %, 99.36 % and 99.73 %) along with high genetic advance as a per cent of mean (110.68 %, 81.53 % and 88.73 %) with the genetic advance of 32.02, 41.60 and 76.98 at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.15 Specific leaf weight (g/cm^2) (15, 30 and 45 DAS)

Specific leaf weight ranged from 0.014 to 0.067, 0.011 to 0.037 and 0.004 to 0.022 with mean values of 0.004, 0.020 and 0.010 at 15, 30 and 45 DAS. The GV and PV values were (0.00 and 0.00), (0.00 and 0.00) and (0.00 and 0.00) at 15, 30 and 45 DAS. The high GCV and PCV (39.28 % and 39.36 %, 32.41 % and 32.56 %, 35.16 % and 35.25 %) at 15, 30 and 45 DAS, respectively. High heritability (99.58 %, 99.05 % and 99.45 %) coupled with high genetic advance as a per cent of mean (80.75 %, 66.44 % and 72.22 %). The genetic advance 0.03, 0.01 and 0.01 was noticed at 15, 30 and 45 DAS, respectively (Table 21).

4.3.1.16 Absolute growth rate ($\text{g}/\text{plant}/\text{day}$) (15, 30 and 45 DAS)

Absolute growth rate varied from 0.060 to 0.295 and 0.007 to 0.400 with average value of 0.22 and 0.24 at 30 and 45 DAS, respectively. The GV and PV (0.006, 0.006) and (0.020 and 0.020) at an interval of 15-30 and 30-45 DAS, respectively. High estimate of GCV and PCV (27.29 % and 27.40 %) and (54.51 % and 54.60 %) were recorded at 30 and 45 DAS, respectively. The trait showed high heritability (99.19 % and 99.68 %) along with high genetic advance as a per cent of mean (55.99 % and 112.12 %) with the genetic advance of 0.12 and 0.27 at 30 and 45 DAS, respectively (Table 21).

4.3.1.17 Crop growth rate ($\text{g}/\text{m}^2/\text{day}$) (15, 30 and 45 DAS)

Crop growth rate was ranged from 1.999 to 9.832 and 0.233 to 13.332 with average mean values of 7.400 and 7.970 at 30 and 45 DAS, respectively. The high heritability (99.11 % and 99.76 %) coupled with high genetic advance as a per cent of mean (55.96 % and 112.18 %) at an interval of 15-30 and 30-45 DAS, respectively. GV and PV were (4.07 and 4.11, 18.87 and 18.92) with high GCV and PCV (27.29 % and 27.41 %, 54.52 % and 54.59 %). The genetic advance of 4.14 and 8.94 were noticed at 30 and 45 DAS, respectively (Table 21).

4.3.1.18 Net assimilation rate ($\text{g}/\text{dm}^2/\text{day}$) (15, 30 and 45 DAS)

Net assimilation rate ranged from 0.0013 to 0.0050 and 0.0001 to 0.0018 with an average value of 0.0030 and 0.0010 at 30 and 45 DAS, respectively. GV and PV (0.00 and 0.00) and (0.03 and 0.03) with high estimates of GCV and PCV (30.56 % and 30.68 %, 53.93 % and 54.00 %) at an interval of 15-30 and 30-45 DAS, respectively. High heritability (93.27 % and 99.79 %) coupled with high genetic advance as a per

Table 21. Mean, range and genetic components for growth parameters in radish

Characters	Mean $\pm$ S.E.m.	Range		GV	PV	GCV (%)	PCV (%)	h ² (%)	GA	GAM (%)
		Min.	Max.							
Leaf area (cm) at 15 DAS	31.72 $\pm$ 0.46	25.99	45.81	36.95	37.58	19.16	19.33	98.30	12.41	39.14
Leaf area (cm) at 30 DAS	149.35 $\pm$ 2.40	69.38	215.04	1570.31	1588.22	26.53	26.68	98.87	81.17	54.34
Leaf area (cm) at 45 DAS	359.61 $\pm$ 4.39	269.68	497.86	4598.18	4655.87	18.86	18.97	98.76	138.82	38.60
Leaf area index at 15 DAS	0.11 $\pm$ 0.001	0.08	0.15	0.00	0.00	19.08	19.48	95.84	0.04	38.47
Leaf area index at 30 DAS	0.50 $\pm$ 0.007	0.23	0.72	0.01	0.01	26.54	26.71	98.75	0.27	54.33
Leaf area index at 45 DAS	1.21 $\pm$ 0.020	0.89	1.71	0.05	0.05	19.53	19.73	97.97	0.48	39.82
Fresh weight of leaves (g/plant) at 15 DAS	8.98 $\pm$ 0.15	0.27	18.42	21.88	21.95	52.11	52.19	99.68	9.62	107.17
Fresh weight of leaves (g/plant) at 30 DAS	34.07 $\pm$ 2.89	6.58	48.62	96.66	121.75	28.86	32.39	79.38	18.04	52.96
Fresh weight of leaves (g/plant) at 45 DAS	60.48 $\pm$ 0.99	12.43	85.72	322.41	325.36	29.69	29.82	99.09	36.82	60.87
Dry weight of leaves (g/plant) at 15 DAS	1.28 $\pm$ 0.02	0.39	1.92	0.22	0.23	37.33	37.43	99.44	0.98	76.68
Dry weight of leaves (g/plant) at 30 DAS	2.85 $\pm$ 0.36	1.23	4.10	0.34	0.72	20.70	29.95	47.74	0.83	29.45
Dry weight of leaves (g/plant) at 45 DAS	4.67 $\pm$ 0.37	1.33	7.46	2.17	2.59	31.62	34.50	84.04	2.78	59.72
Fresh weight of roots (g/plant) at 15 DAS	1.08 $\pm$ 0.02	0.35	4.38	0.80	0.80	82.82	82.86	99.90	1.84	170.53
Fresh weight of roots (g/plant) at 30 DAS	20.91 $\pm$ 0.34	13.13	33.37	22.66	23.01	22.76	22.94	98.47	9.73	46.52
Fresh weight of roots (g/plant) at 45 DAS	105.10 $\pm$ 2.23	47.61	155.67	698.54	713.49	25.15	25.42	97.90	53.87	51.26
Dry weight of roots (g/plant) at 15 DAS	0.19 $\pm$ 0.003	0.04	1.10	0.08	0.08	144.20	144.26	99.91	0.57	296.91
Dry weight of roots (g/plant) at 30 DAS	1.99 $\pm$ 0.04	0.78	3.80	0.54	0.54	37.11	37.19	99.60	1.51	76.30
Dry weight of roots (g/plant) at 45 DAS	3.71 $\pm$ 0.06	1.83	7.12	2.72	2.73	44.50	44.57	99.70	3.39	91.53
Total dry matter (g/plant) at 15 DAS	1.47 $\pm$ 0.02	0.47	2.03	0.25	0.25	33.77	33.85	99.50	1.02	69.39
Total dry matter (g/plant) at 30 DAS	4.80 $\pm$ 0.35	2.69	6.40	0.81	0.83	18.71	18.90	97.95	1.83	38.14
Total dry matter (g/plant) at 45 DAS	9.01 $\pm$ 0.38	3.89	12.41	5.54	5.59	28.03	28.17	99.04	4.83	57.46
SLA (cm ² /g) at 15 DAS	29.84 $\pm$ 0.61	14.76	68.89	257.74	258.50	53.81	53.89	99.71	32.02	110.68
SLA (cm ² /g) at 30 DAS	54.28 $\pm$ 0.94	26.83	86.58	410.56	413.17	39.70	39.83	99.36	41.60	81.53

Continued

SLA (cm ² /g) at 45 DAS	86.75 ± 1.69	44.34	202.76	1400.16	1403.91	43.13	43.19	99.73	76.98	88.73
SLW (g/cm ²) at 15 DAS	0.04±0.0006	0.014	0.067	0.00	0.00	39.28	39.36	99.58	0.03	80.75
SLW (g/cm ²) at 30 DAS	0.02±0.0003	0.011	0.037	0.00	0.00	32.41	32.56	99.05	0.01	66.44
SLW (g/cm ²) at 45 DAS	0.01±0.0002	0.004	0.022	0.00	0.00	35.16	35.25	99.45	0.01	72.22
AGR (g/plant/day) at 15-30 DAS	0.22 ± 0.003	0.17	0.42	0.006	0.006	27.29	27.40	99.19	0.12	55.99
AGR (g/plant/day) at 30-45 DAS	0.24 ± 0.005	0.15	0.78	0.020	0.020	54.51	54.60	99.68	0.27	112.12
CGR (g/m ² /day) at 15-30 DAS	7.40 ± 0.106	3.41	12.38	4.07	4.11	27.29	27.41	99.11	4.14	55.96
CGR (g/m ² /day) at 30-45 DAS	7.97 ± 0.147	5.37	16.08	18.87	18.92	54.52	54.59	99.76	8.94	112.18
NAR (g/dm ² /day) at 15-30 DAS	0.003±0.0005	0.0013	0.0050	0.00	0.00	30.56	30.68	99.25	0.002	62.72
NAR (g/dm ² /day) at 30-45 DAS	0.001±0.00002	0.001	0.0018	0.03	0.03	53.93	54.00	99.71	0.00	110.93

DAS - Days after sowing
PV - Phenotypic variance
GCV - Genotypic coefficient of variation
h² - Broad sense heritability

GV - Genotypic variance
PCV - Phenotypic coefficient of variation
GA- Genetic advance
GAM- Genetic advance as per cent of mean

cent of mean (62.72 % and 110.93 %). The genetic advance of 0.002 and 0.00 were noticed at 30 and 45 DAS, respectively (Table 21).

4.3.1.19 Days to harvest

The days to harvest ranged from 24.33 to 45.67 days, with an average mean value of 36.12 days. GV and PV were 33.27 and 34.61, respectively. Moderate GCV and PCV (15.97 % and 16.29 % %) were recorded. Trait exhibited high heritability (96.14 %) coupled with high genetic advance as per cent mean (32.26 %) with a moderate genetic advance of 11.65, as presented in Table 22.

4.3.1.20 Root length (cm)

Root length varied from 9.96 to 25.01 cm with a mean value of 18.88 cm. GV and PV are 16.31 and 16.54, respectively. The high GCV and PCV (21.39 % and 21.54 %) were observed (Table 22). The high heritability (98.6 %) along with high genetic advance as a per cent of mean (43.75 %) with a low genetic advance of 8.26 was observed for root length.

4.3.1.21 Root diameter (mm)

Root diameter ranged from 19.29 to 32.22 mm, with an average mean value of 23.93 mm. The GV and PV values were 12.60 and 17.36, respectively. The moderate GCV and PCV (14.84 % and 17.41 %) were recorded with high heritability (72.58 %) coupled with high genetic advance as per cent mean (26.03 %) and low genetic advance (6.23) for root diameter (Table 22).

4.3.1.22 Root girth (cm)

Root girth ranged from 6.72 to 11.76 cm, with an average mean value of 9.29 cm. GV and PV values were recorded 2.39 and 2.45 along with moderate GCV and PCV (16.66 % and 16.86 %), respectively. The high estimate of heritability (97.60 %) coupled with high genetic advance as per cent mean (33.90 %) and low genetic advance (3.14) was noticed for root girth (Table 22).

4.3.1.23 Root weight (g)

Root weight ranged from 47.6 to 155.67 g with an average mean value of 105.1 g. The GV and PV values were recorded 698.57 and 713.52, respectively. High GCV and PCV (25.15 % and 25.42 %), respectively. The high estimate of heritability (97.90 %) coupled with high genetic advance as per cent mean (51.26 %) and high genetic advance (53.87) was recorded for root weight (Table 22).

4.3.1.24 Root volume (cc)

Root volume varied from 25.60 to 103.00 cc with a mean value of 72.11 cc. GV and PV values were recorded 464.70 and 468.53, respectively. The High GCV and PCV (29.89 % and 30.02 %) along with high estimate of heritability (99.18 %) coupled with

Table 22. Mean, range and genetic components for root parameters in radish

Characters	Mean $\pm$ S.Em.	Range		GV	PV	GCV (%)	PCV (%)	h ² (%)	GA	GAM (%)
		Min.	Max.							
Days to harvest	36.12 $\pm$ 0.67	24.33	45.67	33.27	34.61	15.97	16.29	96.14	11.65	32.26
Root length (cm)	18.88 $\pm$ 0.28	9.96	25.01	16.31	16.54	21.39	21.54	98.60	8.26	43.75
Root diameter (mm)	23.93 $\pm$ 1.26	19.29	32.22	12.60	17.36	14.84	17.41	72.58	6.23	26.03
Root girth (cm)	9.29 $\pm$ 0.14	6.72	11.76	2.39	2.45	16.66	16.86	97.60	3.14	33.90
Root weight (g)	105.1 $\pm$ 2.23	47.60	155.67	698.57	713.52	25.15	25.42	97.90	53.87	51.26
Root volume (cc)	72.11 $\pm$ 1.13	25.60	103.00	464.70	468.53	29.89	30.02	99.18	44.22	61.33
Root yield per plot (kg)	5.17 $\pm$ 0.09	2.40	7.59	1.76	1.78	25.68	25.84	98.78	2.72	52.58
Root yield per hectare (t)	33.75 $\pm$ 0.57	16.31	43.67	62.07	63.04	23.34	23.52	98.46	16.10	47.71

GV - Genotypic variance
 PV - Phenotypic variance
 GCV - Genotypic coefficient of variation
 h² - Broad sense heritability
 PCV - Phenotypic coefficient of variation
 GA- Genetic advance
 GAM- Genetic advance as per cent of mean

high genetic advance as per cent mean (61.33 %) and high genetic advance (44.22) was observed for root volume (Table 22).

4.3.1.25 Root yield per plot (kg)

The root yield per plot ranged from 2.40 to 7.59 kg with a mean value of 5.17 kg. The GV and PV were 1.76 and 1.78, respectively. PCV and GCV values for this trait were high (25.68 % and 25.84 %), respectively (Table 22). The genetic advance was 2.72. High heritability (98.78 %) with high genetic advance as per cent mean (52.58 %) was observed for root yield per plot.

4.3.1.26 Root yield per hectare (t)

The average root yield per hectare was 33.75 tonnes, and it ranged from 16.31 to 43.67 tonnes. The GV and PV were 62.07 and 63.04, respectively. GCV and PCV values for this trait were high (23.34 % and 23.52 %, respectively). The genetic advance was 16.10. High heritability (98.46 %) with high genetic advance as per cent mean (47.71 %) was observed for this trait (Table 22).

4.3.1.27 Chlorophyll (mg/g) content at 30 DAS

Chlorophyll-a content varied from 0.32 to 0.83 mg with an average of 0.58 mg, chlorophyll-b ranged from 0.14 to 0.74 mg with an average of 0.45 mg, and total chlorophyll content varied from 0.46 to 1.33 mg with an average of 1.03 mg at 30 DAS. The GV and PV of chlorophyll a, b and total chlorophyll were (0.01, 0.01), (0.13, 0.13) and (0.04, 0.04) at 45 DAS. The high estimates of GCV and PCV (24.09 %, 24.22 %), (28.33 %, 28.42 %) and (20.15 %, 20.24 %) were observed for chlorophyll a, chlorophyll-b and total chlorophyll, respectively. The high heritability (98.91 %, 99.32 % and 99.14 %) was observed for along with high genetic advance as per cent of mean (49.35 %, 58.16 % and 41.33 %) for chlorophyll a, chlorophyll b and total chlorophyll, respectively, and low genetic advance (0.17, 0.26 and 0.42) were noticed (Table 23).

4.3.1.28 Chlorophyll (mg/g) content at 45 DAS

Chlorophyll-a content varied from 0.65 to 1.87 mg with an average of 1.48 mg, chlorophyll-b ranged from 0.36 to 1.09 mg with an average of 0.8 mg, and total chlorophyll content varied from 1.01 to 2.93 mg with an average of 2.28 mg at 15, 30 and 45 DAS, respectively. The GV and PV of chlorophyll a, b and total chlorophyll were (0.08, 0.08), (0.03, 0.03) and (0.210, 0.212) at 15, 30 and 45 DAS, respectively. Moderate estimate of GCV and PCV (19.44 % and 19.58 %) was observed for chlorophyll a, whereas the high estimate of GCV and PCV (24.06 %, 24.19 %) and (20.16 %, 20.24 %) were recorded for chlorophyll b and total chlorophyll. The high heritability (98.50 %, 98.91 % and 99.14 %) coupled with high genetic advance as a

per cent of mean (39.74 %, 49.28 % and 41.34 %) was observed for chlorophyll a, b and total chlorophyll with low genetic advance of 0.58, 0.39 and 0.94 (Table 23).

4.3.1.29 Ascorbic acid (mg/100 g)

Ascorbic acid content varied from 12.32 to 28.3 mg, with a mean value of 18.46 mg. The GV and PV were 12.93 and 13.23. High estimate of GCV and PCV (20.01 % and 20.34 %) was observed. High heritability (97.72 %) was recorded along with high genetic advance as per cent of mean (39.66 %) and low genetic advance (7.32) (Table 23).

4.3.1.30 Reducing sugars (%)

Reducing sugar content varied from 1.22 to 2.99 per cent with a mean value of 1.93 per cent. The GV and PV were 0.28 and 0.35. High estimates of GCV (27.41 %) and PCV (30.84 %) were observed. High heritability (79.02 %) was recorded along with high genetic advance as per cent of mean (50.20 %) and low genetic advance (0.96) as shown in Table 23.

4.3.1.31 Non-reducing sugars (%)

Non-reducing sugar content varied from 0.32 to 1.32 per cent with the average mean of 0.61 per cent. The GV and PV were 0.09 and 0.09. High estimates of GCV (49.87 %) and PCV (49.93 %) were observed. High heritability (99.73 %) was recorded along with high genetic advance as per cent of mean (102.58 %) and low genetic advance (0.62) (Table 22).

4.3.1.32 Total sugars (%)

Total sugars varied from 1.65 to 4.20 per cent with an average mean of 2.56 per cent. The GV and PV were 0.43 and 0.51, respectively. The estimates of GCV and PCV were 25.86 per cent and 27.95 per cent, respectively. High heritability (85.57 %) was observed along with high genetic advance as per cent mean (49.27 %) and GA (1.26) (Table 22).

4.4 Genetic divergence

4.4.1 Per cent contribution from different characters to the total divergence

The proportional contribution of certain variables to genetic divergence (D^2) is given in Figure 3. Root yield per plot contributed the maximum (45.26 %) to divergence followed by ascorbic acid (14.74 %), leaf area index (14.00 %), root length (7.37 %), leaf length (4.21 %), root diameter (4.05 %), root weight (3.16 %), number of leaves (3.00 %), plant height (2.11 %) and leaf width and days to harvest each contributing (1.05 %).

Table 23. Mean, range and genetic components biochemical parameters in radish

Characters	Mean ±S.Em.	Range		GV	PV	GCV (%)	PCV (%)	h ² (%)	GA	GAM (%)
		Min.	Max.							
Chlorophyll a (mg/g) at 30 DAS	0.58 ± 0.01	0.32	0.83	0.01	0.01	24.09	24.22	98.91	0.17	49.35
Chlorophyll a (mg/g) at 45 DAS	1.48 ± 0.02	0.65	1.87	0.08	0.08	19.44	19.58	98.50	0.58	39.74
Chlorophyll b (mg/g) at 30 DAS	0.45 ± 0.01	0.14	0.74	0.13	0.13	28.33	28.42	99.32	0.26	58.16
Chlorophyll b (mg/g) at 45 DAS	0.8 ± 0.01	0.36	1.09	0.03	0.03	24.06	24.19	98.91	0.39	49.28
Total Chlorophyll (mg/g) at 30 DAS	1.03 ± 0.01	0.46	1.33	0.04	0.04	20.15	20.24	99.14	0.42	41.33
Total Chlorophyll (mg/g) at 45 DAS	2.28 ± 0.02	1.01	2.93	0.21	0.21	20.16	20.24	99.14	0.94	41.34
Ascorbic acid (mg/100 g)	18.46 ± 0.32	12.32	28.30	12.93	13.23	20.01	20.34	97.72	7.32	39.66
Reducing sugars (%)	1.93 ± 0.16	1.22	2.99	0.28	0.35	27.41	30.84	79.02	0.96	50.20
Non -reducing sugars (%)	0.61 ± 0.01	0.32	1.32	0.09	0.09	49.87	49.93	99.73	0.62	102.58
Total sugars (%)	2.56 ± 0.16	1.65	4.20	0.43	0.51	25.86	27.95	85.57	1.26	49.27

GV - Genotypic variance

PV - Phenotypic variance

GCV - Genotypic coefficient of variation

h² – Broad sense heritability

PCV – Phenotypic coefficient of variation

GA- Genetic advance

GAM- Genetic advance as per cent of mean

4.4.2 Classification of radish genotypes

By following Tocher's method, 20 genotypes were grouped into five clusters by using estimated D^2 values as the square of the generalized distance. The distribution of various clusters is presented in Table 24. Cluster I was found to be the largest with twelve genotypes, followed by cluster II with five genotypes; cluster III, IV and V were the least one genotype each. Intra and inter-cluster average D^2 values are given in Table 24. Among the five clusters, cluster II with five genotypes, showed the maximum intra-cluster distance (211.24), followed by cluster I (166.54). The cluster III, IV and V had no intra-cluster distance as they possessed a single genotype in each cluster.

Based on distances between clusters, *i.e.*, inter-cluster distances, the maximum divergence was observed between cluster I and cluster V (1770.80), followed by cluster III and cluster V (1351.78), cluster IV and cluster V (992.98), cluster II and cluster V (606.19), cluster I and cluster II (601.03), cluster III and cluster IV (521.62), cluster I and cluster IV (403.78), cluster I and cluster III (365.63), cluster II and cluster IV (359.19) and the least inter-cluster values are observed in cluster II and cluster III (332.35) is presented in Table 25.

4.4.3 Cluster means

The mean values of 11 characters for five clusters are presented in Table 26.

4.4.3.1 Plant height (cm) at 45 DAS

The highest cluster mean values for plant height were observed in cluster III (31.61 cm), followed by cluster I (29.12 cm), cluster II (26.45 cm), cluster IV (25.92 cm) and least in cluster V (15.29 cm).

4.4.3.2 Number of leaves at 45 DAS

The highest cluster mean for this trait was noticed in cluster IV (11.13) followed by cluster I (9.68), cluster III (9.60), cluster II (9.41) and least in cluster V (7.73).

4.4.3.3 Leaf length (cm) at 45 DAS

Cluster III (22.60 cm) had the highest cluster mean values for the trait followed by cluster I (22.09), cluster IV (19.96), cluster II (19.60) and the lowest mean was observed in cluster V (8.80).

4.4.3.4 Leaf width (cm) at 45 DAS

The trait had maximum cluster mean for cluster III (8.84 cm) followed by cluster I (8.58 cm), cluster II (7.85 cm), cluster IV (7.78). The lowest cluster mean for this trait was observed in cluster V (6.66).

Table 24. Cluster composition based on D² statistics in radish genotypes

Cluster group	No. of genotypes	List of genotypes
Cluster I	12	Kashi Sweta, ORBI-0527, Kashi Hans, VRRAD-11, VRRAD-199, VBGH-507, Pusa Chetki, Kashi Mooli- 40, VRRAD-91, White Star, Arka Nishant & Palak Patta
Cluster II	5	White Sparkle Tip, Red Radish, Chinese Pink, VRRAD- 4 & VRRAD-200
Cluster III	1	VRRAD-131
Cluster IV	1	Kashi Aardra
Cluster V	1	Scarlet Globe

Table 25. Average intra and inter cluster distance D² for different characters constituted by twenty genotypes of radish

Cluster Distances					
	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Cluster I	166.54	601.03	365.63	403.78	1770.80
Cluster II		211.24	332.35	359.19	606.19
Cluster III			0.00	521.62	1351.78
Cluster IV				0.00	992.98
Cluster V					0.00

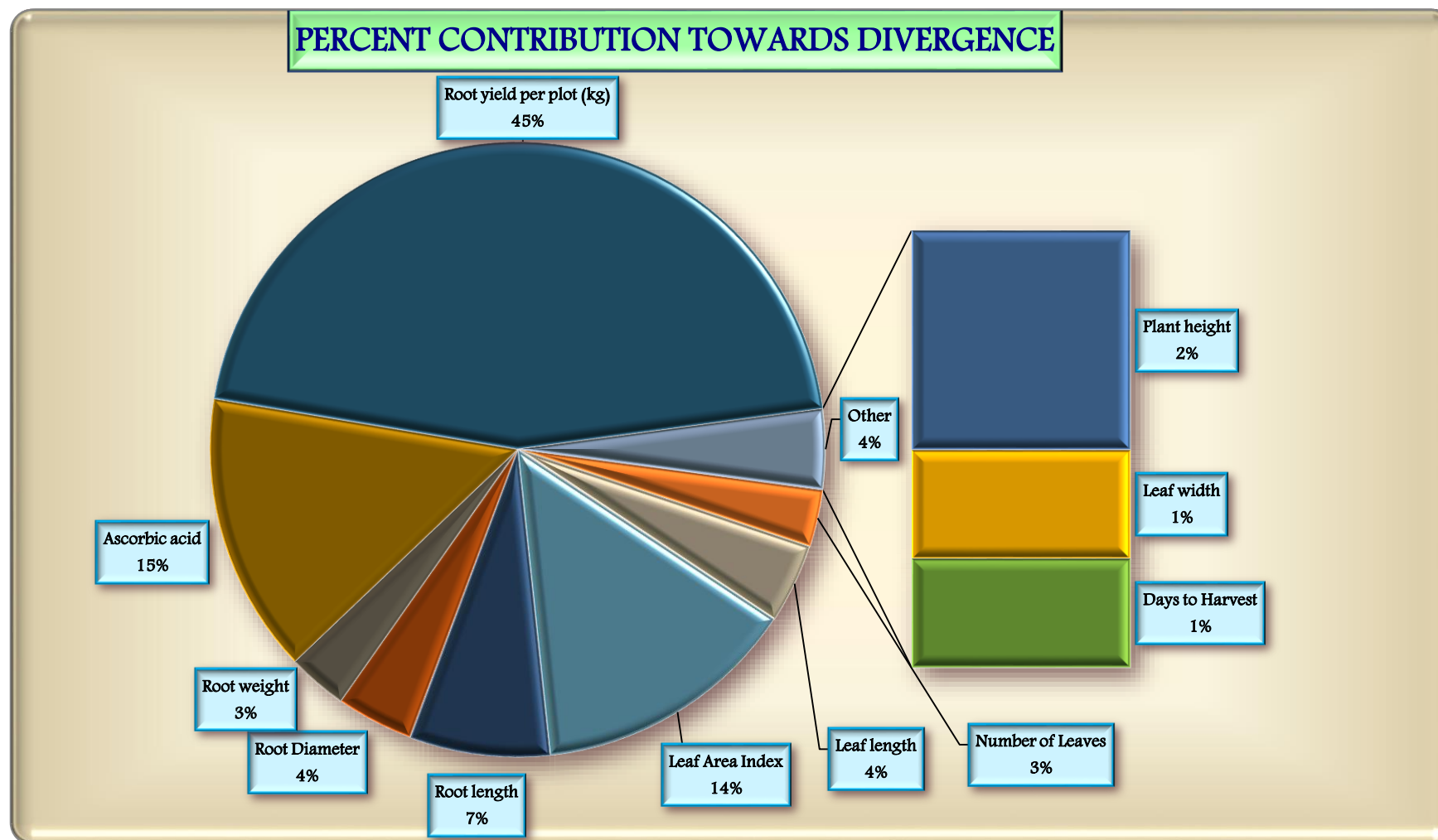


Fig 3. Per cent contribution from different characters to the total divergence in radish genotypes

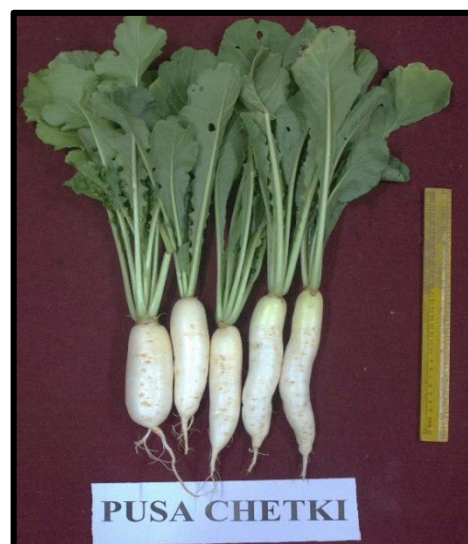
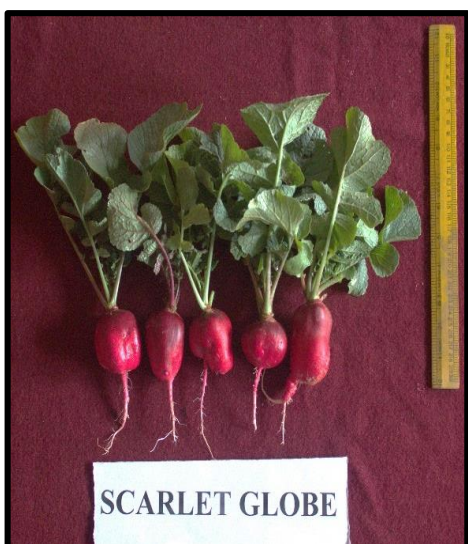
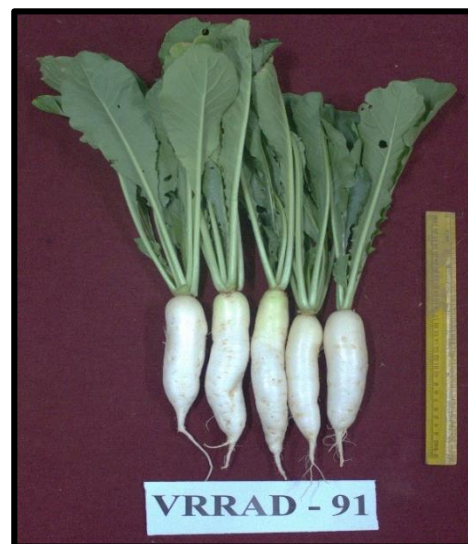
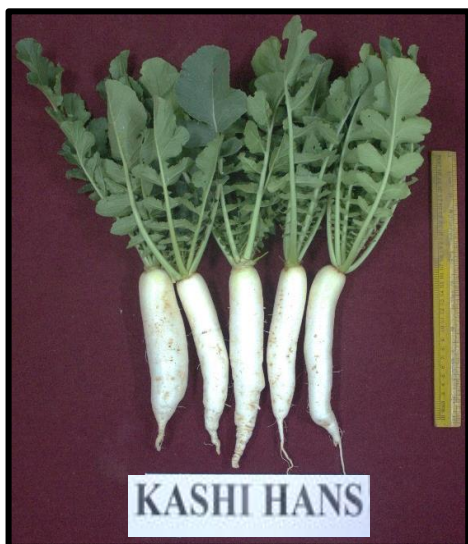


Plate 3. Variability in radish genotypes

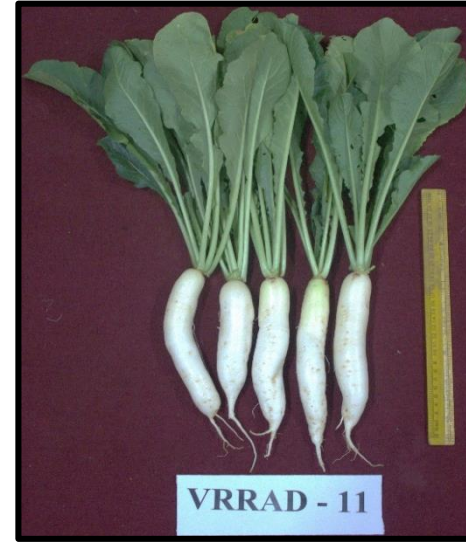
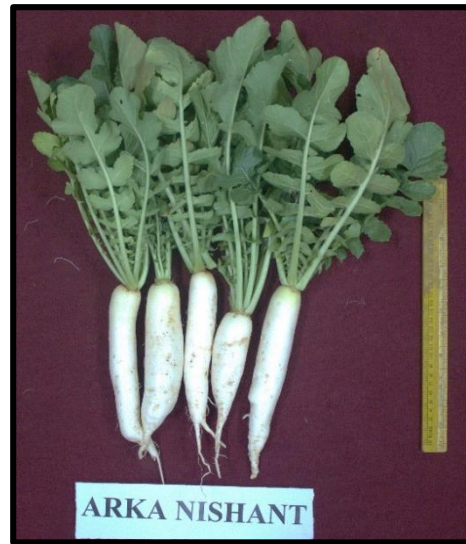
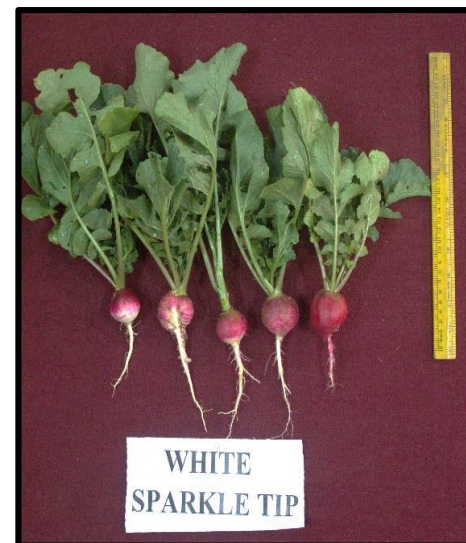


Plate 3. Variability in radish genotypes

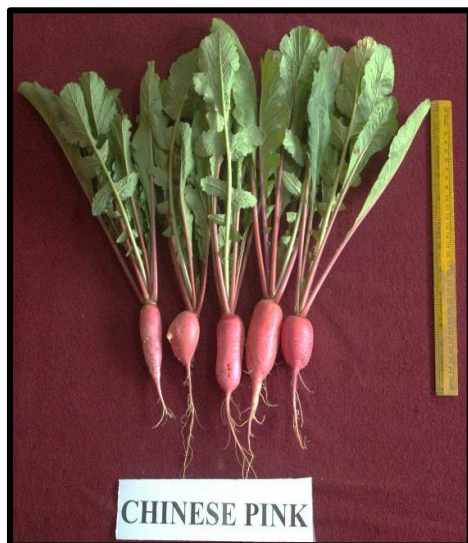


Plate 3. Variability in radish genotypes

4.4.3.5 Leaf area index at 45 DAS

The highest cluster mean values for the leaf area index was observed in cluster IV (1.65) followed by cluster III (1.27), cluster I and cluster II (1.20) and the least cluster V (0.92).

4.4.3.6 Days to harvest

Cluster IV (45.67) had the highest cluster mean value for the trait followed cluster III (38.00), cluster I (37.72), cluster II (32.33) and lowest in cluster V (24.33).

4.4.3.7 Root length (cm)

The trait had maximum cluster mean value in cluster IV (20.90) followed by cluster I (20.89), cluster III (18.00), cluster II (15.35) and least in cluster V (11.34).

4.4.3.8 Root diameter (mm)

The highest cluster mean values for the root diameter were observed in cluster V (32.22 mm), followed by cluster II (26.10 mm), cluster I (22.75 mm), cluster IV (21.93 mm) and least in cluster III (21.06 mm).

4.4.3.9 Root weight (g)

Cluster I (119.14 g) had the highest cluster mean value for the trait, followed by cluster IV (114.97 g), cluster III (101.52 g), cluster II (81.63 g) and lowest in cluster V (47.61 g).

4.4.3.10 Ascorbic acid (mg/100 g)

The trait had maximum cluster mean value in cluster III (28.30 mg), followed by cluster II (20.57 g), cluster V (20.28 g), cluster I (17.12 g) and least in cluster IV (12.32 g).

4.4.3.11 Root yield per plot (kg)

The highest cluster mean values for root yield per plot was observed in cluster IV (5.98 kg), followed by cluster I (5.89 kg), cluster III (5.08 kg), cluster II (3.87 kg) and least cluster V (2.41 kg).

4.5 Correlation coefficient analysis

A simultaneous improvement of multiple traits is eventually required in any crop improvement effort, especially when dealing with complicated traits like yield. This is caused by the physiological interactions and linkage patterns of the genes controlling the various phenotypes. Understanding the relationships between various economic characteristics is crucial in the selection process. As a result, a positive correlation makes it possible to simultaneously improve two or more features, whereas a negative connection suggests that desired traits may need to be compromised. Understanding how the environment affects how genes are expressed can be done through correlation

Table 26. Mean values of different character in five clusters of radish genotypes

Cluster Means: Tocher Method											
	Plant height (cm)	Number of Leaves	Leaf length (cm)	Leaf width (cm)	Leaf area index	Days to harvest	Root length (cm)	Root diameter (mm)	Root weight (g)	Ascorbic acid (mg/100 g)	Root yield per plot (kg)
Cluster I	29.12	9.68	22.09	8.58	1.20	37.72	20.89	22.75	119.14	17.12	5.89
Cluster II	26.45	9.41	19.60	7.85	1.20	32.33	15.35	26.10	81.63	20.57	3.87
Cluster III	31.61	9.60	22.60	8.84	1.27	38.00	18.00	21.06	101.52	28.30	5.08
Cluster IV	25.92	11.13	19.96	7.78	1.65	45.67	20.90	21.93	114.97	12.32	5.98
Cluster V	15.29	7.73	8.80	6.66	0.92	24.33	11.34	32.22	47.61	20.28	2.41

coefficient analysis and estimations of phenotypic and genotypic correlations are presented in Tables 27 and 28.

4.5.1 Genotypic correlation

Genotypic correlation coefficients for different growth and root characters among radish genotypes are presented in Table 27.

4.5.1.1 Root yield per plot

Root yield per plot had shown highly significant and positive correlation with plant height (0.507), leaf length (0.485), leaf width (0.451), leaf area index (0.548), days to harvest (0.551), root length (0.898) and root weight (-0.478). While, it was highly significant and negative correlated with the root diameter (-0.443) and ascorbic acid (-0.491) and significant and positive correlation with number of leaves (0.360).

4.5.1.2 Plant height (cm) at 45 DAS

Plant height was found to have highly significant and positively correlation with the leaf length (0.832), leaf width (0.631), root weight (0.526) and negatively high significant correlation with root diameter (-0.442) whereas significant and positively correlated with the number of leaves (0.371), leaf area index (0.377), days to harvest (0.372), root length (0.403) but it was non-significant and negatively correlated with ascorbic acid (-0.008).

4.5.1.3 Number of leaves at 45 DAS

Number of leaves had shown highly significant and positive correlation with leaf length (0.602), leaf area index (0.504), days to harvest (0.476) and root weight (0.440) and highly significant negatively correlated with root diameter (-0.576) while, it was positive significantly correlated with root length (0.342) and negative significant correlation with ascorbic acid (-0.286) and it showed non-significant positive correlation with leaf width (0.160).

4.5.1.4 Leaf length (cm) at 45 DAS

This trait was highly significant and positively correlated with leaf width (0.463), days to harvest (0.508) and root weight (0.512) and negatively highly significant correlation with the root diameter (-0.691) while it was significant and positively correlated with root length (0.406). This trait had non-significant and positive correlation with leaf area index (0.230) and negative correlation with ascorbic acid (-0.143).

4.5.1.5 Leaf width (cm) at 45 DAS

This trait had highly significant positive correlation with days to harvest (0.434) and root weight (0.464) and significantly positive correlated with root length (0.364) whereas it was non significantly positive correlated with leaf area index (0.074) and

this trait had negative and non-significant correlation with root diameter (-0.129) and ascorbic acid (-0.015).

4.5.1.6 Leaf area index at 45 DAS

Root length (0.466) and root weight (0.558) had shown positive and highly significant correlation with leaf area index whereas this trait showed non-significant positive correlation with days to harvest (0.134) and root diameter (0.002) and the ascorbic acid had non-significant and negative correlation (-0.155) with this trait.

4.5.1.7 Days to harvest

Days to harvest had shown highly significant and positive correlation with root length (0.584) and root weight (0.489) and highly significant negative correlation with root diameter (-0.821), whereas it was significant negatively correlated with ascorbic acid (-0.397).

4.5.1.8 Root length (cm)

Root weight (0.836) had a positive and highly significant correlation with the root length while it was highly significant and negatively correlated with root diameter (-0.513) and ascorbic acid (-0.429).

4.5.1.9 Root diameter (mm)

The trait had found a highly significant and negative correlation with root weight (-0.425). Whereas it was significantly and positively correlated with ascorbic acid (0.309).

4.5.1.10 Root weight (g)

Root weight showed a highly significant and positive correlation with root yield per plot (0.947) and highly significantly negatively correlated with ascorbic acid (-0.478).

4.5.2 Phenotypic correlation

Phenotypic correlation coefficients for different growth and root characters among radish genotypes are presented in Table 28.

4.5.2.1 Root yield per plot

Root yield per plot had shown highly significant and positive correlation with plant height (0.496), number of leaves (0.276), leaf length (0.478), leaf width (0.423), leaf area index (0.546), days to harvest (0.539), root length (0.889) and root weight (0.956). Whereas, it was highly significant and negative correlated with ascorbic acid (-0.484) and significantly negative correlated with root diameter (-0.382).

Table 27. Genotypic correlation coefficient among growth and yield parameters in radish genotypes

Genotypical Correlation Matrix											
Genotypic correlation matrix	Plant height	Number of Leaves	Leaf length	Leaf width	Leaf area index	Days to harvest	Root length	Root diameter	Root weight	Ascorbic acid	Root yield per plot
Plant height	1.0000	0.371*	0.832**	0.631**	0.377*	0.372*	0.403*	-0.442**	0.526**	-0.008	0.507**
Number of Leaves		1.0000	0.602**	0.160	0.504**	0.476**	0.342*	-0.576**	0.440**	-0.286*	0.360*
Leaf length			1.0000	0.463**	0.230	0.508**	0.406*	-0.691**	0.512**	-0.143	0.485**
Leaf width				1.0000	0.074	0.434**	0.364*	-0.129	0.464**	-0.015	0.451**
Leaf area index					1.0000	0.134	0.466**	0.002	0.558**	-0.155	0.548**
Days to harvest						1.0000	0.584**	-0.821**	0.489**	-0.397*	0.551**
Root length							1.0000	-0.513**	0.836**	-0.429**	0.898**
Root diameter								1.0000	-0.425**	0.309*	-0.443**
Root weight									1.0000	-0.478**	0.974**
Ascorbic acid										1.0000	-0.491**
Root yield per plot											1.0000

Critical value r_g 5% - 0.2542 significant at $p=0.05$ Critical value r_g 5% - 0.4142 significant at $p=0.01$

4.5.2.2 Plant height (cm) at 45 DAS

At the phenotypic level, plant height had found a highly significant and positive correlation with the leaf length (0.808), leaf width (0.605) and root weight (0.506) while, significantly and positively correlated with number of leaves (0.296), leaf area index (0.370), days to harvest (0.359) and root length (0.397) and significantly negative correlated with root diameter (-0.380) but it was non significantly negatively correlated with ascorbic acid (-0.012).

4.5.2.3 Number of leaves at 45 DAS

The trait had shown a highly significant and positive correlation with leaf length (0.481), whereas it showed a significant and positive correlation with leaf area index (0.394) and days to harvest (0.393), root length (0.267), root weight (0.346) and significantly negatively correlated with root diameter (-0.375) but it was non-significant and positive correlated with leaf width (0.131) and negatively with ascorbic acid (-0.242).

4.5.2.4 Leaf length (cm) at 45 DAS

Leaf width (0.442), days to harvest (0.499) and root weight (0.500) had highly significant and positive correlation and root diameter (-0.587) had highly significant negative correlation with the leaf length and whereas significantly positive correlated with root length (0.398). This trait had a non-significant positive correlation with leaf area index (0.232) and a negative non-significant with ascorbic acid (-0.144).

4.5.2.5 Leaf width (cm) at 45 DAS

The trait had shown highly significantly positive correlation with root weight (0.437) while it was significantly positive correlated with days to harvest (0.412) and root length (0.339) and this trait was non significantly positive correlated with leaf area index (0.084) and non-significantly negative correlated with root diameter (-0.105) and ascorbic acid (-0.020).

4.5.2.6 Leaf area index at 45 DAS

Leaf area index was positive and highly significantly correlated with root length (0.459) and root weight (0.549) while non-significantly and positive correlated with days to harvest (0.132) and negatively correlated with root diameter (-0.011) and ascorbic acid (-0.157).

4.5.2.7 Days to harvest

Root length (0.574) and root weight (0.478) had a positive and highly significant correlation while, root diameter (-0.676) had a negative highly significant correlation

with the days to harvest, whereas it was significant and negative correlated with ascorbic acid (-0.382).

4.5.2.8 Root length (cm)

The trait had shown a highly significant and positive correlation with root weight (0.818) and it was highly significant and negatively correlated with root diameter (-0.454) and ascorbic acid (-0.421).

4.5.2.9 Root diameter (mm)

Root diameter had shown a significant positive correlation with ascorbic acid (0.274) while it was significantly and negative correlated with root weight (-0.350).

4.5.2.10 Root weight (g)

Root weight had found highly significant and negative correlation with ascorbic acid (-0.464).

4.6 Path coefficient analysis

Path analysis helps in the selection of an elite genotype by dividing the correlation coefficients into the direct and indirect impacts of a group of dependent variables on the independent variable. The direct and indirect contributions of numerous independent characters on a dependent character are measured using path analysis, which is a useful tool for dividing the correlation coefficients into direct and indirect impacts of an independent variable on a dependent variable. With the aid of path analysis, the amount of influence one variable has on another may be quantified.

4.6.1 Phenotypic path coefficient analysis

The phenotypic path coefficient analysis was done for root yield per plot, which was performed with a set of 10 independent characters, viz., plant height, number of leaves, leaf length, leaf width, leaf area index, days to harvest, root length, root diameter, root weight and ascorbic acid as shown in Table 29.

4.6.1.1 Root yield per plot

Root yield per plot showed a positive direct effect on plant height (0.0227), leaf length (0.0290), leaf area index (0.0690), days to harvest (0.0719), root length (0.2856), root diameter (0.0231), root weight (0.6442) and negative direct effect on number of leaves (-0.1032), leaf width (-0.0030) and ascorbic acid (-0.0533).

4.6.1.2 Plant height (cm) at 45 DAS

Plant height at 45 DAS showed indirect positive effect on the number of leaves at 45 DAS (0.0067), leaf length at 45 DAS (0.0184), leaf width at 45 DAS (0.0137), leaf area index at 45 DAS (0.0084), days to harvest (0.0082), root length (0.0090) and root weight (0.0115) and had an indirect negative effect root diameter (-0.0086) and ascorbic acid (-0.0003).

Table 28. Phenotypic correlation coefficient among growth and yield parameters in radish genotypes

Phenotypical Correlation Matrix											
Phenotypic correlation matrix	Plant height	Number of Leaves	Leaf length	Leaf width	Leaf area index	Days to Harvest	Root length	Root diameter	Root weight	Ascorbic acid	Root yield per plot
Plant height	1.0000	0.296*	0.808**	0.605**	0.370*	0.359*	0.397*	-0.380*	0.506**	-0.012	0.496**
Number of Leaves		1.0000	0.481**	0.131	0.394*	0.393*	0.267*	-0.375*	0.346*	-0.242	0.276*
Leaf length			1.0000	0.442**	0.232	0.499**	0.398*	-0.587**	0.500**	-0.144	0.478**
Leaf width				1.0000	0.084	0.412*	0.339*	-0.105	0.437**	-0.020	0.423**
Leaf area index					1.0000	0.132	0.459**	-0.011	0.549**	-0.157	0.546**
Days to Harvest						1.0000	0.574**	-0.676**	0.478**	-0.382*	0.539**
Root length							1.0000	-0.454**	0.818**	-0.421**	0.889**
Root diameter								1.0000	-0.350*	0.274*	-0.382*
Root weight									1.0000	-0.464**	0.956**
Ascorbic acid										1.0000	-0.484**
Root yield per plot											1.0000

Critical value r_g 5% - 0.2542 significant at $p=0.05$

Critical value r_g 5% - 0.4142 significant at $p=0.01$

4.6.1.3 Number of leaves at 45 DAS

Number of leaves exhibited an indirect negative effect on plant height at 45 DAS (-0.0306), leaf length at 45 DAS (-0.0496), leaf width at 45 DAS (-0.0136), leaf area index at 45 DAS (-0.0406), days to harvest (-0.0405), root length (-0.0276) and root weight (-0.0357) and trait had an indirect positive effect on root diameter (0.0387) and ascorbic acid (0.0250).

4.6.1.4 Leaf length (cm) at 45 DAS

Leaf length showed an indirect positive effect through plant height at 45 DAS (0.0234), number of leaves at 45 DAS (0.0139), leaf width at 45 DAS (0.0128), leaf area index at 45 DAS (0.0067), days to harvest (0.0145), root length (0.0115) and root weight (0.0145) and this trait had indirect negative effect on root diameter (-0.0170) and ascorbic acid (-0.0042).

4.6.1.5 Leaf width (cm) at 45 DAS

Leaf width had showed an indirect negative effect on plant height at 45 DAS (-0.0018), number of leaves at 45 DAS (-0.0004), leaf length at 45 DAS (-0.0013), leaf area index at 45 DAS (-0.0003), days to harvest (-0.0012), root length (-0.0010) and root weight (-0.0013), while it had an indirect positive effect on root diameter (0.0003) and ascorbic acid (0.0001).

4.6.1.6 Leaf area index at 45 DAS

Leaf area index exhibited an indirect positive effect on plant height at 45 DAS (0.0255), number of leaves at 45 DAS (0.0272), leaf length at 45 DAS (0.0160), leaf width at 45 DAS (0.0059), days to harvest 0.0091), root length (0.0317) and root weight (0.0379) and exhibited an indirect negative effect on root diameter (-0.0008) and ascorbic acid (-0.0109).

4.6.1.7 Days to harvest

A positive indirect effect had found for days to harvest on plant height at 45 DAS (0.0258), number of leaves at 45 DAS (0.0283), leaf length at 45 DAS (0.0359), leaf width at 45 DAS (0.0296), leaf area index at 45 DAS (0.0095), root length (0.413) and root weight (0.0344) but it had an indirect negative effect on root diameter (-0.0486) and ascorbic acid (-0.0275).

4.6.1.8 Root length (cm)

Root length had showed an indirect positive effect on plant height at 45 DAS (0.1135), number of leaves at 45 DAS (0.0765), leaf length at 45 DAS (0.1135), leaf width at 45 DAS (0.0968), leaf area index at 45 DAS (0.1311), days to harvest (0.1639), root weight (0.2336) but it showed an indirect negative effect on root diameter (-0.1296) and ascorbic acid (-0.1203).

4.6.1.9 Root diameter (mm)

A positive indirect effect was found for root diameter on ascorbic acid (0.0063). This trait also showed an indirect negative effect on plant height at 45 DAS (-0.0088), number of leaves at 45 DAS (-0.0087), leaf length at 45 DAS (-0.0136), leaf width at 45 DAS (-0.0024), leaf area index at 45 DAS (-0.0003), days to harvest (-0.0156), root length (-0.0105) and root weight (-0.0081).

4.6.1.10 Root weight (g)

Root weight recorded an indirect positive effect on plant height at 45 DAS (0.3260), number of leaves at 45 DAS (0.2230), leaf length at 45 DAS (0.3221), leaf width at 45 DAS (0.2817), leaf area index at 45 DAS (0.3536), days to harvest (0.3079) and root length (0.5268) but this trait also recorded indirect negative effect on root diameter (-0.2252) and ascorbic acid (-0.2988).

4.6.1.11 Ascorbic acid (mg/100 g)

Ascorbic acid content had indirect negative effect on root diameter (-0.0146) and an indirect positive effect on plant height at 45 DAS (0.0007), number of leaves at 45 DAS (0.0129), leaf length at 45 DAS (0.0077), leaf width at 45 DAS (0.0011), leaf area index at 45 DAS (0.0084), days to harvest (0.0204), root length (0.0224) and root weight (0.0247).

4.6.2 Genotypic path coefficient analysis

The genotypic path coefficient analysis was done for root yield per plot, which was performed with a set of 10 independent characters, viz., plant height, number of leaves, leaf length, leaf width, leaf area index, days to harvest, root length, root diameter, root weight and ascorbic acid content as shown in Table 30.

4.6.2.1 Root yield per plot

Root yield per plot showed a positive direct effect on leaf length (0.1349), leaf width (0.0230), leaf area index (0.1462), days to harvest (0.0937), root length (0.1901) and root weight (0.7271). While, it showed a direct negative effect on plant height (-0.0973), number of leaves (-0.2126), root diameter (-0.0168) and ascorbic acid (-0.0388).

4.6.2.2 Plant height (cm) at 45 DAS

Plant height at 45 DAS showed an indirect negative effect on the number of leaves at 45 DAS (-0.0361), leaf length at 45 DAS (-0.0810), leaf width at 45 DAS (-0.0614), leaf area index at 45 DAS (-0.0367), days to harvest (-0.0362), root length (-0.0392) and root weight (-0.0512) and had an indirect positive effect on root diameter (0.0430) and ascorbic acid (0.0009).

Table 29. Phenotypic path coefficient analysis among the growth and yield parameters in radish genotypes

Phenotypic path matrix of Root yield per plot (kg)											
	Plant height	Number of leaves	Leaf length	Leaf width	Leaf area index	Days to Harvest	Root length	Root diameter	Root weight	Ascorbic acid	
Plant height	0.0227	0.0067	0.0184	0.0137	0.0084	0.0082	0.0090	-0.0086	0.0115	-0.0003	
Number of Leaves	-0.0306	-0.1032	-0.0496	-0.0136	-0.0406	-0.0405	-0.0276	0.0387	-0.0357	0.0250	
Leaf length	0.0234	0.0139	0.0290	0.0128	0.0067	0.0145	0.0115	-0.0170	0.0145	-0.0042	
Leaf width	-0.0018	-0.0004	-0.0013	-0.0030	-0.0003	-0.0012	-0.0010	0.0003	-0.0013	0.0001	
Leaf area index	0.0255	0.0272	0.0160	0.0059	0.0690	0.0091	0.0317	-0.0008	0.0379	-0.0109	
Days to Harvest	0.0258	0.0283	0.0359	0.0296	0.0095	0.0719	0.0413	-0.0486	0.0344	-0.0275	
Root length	0.1135	0.0762	0.1135	0.0968	0.1311	0.1639	0.2856	-0.1296	0.2336	-0.1203	
Root diameter	-0.0088	-0.0087	-0.0136	-0.0024	-0.0003	-0.0156	-0.0105	0.0231	-0.0081	0.0063	
Root weight	0.3260	0.2230	0.3221	0.2817	0.3536	0.3079	0.5268	-0.2252	0.6442	-0.2988	
Ascorbic acid	0.0007	0.0129	0.0077	0.0011	0.0084	0.0204	0.0224	-0.0146	0.0247	-0.0533	
Root yield per plot	0.496**	0.276*	0.478**	0.423**	0.546**	0.539**	0.889**	-0.382*	0.956**	-0.484**	
Partial R² (rp)	0.0113	-0.0285	0.0138	-0.0012	0.0377	0.0387	0.2540	-0.0088	0.6156	0.0258	

RESIDUAL EFFECT = 0.204 rp = Phenotypic correlation with root yield per plot

4.6.2.3 Number of leaves at 45 DAS

Number of leaves at 45 DAS exhibited an indirect negative effect on plant height at 45 DAS (-0.0789), leaf length at 45 DAS (-0.1279), leaf width at 45 DAS (-0.0342), leaf area index at 45 DAS (-0.1072), days to harvest (-0.1012), root length (-0.0727) and root weight (-0.0935) and exhibited an indirect positive effect on root diameter (0.1225) and ascorbic acid (0.0608).

4.6.2.4 Leaf length (cm) at 45 DAS

Leaf length at 45 DAS recorded an indirect positive effect on plant height at 45 DAS (0.1123), number of leaves at 45 DAS (0.0812), leaf width at 45 DAS (0.0625), leaf area index at 45 DAS (0.0311), days to harvest (0.0685), root length (0.0547) and root weight (0.0691) and exhibited an indirect negative effect on root diameter (-0.0933) and ascorbic acid (-0.0193).

4.6.2.5 Leaf width (cm) at 45 DAS

Leaf width at 45 DAS showed an indirect positive effect on plant height at 45 DAS (0.0145), number of leaves at 45 DAS (0.0037), leaf length at 45 DAS (0.0107), leaf area index at 45 DAS (0.0017), days to harvest (0.0100), root length (0.0084) and root weight (0.0107) and exhibited an indirect negative effect on root diameter (-0.0030) and ascorbic acid (-0.0004).

4.6.2.6 Leaf area index at 45 DAS

An indirect positive indirect effect on plant height at 45 DAS (0.0551), number of leaves at 45 DAS (0.0737), leaf length at 45 DAS (0.0337), leaf width at 45 DAS (0.0109), days to harvest (0.0197), root length (0.0681), root weight (0.0816) and root diameter (0.0003) and showed an indirect negative effect ascorbic acid (-0.0227).

4.6.2.7 Days to harvest

Days to harvest had an indirect positive effect on plant height at 45 DAS (0.0349), number of leaves at 45 DAS (0.0446), leaf length at 45 DAS (0.0476), leaf width at 45 DAS (0.0406), leaf area index at 45 DAS (0.0126), root length (0.0547) and root weight (0.0458) and showed an indirect negative effect on root diameter (-0.0770) and ascorbic acid (-0.0372).

4.6.2.8 Root length (cm)

Root length showed an indirect positive effect on plant height at 45 DAS (0.0767), number of leaves at 45 DAS (0.0650), leaf length at 45 DAS (0.0771), leaf width at 45 DAS (0.0692), leaf area index at 45 DAS (0.0886), days to harvest (0.1111) and root weight (0.1590) and showed an indirect negative effect on root diameter (-0.0976) and ascorbic acid (-0.0816).

4.6.2.9 Root diameter (mm)

Root diameter showed an indirect negative effect on ascorbic acid (-0.0052) and recorded an indirect positive effect on plant height at 45 DAS (0.0074), number of leaves at 45 DAS (0.0097), leaf length at 45 DAS (0.0116), leaf width at 45 DAS (0.0022), leaf area index (0.000), days to harvest (0.0138), root length (0.0086) and root weight (0.0071).

4.6.2.10 Root weight (g)

Root weight exhibited indirect positive effect on plant height at 45 DAS (0.3822), number of leaves at 45 DAS (0.3196), leaf length at 45 DAS (0.3725), leaf width at 45 DAS (0.3374), leaf area index at 45 DAS (0.4060), days to harvest (0.3558) and root length (0.6081) and exhibited an indirect negative effect on root diameter (-0.3088) and ascorbic acid (-0.3474).

4.6.2.11 Ascorbic acid (mg/100 g)

A negative indirect effect had found for ascorbic acid content root diameter (-0.0120) but showed an indirect positive effect on plant height at 45 DAS (0.0003) number of leaves at 45 DAS (0.0111), leaf length at 45 DAS (0.0055), leaf width at 45 DAS (0.0006), leaf area index at 45 DAS (0.0060), days to harvest (0.0154), root length (0.0166) and root weight (0.0185).

Table 30. Genotypic path coefficient analysis among the growth and yield parameters in radish genotypes

Genotypic path matrix of Root yield per plot (kg)										
	Plant height	Number of Leaves	Leaf length	Leaf width	Leaf area index	Days to harvest	Root length	Root diameter	Root weight	Ascorbic acid
Plant height	-0.0973	-0.0361	-0.0810	-0.0614	-0.0367	-0.0362	-0.0392	0.0430	-0.0512	0.0009
Number of Leaves	-0.0789	-0.2126	-0.1279	-0.0342	-0.1072	-0.1012	-0.0727	0.1225	-0.0935	0.0608
Leaf length	0.1123	0.0812	0.1349	0.0625	0.0311	0.0685	0.0547	-0.0933	0.0691	-0.0193
Leaf width	0.0145	0.0037	0.0107	0.0230	0.0017	0.0100	0.0084	-0.0030	0.0107	-0.0004
Leaf area index	0.0551	0.0737	0.0337	0.0109	0.1462	0.0197	0.0681	0.0003	0.0816	-0.0227
Days to harvest	0.0349	0.0446	0.0476	0.0406	0.0126	0.0937	0.0547	-0.0770	0.0458	-0.0372
Root length	0.0767	0.0650	0.0771	0.0692	0.0886	0.1111	0.1901	-0.0976	0.1590	-0.0816
Root diameter	0.0074	0.0097	0.0116	0.0022	0.0000	0.0138	0.0086	-0.0168	0.0071	-0.0052
Root weight	0.3822	0.3196	0.3725	0.3374	0.4060	0.3558	0.6081	-0.3088	0.7271	-0.3474
Ascorbic acid	0.0003	0.0111	0.0055	0.0006	0.0060	0.0154	0.0166	-0.0120	0.0185	-0.0388
Root yield per plot	0.507**	0.360*	0.485**	0.451**	0.548**	0.551**	0.898**	-0.443**	0.974**	-0.491**
Partial R ²	-0.0494	-0.0765	0.0654	0.0104	0.0802	0.0516	0.1706	0.0074	0.7085	0.0190

RESIDUAL EFFECT = 0.113 rp= Genotypic correlation with root yield per plot

DISCUSSION

V DISCUSSION

Any plant breeding program's main goal is to enhance the traits for superior agronomic and economic performance. The breeder can organise a methodical breeding programme with the aid of the kind and degree of genetic variability contained in the germplasm. The degree of variability present in the germplasm is the primary factor determining the success of any crop improvement program. For the breeding programme to be planned properly, understanding genetic variability and the relationships between distinct traits is crucial. Yield is a complex character that results from the interplay of several variables and environmental factors, and it is governed by an association of different features. Selection based on the component character can produce more effective outcome for developing a high yielding variety.

In this context, the present study investigated the root yield in 20 radish genotypes along with the characteristics that contributed to the yield. The amount of variation, heritability and genetic advance were evaluated as a percentage of the mean. The relationship between the features, their direct and indirect impacts on root yield, and the degree of genetic divergence in the genotypes were investigated. This chapter discusses the results obtained from the study.

5.1 Performance of radish genotypes

5.1.1 Morphological parameters

Plant height varied significantly among the different genotypes of radish. The genotype Kashi Hans had recorded the maximum plant height at 15 DAS, Kashi Mooli- 40 at 30 DAS and VRRAD- 131 at 45 DAS. Whereas the genotype Scarlet Globe recorded the minimum plant height at 15, 30 and 45 DAS, respectively. The substantial variation in plant height across the radish genotypes is primarily due to genetic differences. These findings are in accordance with the reports of Naseeruddin *et al.* (2011), Kumari *et al.* (2016), Dongarwar *et al.* (2018), Semba *et al.* (2019), Ola *et al.* (2018), Dahal *et al.* (2021), Singh *et al.* (2021) and Thakur *et al.* (2023).

There was a significant difference among radish genotypes with respect to number of leaves. The genotype Kashi Hans was recorded the maximum number of leaves at 15 DAS, Kashi Aardra at 30 and 45 DAS, respectively. Whereas, the genotype VBGH- 507 recorded the minimum number of leaves at 15 DAS and Scarlet Globe at 30 and 45 DAS, respectively. The variations in number of leaves might be due to the genetic makeup as well as the corresponding environmental conditions. Similar results have been reported by Chapagain *et al.* (2010), Jabeen *et al.* (2010), Kumar *et al.* (2012), Ebrahimi *et al.* (2013), Panwar *et al.* (2013), Dongarwar *et al.* (2018), Ola *et al.* (2018), Semba *et al.* (2019), Dahal *et al.* (2021), Singh *et al.* (2021) and Thakur *et al.* (2023).

Leaf length and leaf width was recorded maximum in the genotype Kashi Hans and Pusa Chetki at 15 DAS, Kashi Hans at 30 DAS and 45 DAS, respectively. Whereas, the minimum leaf length was observed in the genotype Scarlet Globe at 15, 30 and 45 DAS, respectively. While the minimum leaf width was recorded in VRRAD- 11 at 15 DAS and VRRAD- 4 at 30 DAS and Scarlet Globe at 45 DAS. These variation in leaf length and breadth might be due to inherent character. Above findings are in accordance with reports of Kumari *et al.* (2016), Mallikarjunarao *et al.* (2018), Ashraf *et al.* (2021), Singh *et al.* (2021) and Singh *et al.* (2022).

Spread of the plant (N-S) and (E-W) varied significantly. The maximum plant spread for North - South was observed in Pusa Chetki at 15 DAS, Chinese Pink at 30 DAS and Pusa Chetki at 45 DAS, respectively. The plant spread (E-W) was maximum in VRRAD- 131 at 15 and Kashi Mooli- 40 at 30 DAS, while the Red Radish at 45 DAS, respectively. The minimum spread of the plant (N-S) was recorded in the VRRAD-131 at 15 and 30 DAS and Scarlet Globe at 45 DAS, respectively. The minimum spread of the plant (E-W) was recorded Scarlet Globe at 15 DAS and ORBI-0527 at 30 and 45 DAS, respectively. The variation in the spread of the plant due to their character and adaptability. Similar results have been reported by Kumari *et al.* (2016) and Thakur *et al.* (2023).

5.1.2 Growth parameters

Leaf area and leaf area index varied significantly. The maximum leaf area and leaf area index both was observed in the genotype Pusa Chetki at 15 DAS, Kashi Hans at 30 and 45 DAS, respectively. While, the minimum leaf area was observed in Palak Patta at 15 DAS and Scarlet Globe at 30 and 45 DAS, respectively. The minimum leaf area index was observed in Kashi Mooli- 40 at 15 DAS, Scarlet Globe at 30 and 45 DAS, respectively. As the different genotypes had variation in leaf length and width which mainly contributes to the leaf area, so the genotypes with more leaf length and width had more leaf area and its leaf area index. These findings are in accordance with reports of Panwar *et al.* (2013), Sivanthu *et al.* (2014), Dongarwar *et al.* (2018) and Naik *et al.* (2022).

There was a significant difference among radish genotypes for fresh weight of leaves and roots. The maximum fresh weight of both leaves and roots were recorded in Kashi Hans at 15, 30 and 45 DAS, respectively. Whereas, the minimum fresh weight of leaves and roots were recorded in VRRAD- 11 and VRRRAD- 4 at 15 DAS, Scarlet Globe and White Sparkle Tip at 30 DAS and Scarlet Globe at 45 DAS, respectively. The deviation in fresh weights may be related to the differences in the individual varieties. These results are in accordance with the reports of Semba *et al.* (2019), Naik *et al.* (2022) and Thakur *et al.* (2023).

Dry weights of leaves and roots varied significantly among the radish genotypes. The maximum dry weight for leaves and roots were recorded in VBGH- 507 and Kashi Aardra at 15 DAS, White Sparkle Tip and Kashi Hans at 30 DAS and Pusa Chetki and VRRAD- 91 at 45 DAS, respectively. The minimum dry weights of leaves and roots were observed in VRRAD- 200 and VRRAD- 4 at 15 DAS, Scarlet Globe and Chinese Pink at 30 DAS and the genotype Scarlet Globe and VRRAD- 131 at 45 DAS. The total dry matter was noticed maximum in Kashi Hans at 15, 30 and 45 DAS, respectively. Whereas, the minimum dry matter content was observed in Red Radish, Scarlet Globe and Scarlet Globe at 15, 30 and 45 DAS, respectively. The variation in dry weights may be related to the differences in the individual varieties. These results are in accordance with the reports of Semba *et al.* (2019), Naik *et al.* (2022) and Thakur *et al.* (2023).

Among the genotypes, there was significance for specific leaf area and specific leaf weight. The maximum specific leaf area and specific leaf weight were observed in the genotype VRRAD- 200 and VRRAD- 91 at 15 DAS, VRRAD- 131 and VRRAD- 4 at 30 DAS and Scarlet Globe and Pusa Chetki at 45 DAS, respectively. The minimum values were recorded for VRRAD- 91 and VRRAD- 200 at 15 DAS, VRRAD- 4 and VRRAD- 131 at 30 DAS and Pusa Chetki and Scarlet Globe at 45 DAS, respectively. The variation in these characters might be due to rapid growth of the leaves along with its dry weight. These findings are in accordance with report of Naik *et al.* (2022).

The absolute growth rate (AGR), crop growth rate (CGR) and net assimilation rate (NAR) were varied significantly among the radish genotypes. The maximum values for AGR, CGR and NAR were observed for Kashi Sweta and Kashi Hans (AGR and CGR) and Kashi Aardra and Kashi Mooli- 40 (NAR) at an interval of 15 to 30 and 30 to 45 DAS, respectively. The minimum values were observed for Scarlet Globe and VRRAD- 4 (AGR), Scarlet Globe and VRRAD- 4 (CGR) and Scarlet Globe and ORBI – 0527 (NAR) at 15-30 DAS and 30-45 DAS, respectively. These differences in the character is might be due to the varied dry matter content of the genotypes. These findings are in accordance with report of Naik *et al.* (2022).

5.1.3 Root parameters

Days to harvest exhibited significant difference among the radish genotypes. The earliest harvest was observed in Scarlet Globe genotype while, delayed harvest was observed in Pusa Chetki and Kashi Aardra. Due to genetic variations between cultivars and ecological and climatic conditions, there was a significant amount of variability for the days till harvest. Climate throughout plant growth and development has a major impact on radish growth, yield, and quality. Similar results were had been reported by Langthasa and Barah (2000), Roopa *et al.* (2018) and Shreshta *et al.* (2021).

Root length showed significant variation among the genotypes. The genotype Kashi Hans recorded maximum root length. Whereas, the minimum root length was recorded by Scarlet Globe. This indicated that, the genotypes under study were genetically diverse and might be due to their nature of growth. These results were in agreement with the findings of Ijoyah *et al.* (2008), Jabeen *et al.* (2010), Datta *et al.* (2015), Kumari *et al.* (2016), Shreshta *et al.* (2021), Singh *et al.* (2021) and Makhdoomi *et al.* (2022).

Root diameter, root girth and root volume varied significantly among the genotypes of radish. The maximum root diameter and root girth was recorded in Scarlet Globe and root volume in Kashi Hans, respectively. Whereas, the minimum values were recorded for VRRAD- 11, Kashi Aardra and Scarlet Globe, respectively. The Scarlet Globe's spherical shape gave the root its largest width, the other types of roots were thin and lengthy. The difference in these character is due to their genetic constitution and nature. Similar results were reported Naseeruddin *et al.* (2014), Kumari *et al.* (2016), Dongarwar *et al.* (2018), Semba *et al.* (2019), Shreshta *et al.* (2021), Singh *et al.* (2021), Makhdoomi *et al.* (2022) and Thakur *et al.* (2023).

Root weight and root yield per plot varied significantly among the radish genotypes. the highest root weight and root yield per plot was recorded in Kashi Hans, while the lowest was recorded in Scarlet Globe. There could be genetic variance responsible for the variation in root weight. Increased root yield per plot might be caused by increases in root weight root length and root diameter. These findings are in accordance with the results of Ijoyah *et al.* (2008), Thorat *et al.* (2015), Kumari *et al.* (2016), Dongarwar *et al.* (2018), Shreshta *et al.* (2021), Singh *et al.* (2021), Makhdoomi *et al.* (2022) and Thakur *et al.* (2023).

The genotypes showed a significant variation for root yield per hectare. As the root yield per hectare is one of the important traits in the crop improvement programme. Maximum root yield per hectare was observed in Kashi Hans genotype. Whereas, the minimum root yield per hectare was recorded in Scarlet Globe. Since the yield per hectare was determined by multiplying the yield per plot by a hectare factor, it is obvious that the varieties that performed better in a unit area are likely to perform better on a large scale. The genotype interacts with a certain agroclimatic and management parameters to produce the yield. Furthermore, yield is meant to indicate the yield components. Given that all of these varieties were evaluated in the same soil, under the same management and in similar agroclimatic circumstances, the differences in yield among these 20 types may be regarded as varietal differences. Similar results were reported by Soomro *et al.* (2006), Ali *et al.* (2007), Ijoyah *et al.* (2008), Semba *et al.* (2019), Singh *et al.* (2021), Makhdoomi *et al.* (2022).

5.1.4 Quality parameters

The trait which contributes to the quality viz., colour, shape and forking per cent was observed among the radish genotypes. The colour of the roots was white in all cultivars except for Scarlet Globe and Red Radish (red), Chinese Pink (pink), VRRAD- 131 (purple) and White Sparkle Tip (pink and white). The shape of the roots varied from narrow triangular (Kashi Hans), globular (Scarlet Globe), medium oblate (White Sparkle Tip), cylindrical (VRRAD-200) to acicular and oblong (others). The maximum forked roots were recorded in the genotype VRRAD- 199. While no forked roots were observed in Kashi Hans, Kashi Sweta, ORBI- 0527, Palak Patta and Pusa Chetki. The variation in the root colour is due to the presence of colouring pigments viz., anthocyanin. The difference in the root shape is due to their genetic character and the forking might be due to change in soil and environment conditions. These findings are in accordance with reports of Langthasa and Barah (2000), Anjanappa *et al.* (1998), Rao and Manohar (1990), Mapari *et al.* (2009) and Singh *et al.* (2020).

5.1.5 Biochemical parameters

The reducing sugars, non-reducing sugars, total sugars and ascorbic acid content varied significantly among the genotypes. The maximum values for reducing sugars, non-reducing sugars, total sugars and ascorbic acid were observed for ORBI- 0527, Pusa Chetki, ORBI- 0527 and VRRAD- 131, respectively. Whereas, the minimum values were recorded in VRRAD- 131, White Sparkle Tip, VRRAD- 131 and Kashi Aardra. The maximum chlorophyll a, chlorophyll b and total chlorophyll content was recorded in VRRAD- 199 and VRRAD- 199, White Sparkle Tip and VRRAD- 199, Red Radish at 30 and 45 DAS, respectively. Biochemical parameters which contribute to the quality of the radish had a wide range of variation for reducing sugars, non-reducing sugars, total sugars and ascorbic acid content of the radish. These findings are in accordance with the reports of Jahan *et al.* (2011), Kumar *et al.* (2011), Dongarwar *et al.* (2018), Ola *et al.* (2018), Roopa *et al.* (2018), Dahal *et al.* (2020), Arya *et al.* (2020) and Ashraf *et al.* (2021).

5.1.6 Organoleptic evaluation

The sensory evaluation revealed that among all the genotypes of radish, VRRAD- 131 and Kashi Hans showed superiority for appearance, texture, pungency and overall acceptability. The differences in the sensory evaluation is might be due to the preference and taste of individuals. These results were in agreement with the findings of Rajagopal *et al.* (1979), Rao and Manohar (1990) and Arya *et al.* (2020).

5.2 Genetic variability studies

Twenty genotypes of radish were evaluated to know the extent of variability present in genotypes for root yield and yield attributing characters. The analysis of

variance revealed highly significant differences among the genotypes for all the characters studied at one per cent level of significance.

Among the several traits examined, high GCV and PCV were observed for plant height at 30 DAS, leaf length at 30 DAS, leaf width at 15 DAS, leaf area at 30 DAS, leaf area index at 30 DAS, fresh weight of leaves at 15 DAS, 30 DAS and 45 DAS, dry weight of leaves at 15 DAS, dry weight of leaves at 30 DAS, dry weight of leaves at 45 DAS, fresh weight of roots at 15 DAS, 30 DAS and 45 DAS, dry weight of roots at 15 DAS, 30 DAS and 45 DAS, specific leaf area at 15, 30 and 45 DAS, specific leaf weight at 15, 30 and 45 DAS, absolute growth rate at 15, 30 and 45 DAS, crop growth rate at 15, 30 and 45 DAS, net assimilation rate at 15, 30 and 45 DAS, chlorophyll a at 30 DAS, chlorophyll b at 30 DAS, total chlorophyll at 30 DAS, chlorophyll b at 45 DAS, total chlorophyll at 45 DAS, root length, root weight, root volume, root yield per plot, root yield per hectare, ascorbic acid, reducing sugars, non-reducing sugars, total sugars. It suggests that these features have a greater degree of variability, which might be useful for further selection. These results are similar with results of Jain *et al.* (2010), Jabal *et al.* (2015), Kulkarni *et al.* (2019), Singh *et al.* (2019), Nagar *et al.* (2016) for root length and root weight, Mapari *et al.* (2009), Mallikarjunarao *et al.* (2015), Singh *et al.* (2012) for fresh weight of leaves, Khan *et al.* (2011) for root yield, Ullah *et al.* (2010), Singh *et al.* (2022), Kumar *et al.* (2022) for root length, leaf length and root yield, Jamatia *et al.* (2015), Singh *et al.* (2019) for root yield, Sivanthu *et al.* (2014), Thakur *et al.* (2023) dry and fresh weights of roots, leaves and length of the root, Khan *et al.* (2011), Kumar *et al.* (2012), Mallikarjunarao *et al.* (2015) for ascorbic acid, Mukhdoomi *et al.* (2007) and Chaithra *et al.* (2017).

Moderate GCV and PCV were observed for plant height at 15 DAS, plant height at 45 DAS, number of leaves at 15 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 30 DAS, leaf width at 45 DAS, spread of the plant (E-W) at 30 DAS, spread of the plant (E-W) at 45 DAS, days to harvest, root diameter, root girth and ascorbic acid. The variability in these characters is present in a small degree of extent and there is a need for improvement of base population. These findings are in accordance with Sivanthu *et al.* (2014), Mallikarjunarao *et al.* (2015) and Thakur *et al.* (2023).

The high broad sense of heritability was shown by plant height at 15, 30 and 45 DAS, number of leaves at 15 and 45 DAS, leaf length at 30 and 45 DAS, leaf width at 15, 30 and 45 DAS, spread of the plant (N-S) at 15, 30 and 45 DAS, spread of the plant (E-W) at 15, 30 and 45 DAS, leaf area at 15, 30 and 45 DAS, leaf area index at 15, 30 and 45 DAS, fresh weight of leaves at 15, 30 and 45 DAS, dry weight of leaves at 15 and 45 DAS, fresh weight of roots at 15, 30 and 45 DAS, dry weight of roots at 15, 30 and 45 DAS, specific leaf area at 15, 30 and 45 DAS, specific leaf weight at 15, 30 and 45 DAS, absolute growth rate at 30 and 45 DAS, crop growth rate at 30 and

45 DAS, net assimilation rate at 30 and 45 DAS, chlorophyll a, b and total chlorophyll at 30 DAS, chlorophyll a, b and total chlorophyll at 45 DAS, days to harvest, root length, root diameter, root girth, root weight, root volume, root yield per plot, root yield per hectare, ascorbic acid, reducing sugars, non-reducing sugars and total sugars. The similar results were observed by Hussain *et al.* (2005) for plant height, leaf length and fresh root weight, Mapari *et al.* (2009) for plant height, number of leaves, fresh weight of leaves, dry weight of leaves, dry weight of roots and ascorbic acid, Jain *et al.* (2010) for root weight, Mehdi *et al.* (2010) for root diameter, number of leaves per plant and root yield, Rashid *et al.* (2010) for plant height, Tanaka *et al.* (2011) for root weight, Tanaka *et al.* (2012) for root length and root diameter, Vieira *et al.* (2012) for root length, Asima *et. al* (2013) root weight and root yield, Naseeruddin *et al.* (2014) for number of leaves, total plant weight, root weight and ascorbic acid, Sivanthu *et al.* (2014) for number of leaves, root diameter, fresh weight of the plant, dry weight of the plant and fresh weight of root, Santhi *et al.* (2015) for root weight, number of leaves and root diameter, Nagar *et al.* (2016) for root length and root diameter, Teli *et al.* (2017) for root weight and yield per hectare, Ullah *et al.* (2017) for root length and root yield and Thakur *et al.* (2023) for root yield and fresh and dry weights of roots.

The high estimates of heritability coupled with high genetic advance over per cent of mean were observed for plant height at 30 and 45 DAS, number of leaves at 15 DAS, leaf length at 30 and 45 DAS, leaf width at 15 and 30 DAS, spread of the plant (E-W) at 30 and 45 DAS, fresh weight of leaves at 15, 30 and 45 DAS, fresh weight of roots at 15, 30 and 45 DAS, dry weight of the roots at 15, 30 and 45 DAS, chlorophyll a, chlorophyll-b and total chlorophyll at 30 and 45 DAS, days to harvest, root length, root diameter, root girth, root weight, root volume, root yield per plot, root yield per hectare, ascorbic acid, reducing sugars, non-reducing sugars and total sugars content suggesting that these characters can be improved through direct selection due to predominance additive gene action. Similar results were observed by Mukhdoomi *et al.* (2007) for root length, Mapari *et al.* (2009) for number of leaves, root length, root diameter, root weight, root yield per plot, root yield per hectare, days to harvest and ascorbic acid, Jain *et al.* (2010) for root diameter, root length, root diameter, root weight, root yield per hectare and days to harvest, Mehdi *et al.* (2010) for root diameter, number of leaves per plant and root yield, Rashid *et al.* (2010) for plant height, Asima *et. al* (2013) for plant weight and root weight, Naseeruddin *et al.* (2014) for root yield per plant and leaf weight, Sivanthu *et al.* (2014) for number of leaves, root diameter, fresh weight of the plant, dry weight of the plant and fresh weight of root, Santhi *et al.* (2015) for root weight, number of leaves and root diameter, Nagar *et al.* (2016) for root length and root diameter, Teli *et al.* (2017) for root weight per plant and yield per hectare, Ullah *et al.* (2017) for root length and root yield and Thakur *et al.* (2023) for root yield and fresh and dry weights of roots.

5.3 Genetic diversity

The success of a breeding program depends upon the selection of parents. It has been found that the progenies derived from crossing divergent parents give divergent and useful progenies. The multivariate analysis based on Mahalanobis D^2 statistics is employed as a powerful tool for measuring genetic divergence among the tested genotypes.

5.3.1 Mahalanobis generalized distance

The material used for the present study includes 20 genotypes of radish which were grouped into five clusters using Tocher's method as represented in Figure 4. Among the five clusters studied, cluster I was the largest consisting 12 genotypes followed by cluster II having 5 genotypes, cluster III, IV and V were the least with one genotype each. The findings are in accordance with the results of Ivy *et al.* (2010), Singh and Ahmed (2010), Kumar *et al.* (2012), Manisha *et al.* (2022) and Singh *et al.* (2022).

The intra-cluster distance was found maximum for cluster II with five genotypes suggesting the presence of wide genetic diversity among the genotypes. Selection within such clusters might be executed based on the mean value of desirable character.

Based on distances between clusters, *i.e.*, inter-cluster distances, the maximum divergence was observed between cluster I and cluster V, indicating that such highly divergent, high performing genotypes would be of great use in recombination breeding programme.

5.3.2 Cluster mean analysis

The cluster mean analysis for different characters revealed that cluster IV had the highest cluster mean value for root yield per plot followed by cluster I, cluster III, cluster II. The minimum cluster mean value was found in cluster V. Therefore, crosses between these respective clusters may be used to improve root yield per plot which ultimately contributes towards yield.

The highest cluster mean for plant height at 45 DAS was recorded in cluster III, followed by cluster I, cluster II, cluster IV and least in cluster V. Hence, crosses between genotypes belonging to these respective clusters would be helpful for achieving improvement in plant height at 45 DAS.

The highest cluster means for the number of leaves at 45 DAS was noticed in cluster IV followed by cluster I, cluster III, cluster II and least in cluster V. Hence, crosses between the genotypes belonging to these clusters would be more effective in improvement of number of leaves at 45 DAS.

The highest cluster mean for leaf length at 45 DAS was observed in cluster III followed by cluster I, cluster IV, cluster II and the lowest mean was observed in cluster

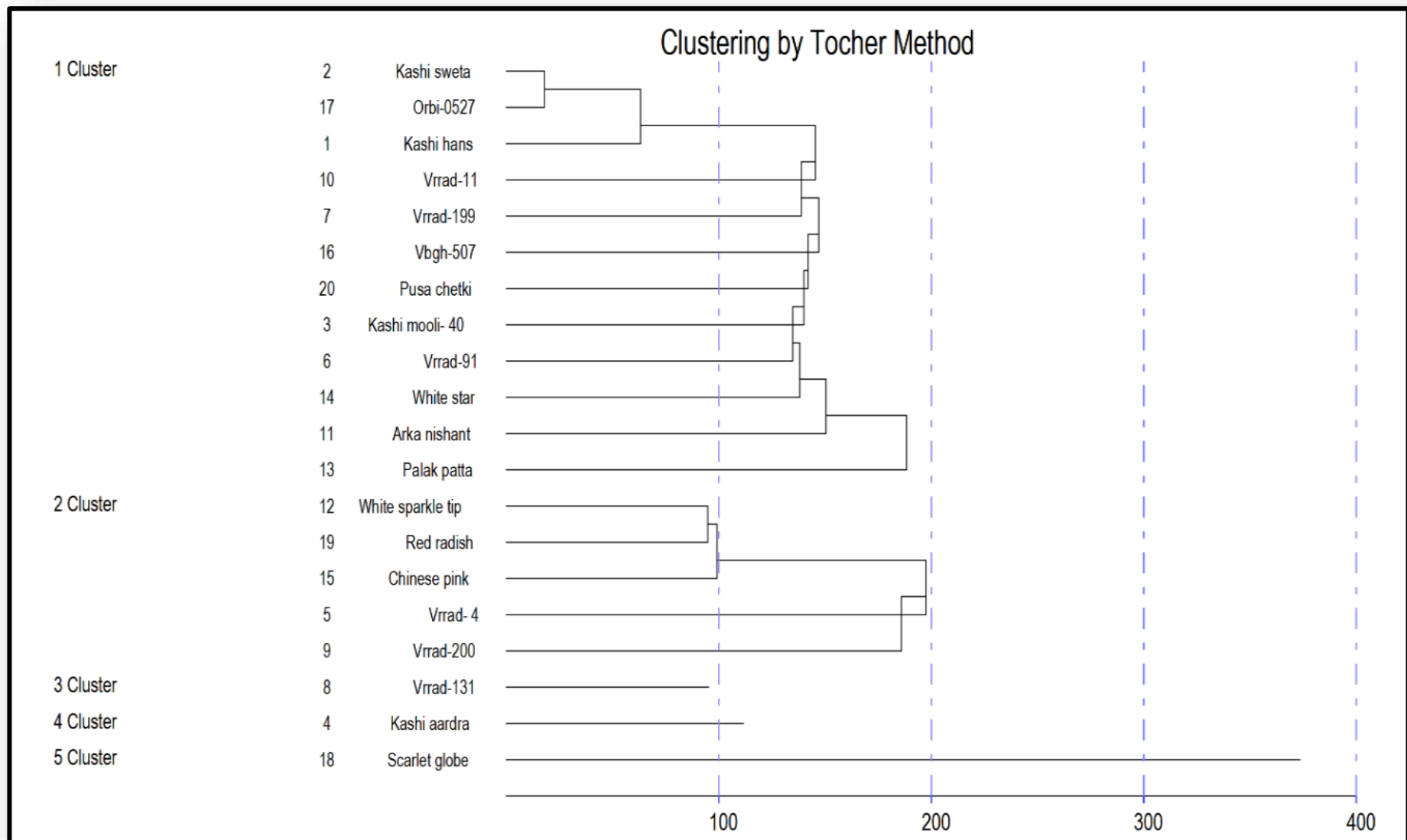


Fig 4. Dendrogram showing the genetic diversity among 20 genotypes of radish using Tocher's method

V. This indicates that the crosses between the genotypes belonging to this cluster may be tried to improve leaf length.

The highest cluster mean for leaf width at 45 DAS was noticed in cluster III followed by cluster I, cluster II, cluster IV. The lowest cluster mean for this trait was observed in cluster V. Hence, crosses between genotypes belonging to these respective clusters would be helpful for improving leaf width at 45 DAS.

The highest cluster mean for leaf area index at 45 DAS was recorded in cluster IV followed by cluster III, cluster I and cluster II and the least cluster V. Therefore, crosses between genotypes belonging to this cluster may be tried to improve leaf area index.

The highest cluster mean for days to harvest was observed in cluster IV followed by cluster III, cluster I and cluster II and the least cluster V. Hence, crosses between genotypes belonging to this clusters would be helpful for achieving improvement in days to harvest.

Cluster IV had the highest cluster mean for root length trait followed by cluster I, cluster III, cluster II and least in cluster V. This indicates crosses between these respective clusters may be tried to improve the root length.

The highest cluster mean values for the root diameter was observed in cluster V, followed by cluster II, cluster I, cluster IV and least in cluster III. Hence, crosses between genotypes belonging to these respective clusters would be helpful for achieving improvement in root diameter.

The highest cluster mean values for the root weight was observed in cluster I had the highest cluster mean value for the trait followed by cluster IV, cluster III, cluster II and lowest in cluster V. This indicates that the crosses between the genotypes belonging to this cluster may be tried to improve root weight.

Cluster III had the highest cluster mean for root ascorbic acid, followed by cluster II, cluster V, cluster and least in cluster IV. This indicates that the crosses between the genotypes belonging to this cluster may be tried to improve ascorbic acid.

5.4 Correlation coefficient studies

Analysis of correlation coefficients is a tool for determining the relationship between two or more variables. They also help in identifying the basic traits of complicated characters. Analysis of correlation coefficients showed that the traits under examination had relationships with one another that varied in closeness. Yield is the end result of interactions between many quantitative features, all of which are significantly impacted by environmental change. As the selection only based on yield is ineffective, the selection of a genotype for higher yield can be contributed by other traits that are positively and directly correlated with yield.

The current investigation found that although there is a strong inherently correlated relationship between the various studied characters, the values of genotypic correlation coefficients are higher for most traits than the values of phenotypic correlation coefficients. However, the difference was very small. Due to the strong genetic foundation of the examined material and the small variation in genotypic and phenotypic correlation coefficients, there was no evidence of environmental influences on the phenotypic expression of these features with root yield per plot. These findings are in accordance with reports of Roopa *et al.* (2018) and Singh (2020).

5.4.1 Genotypic correlation studies in genotypes of radish

In the present investigation, root yield per plot showed a highly significant and positive relation with plant height at 45 DAS, leaf length, leaf width, leaf area index, days to harvest, root length and root weight at genotypic level. Positive and significant correlation was recorded with number of leaves suggesting that these character could be considered important for direct selection for improving root yield in radish crop improvement. Similar results were obtained by Sivathanu *et al.* (2014) and Jabal *et al.* (2015) for length of root, Panwar *et al.* (2003) for root weight, Kumar *et al.* (2009) for leaf length, leaf width, root length and root weight, Rashid *et al.* (2010) and Naseeruddin *et al.* (2011) for plant height, Mehdi *et al.* (2010) for leaf length, Thakur *et al.* (2015) for and leaf length, Kaur *et al.* (2017) and Roopa *et al.* (2018) root weight and root length, Chakraborty *et al.* (2017) for root weight, days to root harvest, root length, leaf width and leaf length, Singh *et al.* (2022) for plant height, leaf length and root length, Mapari *et al.* (2009) and Thakur *et al.* (2015) for number of leaves.

Whereas, highly significant and negative association was recorded with root diameter and ascorbic acid. These findings are in accordance with the reports of Panwar *et al.* (2003), Ullah *et al.* (2010) and Nagar *et al.* (2016).

5.4.2 Phenotypic correlation studies in genotypes of radish

Root yield per plot had exhibited highly significant and positive association with plant height at 45 DAS, leaf length, leaf width, leaf area index, days to harvest, root length and root weight at phenotypic level. Positive and significant correlation was recorded with number of leaves. This association indicated that these traits can be improved through direct selection. These findings are in accordance with Panwar *et al.* (2003) for root weight, Kumar *et al.* (2009) for leaf length, leaf width, root length and root weight, Rashid *et al.* (2010) and Naseeruddin *et al.* (2011) for plant height, Mehdi *et al.* (2010) for leaf length, Thakur *et al.* (2015) for and leaf length, Mapari *et al.* (2009) and Thakur *et al.* (2015) for number of leaves, Kaur *et al.* (2017) and Roopa *et al.* (2018) root weight and root length, Chakraborty *et al.* (2017) for root weight, days to root harvest, root length, leaf width and leaf length and Singh *et. al* (2022) for plant height, leaf length and root length.

Whereas, highly significant and negative association was recorded with ascorbic acid and significantly and negatively correlated with root diameter. These findings are in accordance with the reports of Panwar *et al.* (2003) and Ola *et al.* (2018) for ascorbic acid, Ullah *et al.* (2010), Jatoi *et al.* (2011) and Nagar *et al.* (2016) for root diameter.

5.5 Path coefficient analysis

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

At phenotypic level plant height at 45 DAS had shown positive direct effect on root yield per plot, and this trait showed indirect positive effect through the number of leaves at DAS 45, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, root length and root weight. This trait had an indirect negative effect through root diameter and ascorbic acid. Similar results were obtained by Ullah *et al.* (2017) for plant height, Kumar *et al.* (2009) for number of leaves, leaf length, leaf width and root length, Vieira *et al.* (2012) for root diameter. At genotypic level plant height at 45 DAS showed a direct negative effect on root yield per plot, whereas it had an indirect negative effect through number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight and had an indirect positive effect through root diameter and ascorbic acid. These results are in accordance with reports of Singh *et al.* (2005), Kaur *et al.* (2017), Ullah *et al.* (2017) and Singh (2020).

At both phenotypic and genotypic level, the number of leaves had direct negative effect through root yield per plot whereas, it exhibited an indirect negative effect through plant height at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight and exhibited an indirect positive effect through root diameter and ascorbic acid. Similar finding was also noticed by Naseeruddin *et al.* (2018).

At both phenotypic and genotypic level, the leaf length had direct positive effect through root yield per plot, while it recorded an indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf width at 45 DAS, leaf area index

at 45 DAS, days to harvest, root length and root weight and exhibited an indirect negative effect through root diameter and ascorbic acid. These results are in accordance with reports of Kumar *et al.* (2009).

At phenotypic level leaf width had shown a direct negative effect through root yield per plot, it also shown an indirect negative effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight, while it had an indirect positive effect through root diameter and ascorbic acid. At genotypic level, leaf width had shown direct positive effect through root yield per plot and it exhibited indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight, while it had an indirect negative effect through root diameter and ascorbic acid. Likewise, Jatoi *et al.* (2011) also observed the negative direct effect through dependent horticultural trait *i.e.*, root yield per plot *via* leaf width.

The leaf area index showed direct positive effect through root yield per plot. Whereas, it exhibited an indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, days to harvest, root length and root weight and exhibited an indirect negative effect through root diameter and ascorbic acid. These findings are similar with results of Roopa *et al.* (2018).

Days to harvest showed a positive direct effect through root yield per plot, whereas it had an indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, root length and root weight but it had an indirect negative effect through root diameter and ascorbic acid. Nagar *et al.* (2016) and Ullah *et al.* (2010) observed that the independent trait days to harvest showed positive direct effect through character trait root yield.

Root length had shown a direct positive effect through root yield per plot, while it showed an indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest, root weight but it showed an indirect negative effect through root diameter and ascorbic acid. Similar results were reported by Singh *et al.* (2005), Kumar *et al.* (2009), Mapari *et al.* (2009) and Mallikarjunarao *et al.* (2015).

At phenotypic level root diameter had positive direct effect through root yield per plot while it had an indirect positive effect through ascorbic acid. The trait also showed an indirect negative effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight. At genotypic level root diameter showed direct negative effect through root yield per plot and indirect negative effect through ascorbic

acid, while the indirect positive effects were exhibited through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight. These results are in accordance with reports of Ullah *et al.* (2010) and Roopa *et al.* (2018).

Root weight exhibited a positive direct effect through root yield per plot, while it exhibited an indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest and root length and exhibited an indirect negative effect through root diameter and ascorbic acid. These findings are similar with the results of Singh *et al.* (2005), Kumar *et al.* (2009), Vieira *et al.* (2012), Kaur *et al.* (2017) and Esho and Alhuseein (2022).

Ascorbic acid showed a negative direct effect through root yield per plot, whereas it had an indirect negative effect through root diameter but showed an indirect positive effect through plant height at 45 DAS, number of leaves at 45 DAS, leaf length at 45 DAS, leaf width at 45 DAS, leaf area index at 45 DAS, days to harvest, root length and root weight. The findings of Kaur *et al.* (2017) Naseeruddin *et al.* (2018) and Singh (2020).

Conclusion

- On the basis of overall performance, out of twenty genotypes Kashi Hans (7.58 kg) was found superior for root yield per plot followed by Kashi Sweta (6.82 kg) and ORBI- 0527 (6.27 kg) (Plate 4). These genotypes were also found superior for the other horticultural traits like fresh weight of leaves, fresh weight of roots, root length, root weight and root yield per hectare.
- The horticultural trait root yield per plot showed high heritability and high genetic advance (as percentage of mean) suggesting that selection for root yield per plot would be much effective.
- The character root yield per plot was significantly and positively correlated with the characters average plant height, number of leaves, leaf length, leaf width, leaf area index, days to harvest, root length and root weight suggesting that selection for improvement of these traits could help in improvement of the yield in case of radish.
- On the basis of path coefficient analysis, it was concluded that characters root weight followed by root length, leaf area index, leaf length, days to harvest and leaf width had positive direct effect on root yield per plot.

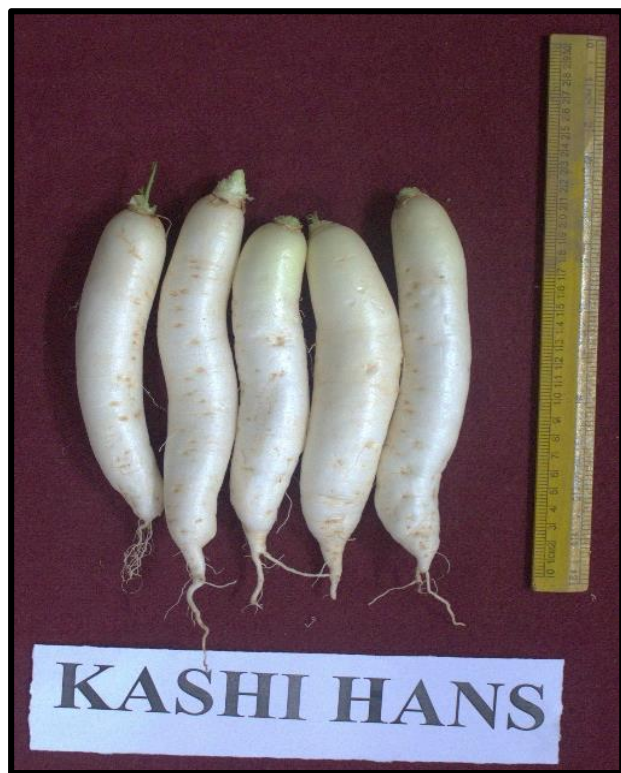


Plate 4. Best performing radish genotypes

Future line of work

- Further evaluation of identified promising high yielding genotypes *i.e.*, Kashi Hans, Kashi Sweta and ORBI- 0527 can be done over different locations and seasons for yield and stability.
- The characters which exhibited high heritability coupled with high or moderate genetic advance may be considered for further selection in crop improvement.
- The traits which exhibited desirable correlation and direct effects with root yield should be given attention during genetic improvement of radish.

SUMMARY

VI SUMMARY

The present investigation entitled "Genetic investigation of radish genotypes (*Raphanus sativus* L.) under hill zone of Karnataka" was carried out at an experimental block of Department of Vegetable Science, College of Horticulture, Mudigere, Keladi Shivappa Nayaka University of Agriculture and Horticultural Sciences, Shivamogga during summer season of the year 2022-23 with a main objective to evaluate the yield and yield attributing traits. The experiment was conducted to study the performance, variability, associated characters and genetic divergence of twenty radish genotypes which were collected from different sources, in Randomized Complete Block Design (RCBD) with three replications. The salient findings of the present investigations are summarized in this chapter.

The observations were recorded for growth, yield and quality parameters. The data were subjected to statistical analysis by applying statistical procedure, for elucidating the information on performance, existing genetic variability, genotypic and phenotypic variance, genotypic and phenotypic coefficient of variance, heritability, genetic advance, genetic advance as per cent mean, correlation coefficient, path co-efficient analysis and genetic divergence among the different components of root yield and yield attributing characters.

The analysis of variance revealed the existence of significant differences among the twenty genotypes for all the traits, which indicated that the presence of variability within the studied material.

The highest plant was observed in the genotype VRRAD-131 followed by Kashi Hans at 45 DAS. The highest fresh weight of the leaves and roots were found Kashi Hans followed by Kashi Sweta.

Among the genotypes, the Scarlet Globe took minimum number of days to harvest followed by White sparkle tip. The genotype Kashi Hans recorded maximum root length followed by Kashi Sweta. The maximum root diameter was recorded in the genotype Scarlet Globe which was on par with White sparkle tip and Kashi Hans. Root weight and root yield per plot was recorded maximum in Kashi Hans followed by Kashi Sweta and ORBI- 0527.

The narrow difference between the GCV and PCV indicates less influence environment on expression of traits. For root characters, high heritability coupled with high genetic advance as per cent of mean was recorded by root volume followed by root yield per plot, root length, root yield per hectare, root weight, root girth and root diameter which indicates that these characters were governed by additive genes and these characters were less influenced by environmental factors and selection based on the phenotypic performance will be rewarding for improvement of such characters.

The diversity study classified 20 genotypes of radish into five clusters using Tocher's method. Out of the five clusters, cluster I was the largest consisting of twelve genotypes followed by cluster II having 5 genotypes, cluster III, IV and V were the least with one genotype each. The Genotypes were not clustered according to geographical distributions.

Based on the distance between clusters, *i.e.*, inter-cluster distances, the maximum divergence was observed between cluster I and cluster V, indicating that such highly divergent, high performing genotypes would be of great use in recombination breeding programme.

The intra-cluster distance was found maximum for cluster II with five genotypes suggesting the wide genetic diversity presence among the genotypes. Selection within such clusters might be executed based on the mean value of desirable character.

Root yield per plot contributed maximum to the genetic diversity among the characters followed by ascorbic acid, leaf area index, root length, root diameter, leaf length, root weight and number of leaves.

Estimation of character association indicated that the genotypic correlation coefficients were higher than the phenotypic correlation coefficients depicting a strong inherent association among the various characters studied. The root yield per plot showed a positive relation with plant height at 45 DAS, leaf length, leaf width, leaf area index, days to harvest, root length and root weight at phenotypic level suggesting that these character could be considered important for direct selection for improving root yield in radish crop improvement. Path analysis revealed that plant height, leaf length, leaf area index, days to harvest, root length and root weight had direct positive effect on root yield per plot indicating the importance of these traits in selection.

The top three best genotypes identified from the present study based on the mean performance are Kashi Hans, Kashi Sweta and ORBI- 0527 for root yield.

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VII REFERENCES

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*Original copy not seen.

APPENDICES

VIII APPENDICES

Appendix I: Monthly mean meteorological data recorded during the experimental year 2022–23 recorded at the KVK, Mudigere

Month	Rain fall (mm)	Mean Temperature (°C)		Mean Relative Humidity (%)	
		Minimum	Maximum	Minimum	Maximum
September - 2022	294.00	18.76	25.79	95.43	99.50
October - 2022	23.50	18.00	28.01	85.80	99.00
November - 2022	7.50	17.04	28.28	75.97	94.07
December - 2022	14.00	15.73	28.05	63.40	92.83
January - 2023	0.50	12.35	29.20	50.07	96.27
February - 2023	4.50	17.84	29.08	77.00	82.71
March - 2023	5.00	23.94	24.21	66.63	78.67
April - 2023	10.00	18.30	33.11	62.70	95.93
May - 2023	76.00	19.93	30.92	81.43	98.07
June - 2023	101.00	20.10	27.23	92.30	97.73
July - 2023	553.00	19.91	24.04	97.03	99.57
August - 2023	61.00	19.01	26.63	90.23	98.97
Total	1150	-	-	-	-
Average	-	12.35	33.11	50.07	99.57

Appendix-II: Physical, chemical properties and fertility status of experimental site

Sl. No.	Particulars	Values	Methods employed
Physical properties			
1	Sand (%)	48.30	Hydrometer method (Piper, 1966)
2	Clay (%)	23.00	
3	Silt (%)	28.00	
4	Texture	Sandy loam	
Chemical properties			
1	Soil pH	6.45	PH meter
2	Electrical conductivity	0.447	Conductivity bridge (Jackson, 1967)
3	Organic carbon (%)	0.72	Walkey and Blacks method (1934)
4	Available nitrogen (kg/ha)	303	Alkaline permanganate method (Subbaiah and Asija, 1956)
5	Available phosphorous (kg/ha)	20	Bray’s method (Jackson, 1967)
6	Available potassium (kg/ha)	57	Neutral normal ammonium acetate method (Jackson, 1967)
7	Available boron (%)	0.35	Hot water treatment

Appendix- III: Morphological characteristics of the radish genotypes

Genotypes	Leaf shape	Stem colour
Kashi Hans	Lyrate	Green
Kashi Sweta	Lyrate	Green
Kashi Mooli – 40	Lyrate	Green
Kashi Aardra	Lyrate	Green
VRRAD – 4	Lyrate	Green
VRRAD – 91	Lyrate	Green
VRRAD – 199	Lyrate	Green
VRRAD – 131	Lyrate	Purple
VRRAD – 200	Lyrate	Green
VRRAD – 11	Lyrate	Green
Arka Nishant	Lyrate	Green
White Sparkle Tip	Lyrate	Green
Chinese Pink	Lyrate	Pink
Palak Patta	Spatulate	Green
White Star	Lyrate	Green
VBGH – 507	Spatulate	Green
ORBI- 0527	Spatulate	Green
Scarlet Globe	Lyrate	Green
Red Radish	Spatulate	Red
Pusa Chetki	Spatulate	Green

Appendix-IV: List of symbols and abbreviations

Symbols	Abbreviations
%	Per cent
°C	Degree Celsius
dm ²	Deci meter square
cm	Centimetre
cm ²	Centimetre square
m	Meter
m ²	Meter square
ha	Hectare
<i>et al.</i>	and other
g	Gram
<i>i.e.,</i>	That is
kg	Kilogram
t	Tonnes
mg	Milligram
ml	Millilitre
lt	Litre
mm	Millimetre
CD	Critical difference
S.Em.	Standard Error of Mean
S.D	Standard deviation
<i>viz.,</i>	Namely
DAS	Days after sowing
DUS	Distinctness, Uniformity and Stability
nm	Nano meter
AGR	Absolute growth rate
RGR	Relative growth rate
CGR	Crop growth rate
NAR	Net assimilation rate
SLA	Specific leaf area
SLW	Specific leaf weight