Advances in Agricultural Technology & Plant Sciences
ISSN: 2640-6586

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Research Article *Volume 7 Issue 2*

Correlation and Path Analysis Studies among Growth and Yield Contributing Parameters of Different Varieties of Radish (Raphanus Sativus L.)

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Received Date: July 19, 2024; **Published Date:** August 23, 2024

Abstract

The field investigation was carried out at Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra (India) during rabi season 2013-14 to find out suitable variety for better quality and maximum yield of radish under Akola conditions. The experiment was laid out in Randomized Block Design with seven treatments (varieties) of plant with three replications. From correlation study, it is reasonable that a great deal of success can be achieved in improvement of root yield per hectare by applying selection pressure on plant height (cm) at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root diameter (cm), fresh weight of root (g), total fresh weight (g) of plant, root to shoot ratio, moisture content (%), ascorbic acid content (mg 100g-1) and total soluble solids (0 Brix) content as these traits had significant and positive correlation with root yield per hectare (tons). Also, path analysis revealed maximum positive direct effect on root yield through leaf area (cm2) at harvest, fresh weight of root and total fresh weight of plant. Hence, Plant breeders can use above traits for improvement of root yield of radish and to find out the suitable variety with better yield and quality..

Keywords: Radish; Correlation; Path Analysis; Variety; Quality; Yield

Introduction

Radish (*Raphanus sativus* L.) is one of the most important edible and nutritious root vegetable crops in world, belongs to genus *Raphanus,* family Brassicaceae or Cruciferae, originated from the Central and Western China and India [1]. Radish (*Raphanus sativas* L.) is a popular vegetable in both tropical and temperate region. Radish is one of the most ancient vegetable. It is cultivated under protected conditions for early production but large scale production on field is more common.

Radish is grown in both temperate and tropical climate for its young tender tuberous roots which are eaten raw as a salad or leaves cooked as a vegetable. It is rich source of Vit-C (ascorbic acid), calcium and minerals. It is relished for its pungent flavor and is considered as an appetizer and having medicinal properties. The young leaves are also cooked as vegetable and eaten. Radish has refreshing and depurative properties. Radish is useful in liver and gall bladder troubles. In homoeopathy, they are used for neuralgic headache, sleeplessness and chronic diarrhoea. Roots, leaves, flower and pod are quite effective against gram positive bacteria.

The roots are said to be useful in urinary complaints, piles [2] and in gastrodynia. A salt extracted from roots, dried and burnt to white ash is said to be used as diuretic and laxative. The seeds are said to be pectin, expectorant, diuretic and carminative [3].

Radish is an annual or biannial herb depending on root or seed production. The edible part of radish is tap root. The edible portion of radish root develops from both primary root and hypocotyls.

In India, radish was cultivated maximum in states of West Bengal, Bihar, Uttar Pradesh, Punjab, Haryana, Gujarath, Himachal Pradesh, Karnataka [4]. Radish is predominantly a cool season vegetable crop. Being a cool season crop, it is sown during winter from September to January in Northern plains. In the mild climate of peninsular India, radish can be grown almost all the year round except for few months of summer. Radish is short duration crop grown all over the country. The varieties of radish were ready for harvest from 43 to 58 days after sowing. It is thermo-sensetive crop particularly during early growing seasons and root development stage. Though Akola is situated in subtropical zone with mean annual minimum and maximum temperature of 19.13 0C to 43.40 0C, during winter season the temperature is cooler which has felt good for initial growth of radish. But later on temperature increase slowly which may affect the root development of radish.

In recent years, due to increased urbanization and change in food habits, the demand for salad vegetables is increasing very fastly in world as well as in all states of India. In India, with increase in population and improvement in dietary habits, the consumption of vegetable has improved. People realizes the importance of vegetables in their diet as vegetables have high nutritive value, which are vital for the body. The vegetables from Akola, Maharashtra region are also sold in the big markets like Mumbai, Pune, Nagpur and Hyderabad. One of the most important reasons for low production of the radish in farmer's field is lack of knowledge on suitable varieties [5]. The information regarding the radish varieties suitable for Vidharbha region is scanty. Farmers are asking for high yielding varieties with good quality of roots. The growth, yield and quality performance of the radish varieties varies from place to place and region to region. Some local types are also under cultivation since long time. The selection of local radish cultivars in radish cultivation resulting in to poor yield and low quality of radish. Further, some new varieties from State Agriculture Universities, National Institutes and Centers were also released during the recent past. A proper selection of varieties is a bottle neck to get higher yield and gross return. If variety selection is wrong, it gives small size root and it may results in decrease root yield and net return.

The new trend in vegetable production is not only to obtain higher yields but also to have better quality produce, as producers are getting higher price for quality produce. There are several factors like variety, season of planting, nutrition and irrigation which plays a dominant role in yield contribution and quality production. Among these factors variety is a predominant. Higher yield, long sized roots and earliness are some of the characters which might be responsible for increase in the profit of radish growing farmers.

In order to fulfill the demand of people for the improved quality radish, it is essential to increase the production of radish considerably. This can be achieved by bringing more area under cultivation and increasing the productivity. The growth and yield of radish greatly depends on soil and climatic conditions. Different varieties have different soil and climatic requirement for their optimum performance. India being a vast country with varied agro-climatic regions viz., temperate, subtropical, tropical, costal tropical and humid region. A single variety may not be suitable for the entire agro-climatic region. Hence, different varieties have to be identified for specific regions, for the demand of higher root yield and quality of radish production, systemic study is taken up to evaluate proper varieties of radish in Akola conditions and to evaluate the proper variety it is essential to study the correlation of various growth, yield attributing parameters and quality of radish with its root yield performance.

As most of the traits of economic importance are complex involving several related traits, the knowledge of correlation between these traits is important [6]. The association between two variables which can be directly observed is termed as phenotypic correlation. Phenotypic correlation fails to give the true picture of relationship between two characters because along with genetic value it is also influenced by the environment.

Therefore, genotypic correlation is essential for studying the real genetic variation in different characters and the manner in which environmental variation affects the expression of such variation. The genetic improvement in dependent trait can be achieved by applying strong selection to a character which is genetically correlated with the dependent character. Therefore, keeping this point of view, the present study entitled "Correlation and Path Analysis Studies among Growth and Yield Contributing Parameters of Different Varieties of Radish (*Raphanus Sativus L.*) was attempted.

Material and Methods

The present experiment was conducted at Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth,

Akola, during *rabi* season, 2013 - 14. Akola is situated in sub-tropical region between 22.20 N latitude and 77.020 E longitudes. The altitude of place is 307.2 m above mean sea level. The climate of Akola is semi-arid and characterized by three distinct seasons. Hot and dry summer from March to May, warm humid and rainy monsoon from June to October, and mild cold winter from November to February. The meteorological data in respect of rainfall, humidity, maximum and minimum temperature was recorded at meteorological observatory, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during the experimental period i.e. October to December 2013.

The experimental plot was having medium light soil with uniform texture, colour and good drainage capacity.

The experiment was laid out in Randomized Block Design (RBD) with three replications and seven treatments (Table 1). The entire experiment was devided into 21 plots with 3.60 x 2.30 m of gross and 3.00 x 2.00 m of net plot size. Sowing was done on ridges and furrows having spacing 30 cm ridge to ridge x 10 cm plant to plant on dated 21st October, 2013. Seed were sown 1.5 to 3 cm deep in soil. The plant population maintained was nearly 200 plants per plot.

Sr. No	Treatments	Varities Name	Source of seed
1	V1	Pusa Desi	IARI New Delhi
2	V2	Pusa Himani	IARI New Delhi
3	V3	Pusa Reshmi	IARI New Delhi
4	V4	Pusa Chetki	Chilli and Vegetable Research Unit, Dr. PDKV, Akola.
5	V5	Arka Nishant	Department of Horticulture, Dr. PDKV, Akola
6	V6	Japanese White	Local Market
7	V7	I H R -1-1	IIHR Bangalore

Table 1: Varieties/Treatments detail.

The experimental field was ploughed twice and harrowed once to get a fine tilth and a tractor-drawn rotavator is also used. Prior to harrowing a well decomposed FYM was incorporated into the field at the rate of 20 t ha-1 and mixed thoroughly in soil. Later the plots were laid out as per the plan. Stubble and weed were cleaned from the experimental area and preparation of fine ridges and furrows bed. Nitrogen @ 100 kg ha-1 was applied in the form of Urea in two equal split dose. The basal dose was given at the time of sowing and remaining half dose was given 30 days after sowing. The basal dose of P2O5 kg ha-1 was applied in the form of single super phosphate at the time of sowing. The seed of radish cv. Pusa Chetki, Arka Nishant varieties were treated in *Trichoderma viride* @ 4g kg-1. Treated seed were taken out and sowing in field. All the recommended cultural operations viz., sowing, thinning, gap filling, irrigation, weeding, fertilizer application, plant protection etc., were followed to raise a healthy crop Choudhary [7] and The outermost row on either side was left as border row and the next row adjacent to both the sides were utilized for plant sampling at a periodic interval for recording observations on field crop and quality analysis. Observations were recorded in five randomly selected plants per replication for each genotype for all the characters.

Growth observations viz., plant height (cm), leaf area (cm2) and number of leaves per plant and chlorophyll content (mg g-1) were recorded at 20th, 40th days after sowing and at the time of harvesting. The plant height was measured with the help of the meter scale in centimeter and leaf area was measured with leaf area meter (Systronic leaf area meter-2011) and values were expressed in centimeter square. The chlorophyll content of the leaves in the form of chlorophyll 'a', chlorophyll 'b' was estimated by the procedure, suggested by Hiscox, et al. [8]. The chlorophyll from leaves calculated as per Arnon [9] equation and it was expressed in mg g-1.

Yield contributing characters viz., Days required to harvest, Length of root (cm), Diameter of root (cm), Fresh weight of leaves (g), Fresh weight of root (g), Total fresh weight of plant (g) were recorded from five observational plants and Root yield per plot (kg), Root yield per ha (tons) and Root to shoot ratio were calculated by them. Shape of root was recorded by observing appearance.

Among quality attributes Moisture content of root (%) was measured from 5 gm sample of root on electric moisture meter (Shimadzu, electronic moisture balance, MOC- 120H). The average of the observations was calculated and expressed in percentage. Crude fiber content of root (%) calculated by

using procedure and formula suggested by Ranganna [10]. Ascorbic acid content of root (mg 100g-1). Ascorbic acid content in root was estimated by the procedure suggested by Muzumdar, et al. [10]. Freshly harvested roots were cut into three to four pieces and observations of pithiness were undertaken after cutting the root at middle portion. Total Soluble Solids of the root (0Brix) was measured with the help of electronic digital refractometer (ATAGO). The mean of observations was recorded in degree Brix.

The data were analyzed statistically applying the analysis of variance produce for Randomize Block Design and the significance was tested as Panse VG, et al. [12] 'f' test critical difference for examining treatments means for their significance was calculated at 5% level of significance. The data on correlation was analyzed using OPSTAT software programme. For the analysis of the data the following statistical methods were exercised, namely analysis of variance, genetic parameters viz., genotypic and environmental variance, environmental co-efficient of variation [13] and classified (high/medium/low) as described by Sivasubramanian, et al. [14]. Correlations and path coefficient analysis were done by the method given by Dewey JR, et al. [15].

Figure 1: General view of experimental plot.

Results and Discussion

The observations were recorded on various aspect viz., growth, yield and quality parameters of radish.

Genotypic and Phenotypic Correlation of Yield with other Characters

Correlation studies are used to find out the degree and direction of relationship between two or more variables. Knowledge on degree of association of yield with its components is of great importance, because yield is not an independent character, but it is the resultant of the interactions of a number of component characters in which the plant grow.

Further, each character is likely to be modified by action of genes present in the genotypes of plant and also by the environment and it becomes difficult to evaluate this complex character directly. Therefore, correlation study of yield with its component traits has been executed, to find out the yield contributing traits. In the present study both genotypic (Table 2) and phenotypic (Table 3) correlations were worked out for root yield per hectare (tons) and its contributing traits.

Characters	PH	NL	LA	CHL	DH	LR	DR	FL	FR	TFW	RS	MC	CFC	ASC	TSS	RY
PH	1															
NL	0.187^{NS}	1														
LA	0.939**	0.659**	1													
CHL	0.770**	0.156^{NS}	0.650**	1												
DH	-0.562**	0.416^{NS}	-0.280^{NS}	-0.736**	1											
LR	0.208^{NS}	0.669**	0.360^{NS}	0.468*	-0.090^{NS}	1										
DR	1.090**	-0.174^{NS}	0.886**	0.812**	-0.879**	0.264^{NS}	1									
FL	-0.659**	0.494*	-0.504*	-0.236^{NS}	0.540*	0.178^{NS}	-0.871**	1								
FR	0.849**	0.372^{NS}	0.759**	1.017**	-0.779**	0.394^{NS}	0.956**	-0.477*	1							
TFW	0.804**	0.822**	0.873**	0.940**	-0.389^{NS}	0.557**	0.729**	-0.189^{NS}	0.875**	1						
RS	0.667**	0.200^{NS}	0.579**	0.396^{NS}	-0.644**	0.398^{NS}	0.892**	-0.381^{NS}	0.669**	0.528*	1					
MC	0.681**	0.128^{NS}	0.520*	0.994**	-0.934**	0.349^{NS}	0.874**	-0.414^{NS}	0.970**	0.732**	0.654**	1				
CFC	-0.555**	0.464*	-0.301^{NS}	-0.688**	0.947**	-0.189^{NS}	-0.907**	0.693**	-0.734**	-0.340^{NS}	-0.581**	-0.866**	1			
ASC	0.707**	0.791**	0.777**	0.974**	-0.261^{NS}	0.586**	0.580**	-0.098^{NS}	0.772**	0.951**	0.281^{NS}	0.633**	-0.251^{NS}	1		
TSS	0.422^{NS}	-0.604**	0.165^{NS}	0.321^{NS}	-0.883**	-0.186^{NS}	0.785**	-0.735**	0.538*	0.081^{NS}	0.594**	0.665**	-0.878**	-0.104^{NS}	1	
RY	0.895**	0.390^{NS}	0.814**	0.958**	-0.754**	0.425^{NS}	1.017**	-0.520*	0.995**	0.882**	0.741**	0.943**	-0.725**	0.759**	0.544*	1 0

*Significance at 5% level of significance. ** Significance at 1% level of significance.

PH-Plant Height (cm) at harvest, NL- Number of leaves at harvest, LA- Leaf area (cm2) at harvest, CHL- Chlorophyll content (mg/g) at harvest, DH- Days to harvesting, LR- Length of root(cm), DR- Diameter of root (cm), FL- Fresh weight of leaves(g), FR- Fresh weight of root(g), TFW- Total fresh weight(g), RS-Root to shoot ratio, MC-Moisture content (%),CFC- Crude fibre content(%), ASC- Ascorbic acid content(mg/100g), TSS- Total soluble solids (0 Brix), RY- Root yield per hectare (t/ha).

Table 2: Genotypic Correlations coefficient among different characters and root yield per hectare in radish (Raphanus sativus L.).

In the present experiment, root yield per hectare (tons) was significantly and positively correlated with plant height (cm) at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root diameter(cm), fresh weight of root (g), total fresh weight (g), root to shoot ratio, moisture content (%), ascorbic acid content (mg 100g-1) and TSS (0 Brix) at both genotypic and phenotypic level (Tables 2 & 3). Similar trend of results are were observed by Rupa, et al. [16] for leaf area, root diameter and root weight, Kumar, et al. [17] for root diameter and root to shoot ratio; Jatoi, et al., for root weight and root diameter; Sivathanu, et al. [18] for root diameter; Mallikarjunrao, et al. [19] for root diameter, root weight; Nagar, et al. [20] for root weight; Naseeruddin, et al. [21] for root diameter.

Characters	PH	NL	LA	CHL	DH	LR	DR	FL	FR	TFW	RS	MC	CFC	ASC	TSS	RY
PH	1															
NL	0.193^{NS}	1														
LA	0.854**	0.413^{NS}	1													
CHL	0.546*	0.309^{NS}	0.458*	1												
DH	-0.519*	0.193^{NS}	-0.275^{NS}	-0.577**	1											

LR	0.197^{NS}	0.343^{NS}	0.350^{NS}	0.287^{NS}	-0.063^{NS}	1										
DR	0.736**	0.010^{NS}	0.594**	0.418^{NS}	-0.606**	0.168^{NS}	1									
FL	-0.622**	0.261^{NS}	-0.487*	-0.216^{NS}	0.544*	0.192^{NS}	-0.651**	1								
FR	0.762**	0.212^{NS}	0.756**	0.717**	-0.765**	0.375^{NS}	0.659**	-0.464*	1							
TFW	0.744**	0.508*	0.870**	0.681**	-0.385^{NS}	0.531*	0.501*	-0.186^{NS}	0.873**	1						
RS	0.615**	0.119^{NS}	0.579**	0.277^{NS}	-0.630**	0.395^{NS}	0.622**	-0.367^{NS}	0.667**	0.526*	1					
MC	0.589**	0.062^{NS}	0.494*	0.728**	-0.843**	0.401^{NS}	0.590**	-0.361^{NS}	0.901**	0.684**	0.625**	1.0001				
CFC	-0.513*	0.280^{NS}	-0.301^{NS}	-0.504*	0.936**	-0.178^{NS}	-0.639**	0.681**	-0.732**	-0.340^{NS}	-0.580**	-0.808**	1			
ASC	0.646**	0.472*	0.775**	0.704**	-0.254^{NS}	0.562**	0.391^{NS}	-0.094^{NS}	0.771**	0.950**	0.281^{NS}	0.595**	-0.250^{NS}	1		
TSS	0.385^{NS}	-0.372^{NS}	0.165^{NS}	0.227^{NS}	-0.869**	-0.175^{NS}	0.547*	-0.718**	0.537*	0.081^{NS}	0.593**	0.623**	-0.877**	-0.104^{NS}	1	
RY																1
	0.788**	0.234^{NS}	0.804**	0.670**	-0.738**	0.403^{NS}	0.674**	-0.488*	0.985**	0.873**	0.732**	0.865**	-0.716**	0.751**	0.538*	0
*Significance at 5% level of significance. ** Significance at 1% level of significance.																
PH-Plant Height (cm) at harvest, NL- Number of leaves at harvest, LA- Leaf area (cm2) at harvest, CHL- Chlorophyll content (mg/g) at harvest, DH- Days to harvesting, LR- Length of root(cm), DR- Diameter of root (cm), FL- Fresh weight of leaves(g), FR- Fresh weight of root(g), TFW- Total fresh weight(g), RS-Root to shoot ratio, MC-Moisture content (%),CFC- Crude fibre content(%), ASC- Ascorbic acid content(mg/100g), TSS- Total soluble																
solids (0 Brix), RY- Root yield per hectare(t/ha).																

Table 3: Phenotypic Correlations coefficient among different characters and root yield per hectare in radish (Raphanus sativus L.).

Since, these yield attributing traits are in appropriate direction, selection for such traits would be more worthwhile in improving the root yield per hectare.

Plant height (cm) at harvest was significantly and positively correlated with leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root diameter (cm), fresh weight of root (g), total fresh weight (g), root to shoot ratio, moisture content (%), ascorbic acid content (mg 100g-1) and root yield per hectare (t/ha) at both genotypic and phenotypic level. This indicates plant height is an important trait as it increases the root yield per hectare as well as affect quality. However, this is undesirable correlations since it decrease the overall marketable root mass and thus yield. Consumer preference is for long roots and size and not for more plant height. Similar results observed by Kaur, et al. [22].

Leaf area (cm2) at harvest was significantly and positively correlated with plant height (cm) at harvest, chlorophyll content at harvest (mg g-1), root diameter (cm), fresh weight of root (g), total fresh weight (g), root to shoot ratio, moisture content(%), ascorbic acid content (mg 100g-1) and root yield per hectare (tons) at both genotypic and phenotypic level. While, had significant and positive correlation with number of leaves at harvest at only genotypic level. This indicates leaf area at harvest is an important trait as it increases the root yield per hectare as well as affect quality. The similar results are observed by Panwar, et al. [23] for root diameter and root weight.

Chlorophyll content at harvest (mg g-1) was significantly and positively correlated with plant height (cm) at harvest, leaf area (cm2) at harvest, fresh weight of root (g), total fresh weight (g), moisture content (%), ascorbic acid content (mg 100g-1) and root yield (tons) per hectare at both genotypic and phenotypic level. While, had significant and positive correlation with root diameter (cm) at only genotypic level. This indicates chlorophyll content at harvest is an important trait as it increases the root yield per hectare as well as affect quality and shows maximum effect on root yield, similar to the results of Mapari, et al. [24].

Root diameter (cm) had significant and positive correlation with plant height (cm) at harvest, leaf area (cm2) at harvest, fresh weight of root (g), total fresh weight (g), root to shoot ratio, moisture content (%), TSS (0 Brix) and root yield per hectare (tons) at both genotypic and phenotypic level. While, had significant and positive correlation with chlorophyll content at harvest (mg g-1) and ascorbic acid content (mg 100g-1) at only genotypic level. It indicates if more the root diameter it increases the root yield per hectare. The quite similar results are observed by Rupa, et al. [16] for leaf area, root diameter and root weight, Sivathanu, et al. [18] for root yield/ha; Mallikarjunrao, et al. [19] for root weight and root to leaf ratio.

Fresh weight of root (g) was significantly and positively correlated with plant height (cm) at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root diameter, total fresh weight, root to shoot ratio, moisture content, ascorbic acid content (mg 100g-1), TSS (0 Brix) and root yield per hectare (tons) at both genotypic and phenotypic level. The similar kind of results are opined by Rupa, et al. [16] for leaf area, root diameter and root weight, Mallikarjunrao, et al. [19] for root weight, root to leaf ratio and root yield per hectare; Kaur, et al. [22] with root weight, root to leaf ratio and root yield per hectare.

Total fresh weight of plant was significantly and positively correlated with plant height (cm) at harvest, number of leaves at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root length (cm), root diameter(cm), fresh weight of root(g), root to shoot ratio, moisture content(%), ascorbic acid content (mg 100g-1) and root yield per hectare (tons) at both genotypic and phenotypic level. The results are in agreement with the results of Mapari, et al. [24] for chlorophyll content and root yield.

Root to shoot ratio was significantly and positively correlated with plant height (cm) at harvest, leaf area (cm2) at harvest, root diameter(cm), fresh weight of root(g), total fresh weight(g), moisture content(%), TSS (0 Brix) and root yield per hectare (tons) at both genotypic and phenotypic level. This indicates that while, selecting for high yielding genotypes in radish, varieties with high root to shoot ratio is considerable. The results are in agreement with the results of Rupa, et al. [16] and Kaur, et al. [22] for root weight and root yield per hectare.

Moisture content was significantly and positively correlated with plant height (cm) at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root diameter(cm), fresh weight of root (g), total fresh weight (g), root to shoot ratio, ascorbic acid content (mg 100g-1), TSS (0 Brix) and root yield per hectare (tons) at both genotypic and phenotypic level. This indicates that while, selecting for high yielding genotypes in radish, varieties with high moisture content (%) is considerable.

Ascorbic acid content was significantly and positively correlated with plant height (cm) at harvest, number of leaves at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root length(cm), fresh weight of root(g), total fresh weight(g), moisture content(%) and root yield per hectare (tons) at both genotypic and phenotypic level. While, had significant and positive correlation with root diameter (cm) at only genotypic level. This indicates ascorbic acid content (mg 100g-1) was an important trait while selecting for high yielding genotypes in radish. Similar results found by Mapari, et al. [24] for root yield per hectare. Total Soluble Solids (0 Brix) content was significantly and positively correlated with root diameter(cm), fresh weight of root(g), root to shoot ratio, moisture content(%) and root yield per hectare (tons) at both genotypic and phenotypic level. This indicates TSS (0 Brix) content was an important trait while selecting for high yielding genotypes in radish. Similar results proposed by Panwar, et al. [23] for root diameter, fresh weight of root and root yield.

Path Coefficient Analysis

Yield is intricate character and correlation between constituent traits could be ambiguous due to mutual cancellation effect of desirable and undesirable components [25]. To overcome this limitation, path analysis provides for partitioning of relationships in to specific direct and indirect effects of the causal factors [26].

Direct Effect of Characters

From the data Table 4) among 15 characters observed, all 15 characters had a direct and positive effect on root yield per hectare. Leaf area (cm2) at harvest (30.209), fresh weight of root (g) (28.858) and total fresh weight of plant (g) (26.243) exhibited higher direct and positive on root yield (t/ha) as also reported by other workers [27,28].

Characters	PH	NL	LA	CHL	DH	LR	DR	FL	FR	TFW	RS	MC	CFC	ASC	TSS	RY
PH	**2.768**	0.35	2.843	1.672	-1.683	0.603	2.305	-1.956	2.578	2.441	2.023	1.93	-1.683	2.144	1.282	2.692
NL	0.242	**0.876**	0.934	0.158	0.582	0.907	-0.172	0.686	0.529	1.167	0.283	0.17	0.66	1.122	-0.858	0.549
LA	25.9	12.29	**30.21**	14.09	-8.362	10.39	18.67	-14.91	22.978	26.408	17.51	14.71	-9.119	23.51	5.005	24.41
CHL	0.854	0.117	0.79	**0.871**	-0.884	0.543	0.688	-0.281	1.237	1.143	0.481	1.13	-0.836	1.185	0.391	1.155
DH	-4.965	2.482	-2.708	-5.106	**9.554**	-0.835	-5.93	5.116	-7.541	-3.767	-6.233	-8.45	9.166	-2.527	-8.559	-7.24
LR	1.232	2.679	2.332	2.177	-0.579	**6.2**	1.193	1.13	2.557	3.616	2.58	2.117	-1.229	3.805	-1.21	2.734
DR	1.015	-0.11	0.903	0.594	-0.885	0.257	**0.711**	-0.87	0.976	0.744	0.91	0.834	-0.926	0.591	0.802	1.029
FL	-4.566	2.314	-3.819	-1.286	4.048	1.289	-4.611	**7.431**	-3.624	-1.437	-2.89	-2.939	5.264	-0.747	-5.589	-3.919
FR	22.36	6.628	21.872	21.02	-22.16	10.84	19.21	-13.46	**28.86**	25.26	19.3	26.15	-21.19	22.28	15.54	28.46

TFW	19.25	13.3	22.86	17.65	-10.07	13.94	13.33	-4.854	22.973	**26.24**	13.83	17.95	-8.931	24.95	2.139	22.95
RS	0.264	0.054	0.251	0.123	-0.276	0.165	0.27	-0.162	0.291	0.229	**0.434**	0.266	-0.252	0.122	0.258	0.319
MC	1.778	0.226	1.487	2.038	-2.639	0.953	1.743	-1.16	2.778	2.097	1.872	**2.676**	-2.479	1.813	1.906	2.678
CFC	-0.149	0.084	-0.088	-0.145	0.274	-0.053	-0.185	0.199	-0.216	-0.1	-0.17	-0.237	**0.294**	-0.074	-0.258	-0.211
ASC	2.36	1.786	2.84	2.554	-0.943	2.048	1.478	-0.353	2.828	3.483	1.029	2.166	-0.917	**3.66**	-0.382	2.753
TSS	0.265	-0.256	0.113	0.158	-0.599	-0.122	0.376	-0.495	0.37	0.056	0.408	0.427	-0.604	-0.072	**0.688**	0.371
RY	7.557	2.227	7.52	6.352	-6.888	3.752	6.561	-4.713	9.211	8.168	6.852	8.16	-6.709	7.021	5.043	**9.178**
PH-Plant Height (cm) at harvest, NL- Number of leaves at harvest, LA- Leaf area (cm2) at harvest, CHL-Chlorophyll content (mg/g) at harvest, DH- Days to harvesting, LR- Length of root(cm), DR-Diameter of root (cm), FL-Fresh weight of leaves(g), FR- Fresh weight of root(g), TFW-Total fresh weight(g), RS-Root to shoot ratio, MC-Moisture content (%), CFC-Crude fibre content(%), ASC-Ascorbic acid content (mg/100g), TSS- Total soluble solids (0 Brix), RY-Root yield per hectare (t/ha).																

Table 4: Path coefficient analysis of direct (diagonal) and indirect (above and below diagonal) effects of different characters on root yield per hectare in radis (Raphanus sativus L.).

Indirect Effects of Characters

From the data Table 4, among 15 characters observed, 12 characters had indirect and positive effect on root yield per hectare. Whereas, 3 characters had indirect and negative effect on root yield per hectare. Fresh weight of root (g) (9.211) had the highest positive indirect effect on the root yield (t/ha) followed by the total fresh weight of plant (g) (8.168). On the other hand 3 characters viz., days to harvesting, fresh weight of leaves(g) and crude fibre content(%) had negative indirect effect on root yield (t/ha) and have no significance in selection programme. Similar results were proposed by Mapari, et al. [23].

Conclusion

From the above preceding discussion, it is reasonable that a great deal of success can be achieved in improvement of root yield per hectare by applying selection pressure on plant height (cm) at harvest, leaf area (cm2) at harvest, chlorophyll content at harvest (mg g-1), root diameter (cm), fresh weight of root (g), total fresh weight of plant (g), root to shoot ratio, moisture content (%), ascorbic acid content and TSS (0 Brix) content as these traits had significant and positive correlation with root yield per hectare (tons). Also, path analysis revealed maximum positive direct effect on root yield (t/ha) is through leaf area (cm2) at harvest, fresh weight of root (g) and total fresh weight of plant (g). Negative indirect correlation was obtained with days to harvesting, fresh weight of leaves (g) and crude fibre content (%). Hence, Plant breeders can use above traits for improvement of root yield of radish and to find out the suitable variety with better yield and quality.

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