PERFORMANCE OF BEET ROOT (*Beta vulgaris* L.) FOR GROWTH, YIELD AND QUALITY

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(2018 - 12 - 003)

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by

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THESIS

Submitted in partial fulfilment of the requirements for the degree of

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2020

DECLARATION

I, hereby declare that this thesis entitled **"PERFORMANCE OF BEET ROOT (*Beta vulgaris* L.) FOR GROWTH, YIELD AND QUALITY"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"PERFORMANCE OF BEET ROOT (*Beta vulgaris* L.) FOR GROWTH, YIELD AND QUALITY"** is a record of research work done independently by Ms. Arya P. J., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of Ms. Arya P. J., a candidate for the degree of **Master of Science in Horticulture** with major in Vegetable Science, agree that the thesis entitled **“PERFORMANCE OF BEET ROOT (*Beta vulgaris* L.) FOR GROWTH, YIELD AND QUALITY”** may be submitted by Ms. Arya P. J. in partial fulfilment of the requirement for the degree.

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Arya P. J.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
µg	Micro gram
^{0}B	Degree Brix
^{0}C	Degree Celsius
CD	Critical difference
cm	Centimeter
cv.	Cultivar
et al.	And others
Fig.	Figure
G	Gram
GA	Genetic advance
GCV	Genotypic coefficient of variation
H^2	Heritability
ha	Hectare
I.U.	International Unit
Kg	Kilogram
m	Meter
mg	Milligram
ml	Milliliter
PCV	Phenotypic coefficient of variation
SE	Standard error
t	Tons
T.S.S	Total soluble solid
var.	Variety
viz.	Namely
β	Beta

INTRODUCTION

1. INTRODUCTION

Beet root (*Beta vulgaris* L.), known by various names, *viz.* beet, red beet, table beet, garden beet, *etc.*, is a cool season root vegetable, belonging to the family Amaranthaceae. It is indigenous to Southern Europe (Campbell, 1979). During 8000 B.C., beet cultivation began in Mesopotamia, later in Asia minor and spread to Meditteranean region (Biancardi *et al.,* 2012). The chromosome number of cultivated beet root is 2n=2x=18. In India, beet root is mostly grown in the states of Haryana, Uttar Pradesh, Himachal Pradesh, Maharashtra and Tamil Nadu (Kale *et al*., 2018). The total area under beet root cultivation in India is about 2164 ha, production 36260 t and productivity 16.75 t ha^{-1} (Bauskar, 2015).

Beet root is a highly productive, popular root vegetable grown mainly for its fleshy, enlarged roots. Shapes are variable and may be globular, cylindrical, top like and flattened. Upper portion of root develop from hypocotyl and lower from tap root. The tap root may penetrate the soil to a depth of 3 m (Weaver and Bruner, 1927). It is a rich source of carbohydrate (9.56 g 100 g^{-1}), protein (1.61g $100g^{-1}$), dietary fibre (2.8 g $100g^{-1}$), vitamin A (33 I.U. $100g^{-1}$), vitamin C (4.9 mg $100g^{-1}$), folate (109 µg $100g^{-1}$) and minerals *viz*., potassium (325 mg $100g^{-1}$), sodium (78 mg $100g^{-1}$), phosphate (40 mg $100g^{-1}$), calcium (16 mg $100g^{-1}$), zinc (0.35 mg $100g^{-1}$) and iron (0.80 mg $100g^{-1}$) (Chawla *et al.,* 2016). The main nitrogen pigment present in beet root known as betalains comprising of red coloured β- cyanin and yellow coloured β- xanthin have antioxidant property (Kanner *et al*., 2001; Singh and Hanthan, 2014), anti-inflammatory effect (Clifford *et al*., 2015; Neha *et al*., 2018), hepatoprotective and anti-cancer properties (Georgiev*et al.*, 2010; Chhikara *et al*., 2018). The ratio of these two pigments varies with cultivation and changes during the growth and environmental conditions (Nilsson, 1973).

Beet root is eaten boiled or as salad, cooked with other vegetables and also used in pickles, chutneys and in canned food products. Green leaves are rich in iron, vitamin A, thiamine and ascorbic acid (Bhat, 2007). It does not contain significant amount of fat, hence ideal for health conscious people. It is an excellent source of folate, iron, magnesium, sodium, potassium and betanin which are important for cardiovascular health. Beets are also good for keeping cholesterol levels in body which protects the body against heart diseases. The recent interest of people in beet root cultivation has increased, primarily driven by the discovery that sources of dietary nitrate may have important implications for managing cardiovascular health (Lundberg *et al.*, 2008). In beet root, sucrose is the most abundant endogenous sugar, 10 times higher than glucose and fructose (Gujar, 2013). Beet root is generally grown during the winter season because good quality tubers, rich in sugar with intense red colour are obtained during cool weather, when temperatures vary between 18.3 ^{0}C and 21.1 ^{0}C (Nath *et al*., 1987). Beet root is having minimum cost of cultivation and gives bumper production with higher market value, but the crop remains neglected. The major reason is lack of awareness about scientific production as well as production technology under varying climatic conditions (Gaharwar *et al*., 2017).

Among cool season vegetables, cabbage and cauliflower cultivation has gained momentum in Kerala, during the period from November to February, due to the introduction of tropical varieties and hybrids. But cultivation of beet root has not become popular in Kerala. The demand for beet root in Kerala is increasing due to its nutritional and health benefits. A number of hybrids and varieties are grown in different regions of India. Hence, the present study has been undertaken with the following broad objectives:

1. To evaluate beet root varieties and hybrids for growth, yield and quality under Kerala conditions.

2. To assess the genetic variability present in beet root varieties and hybrids.

3. To study the adaptability of beet root in Kerala.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Beet root (*Beta vulgaris* L.) is a cool season root vegetable, which has nutritional, medicinal and industrial importance. Now it has become popular as a super food in the Indian daily diet, due to its nutritional values and health benefits. Beet root grows best in winter with a bit warm climate in the plains of India. Various studies on improvement in yield and quality of beet root through the use of F_1 hybrids and open pollinated varieties and improved cultural practices have been undertaken in other states in India.

A systematic evaluation of varieties and hybrids with different horticultural traits under different regions is essential to explore the possibility of popularizing beet root in the areas where it is under exploited and also helps to identify superior varieties and F_1 hybrids for commercial cultivation, especially in the plains of India. In this chapter, an effort has been made to review the available literature about the evaluation of varieties and hybrids in beet root and other root crops for growth, yield and quality attributes. The review is presented under the following sections:

2.1 MEAN PERFORMANCE

2.1.1 Vegetative Characters

Rekowska and Jurga (2009) evaluated beet root cultivars and found that the highest plant height was recorded by 'Czerwona Kula' (53.10 cm) and the lowest by 'Rocket' (44.50 cm). The mean performance of cultivars for number of leaves ranged from 9.50 ('Pablo F_1') to 15.60 ('Chobry').

Zarate *et al.* (2010) studied the effect of soil covered with chicken manure, with and without hilling, on beet root variety 'Tall Top Early Wonder' and observed that plants cultivated using manure covering with two hillings showed greater plant height of 25.22 cm and were superior than control plants.

Straus *et al.* (2012) compared the performance of beet root in different production systems *viz.*, conventional, integrated, organic and control. The results of the study revealed that the crop grown under conventional production system recorded the highest number of leaves per plant (14) and highest leaf length (36 cm), while the control plots produced the lowest (12 and 27 cm respectively).

Evaluation of soilless media under polyhouse condition in beet root variety 'Nobol' was done by Murumkar *et al*. (2012). The highest plant height of 36.17 cm was recorded by growing media composed of peat and vermicompost (1:1), while that composed of coir pith and vermicompost recorded the lowest 30.44 cm. Khogali *et al*. (2012) evaluated the performance of three fodder beet varieties, under different nitrogen rates and spacing, and found that the highest leaves per plant was recorded by 'Voroshenger' (33.34) followed by 'Polyproductiva' (32.32) and the lowest by 'Anisa' (24.74).

Genetic variability studies on twenty five genotypes of beet root were conducted by Sharma (2013) and reported that maximum numbers of leaves of 13.41 was recorded in 'BETA-2221' followed by 'TNBR-2' (13.01 cm) while minimum in 'BETA-344' (7.95). 'TNBR-1' recorded the highest leaf length and leaf breadth (25.22 cm and 9.80 cm respectively). The lowest leaf length was recorded by 'BETA-273' (12.28) and leaf width by 'BETA-33' (5.26 cm). Gujar (2013) stated that combined inoculation of *Gluconacetobacter diazotrophicus* and *Vesicular Arbuscular Mycorryza* along with nitrogen fertilizer notably improved the plant height of beet root (34.42 cm) over control (24.92 cm).

El Sherbeny and Da Silva (2013) studied the effect of foliar treatment of proline and tyrosine at different concentrations on growth and yield of beet root. The highest plant height (25.07 cm, 27.13 cm), foliage weight (47.00 g, 49.22 g) and maximum number of leaves (12.68, 13.01) was observed at proline and tyrosine, both at 100 mg L^{-1}. The control plants recorded lowest plant height (21.83 cm), foliage weight (30.66 g) and leaf number (9.77).

The effect of vermicompost and vermiwash on growth and yield of beet root was studied by Kibatu and Mamo (2014) and observed that the crop treated with the highest level of application of 7.5 t ha^{-1} of vermicompost produced the highest plant height of 40 cm, maximum number of leaves (15) and maximum shoot weight (103.4 g) while control plot recorded the minimum plant height (29 cm), number of leaves (10) and shoot weight (21.9 g).

Effect of different rates of vermicompost on growth and yield of beet root cultivar 'Crimson Globe' was studied by Mbithi *et al*. (2015) and recorded that the crop treated with the highest level of vermicompost (30 t ha^{-1}) produced maximum leaf number (14.80) and plant height also increased with an increased rate of application of vermicompost. Baliram (2015) evaluated the effect of different levels of nitrogen and phosphorus on growth parameters of beet root. The maximum plant height of 48.20 cm and 48.51 cm was recorded under an individual effect of 80 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} respectively. The interaction effect was found insignificant.

A field experiment was conducted by Bauskar (2015) to study the effect of dates of sowing and spacing on growth and yield of beetroot cv. Red Queen and observed that vegetative characters *viz.* plant height (56.63 cm), number of leaves (18.27), leaf length (31.36 cm) and leaf width (21.10 cm) were the highest in 16th October planting with wider spacing of 75 cm × 10 cm. Effect of planting date and spacing on growth and yield of beet root cultivars was studied by Patel *et al*. (2015). Beet root variety 'Detroit Dark Red' performed better compared to 'Crimson Globe' for number of leaves per plant (10.26).

Gaharwar *et al*. (2017) studied the influence of spacing on growth and productivity of beet root and observed that the highest plant height of 41.17 cm was observed for the closer spacing (30 cm x 10 cm). Maximum leaf number of 22.1 was recorded for plants with wider spacing (45 cm x 45 cm) while the closely planted plants produced the lowest number of leaves (15.29). Maximum foliage weight of 146.45 g was recorded with a plant spacing of 45 cm x 45 cm.

Productivity and qualitative characteristics of six beet root varieties was studied by Coutinho *et al.* (2018). The results revealed that the highest plant height was recorded by ‘Maravilha’ (54.25 cm) and the lowest by ‘Kestrel’ (40.41 cm). The mean performance of cultivars for number of leaves ranged from 10.31 (‘Maravilha’) to 13.51 (‘Tall Top Early Wonder’).The mean performance of radish for plant height among seven varieties ranged from 23.50 cm to 28.29 cm (Dongarwar *et al*., 2018). Poudal *et al.* (2018) reported a range of 10.33 to 16.98 in radish for number of leaves.

Wotchoko *et al*. (2019) studied the effects of basalt dust, poultry manure and NPK 20-10-10, single and combined, on the growth and yield of beetroot and noticed that the mean plant height ranged from 15.51 cm to 36.04 cm, number of leaves from 8.34 to 18.62, leaf length from 11.92 cm to 12.36 cm, and leaf breadth from 10.50 cm to 17.54 cm. Effect of plant density on production of beet root grown in sacks was studied by Mtsweni (2019) and observed that relative to the reference plant density of 5 plants per sack, there was a remarkable increase of plant height by about 1% as plant density was increased to 10 plants per sack. The number of leaves decreased with increase in planting density.

2.1.2 Root and Yield Characters

2.1.2.1 Root Shape

Pink (1993) observed variation in root shape of beet root from spherical, flattened spherical, cylindrical to conical. IPGRI (1995) classified the root shapes of *Beta spp*. into narrow elliptic, elliptic, circular, broad elliptic and narrow obtriagular based on longitudinal section of root. According to Goldman (1995), the planting density influence root shape of beet root and more cylindrical roots were observed at high density planting.

Baranski *et al.* (2001) studied the genetic diversity in garden beet group consisting of 40 accessions and reported that accessions characterized by circular root shape were most common. Evaluation of morphological parameters and bioactive compounds in different beet root varieties was done by Ruboczki *et al*. (2015) and observed cylindrical and spherical root shapes. The regular spherical shape was recorded by ‘Libero’, ‘Mona Lisa’ and ‘Rubin’, which is favoured by both the processing industry and fresh market. Yasaminshirazi *et al*. (2020) reported two types of root shapes in 15 beet root genotypes studied *viz*., spherical and cylindrical.

2.1.2.2 Root Length

Ijoyah *et al.* (2008) compared the yield performance of four beet root varieties with the local cultivar 'Detroit' and reported that the longest root of 12.76 cm was recorded by 'Crosby', 'Detroit-243' being on par with it. The lowest root length of 6.82 cm was recorded by 'Detroit' which was on par with 'Moronia'. Rekowska and Jurga (2009) evaluated ten beet root cultivars for selected quality traits and found that the highest root length was recorded by 'Rocket' (13.0 cm) and the lowest by 'Egipski' (4.0 cm). Sharma (2013) conducted genetic variability studies in 25 genotypes of beet root and observed a maximum root length of 10.46 cm in 'TNBR-1' followed by 'TNBR-4' (9.56 cm) and minimum in 'BETA-340' (5.50 cm).

The highest root length of 15.50 cm was recorded by beet root cultivated by conventional farming, which was on par with integrated farming (15.14 cm) while 13.03 cm long root was recorded under organic farming (Szopinska and Gaweda, 2013). Kibatu and Mamo (2014) studied the effect of vermicompost and vermiwash on growth and yield of beet root and observed that the highest level of vermicompost (7.5 t ha^{-1}) produced the longest root of 21.3 cm, while control, the lowest (12.0 cm).

A study on the effect of date of sowing, nitrogen and phosphorus on growth yield and quality of beet root was conducted by Baliram (2015). The highest root length of 17.02 cm and 16.97 cm were recorded from the individual application of 120 kg P_20_5 ha^{-1} and 70 kg N ha^{-1} respectively. Effect of planting date and spacing on growth, yield and quality of two beet root cultivars were studied by Patel *et al.* (2015). The experiment revealed that maximum root length of 6.86 cm and 6.50 cm was obtained at a wider spacing of 30 cm x 30 cm and 15th November planting respectively. Among cultivars, 'Detroit Dark Red' produced the longest root of 6.39 cm compared to 'Crimson Globe'.

Kadam *et al*. (2018) studied the effect of different spacing and fertilizer levels on yield and economics of beetroot. The highest root length of 15.61 cm was observed in the closer spacing of 30 cm × 15 cm and 16.57 cm long root with the maximum recommended dose of fertiliser. Coutinho *et al.* (2018) observed considerable differences among beet root cultivars for root length, which ranged from 60.28 mm ('Maravilha') to 71.63 mm ('Merlot').

2.1.2.3 Root Diameter

According to Goldman (1995), beet root with more than 5 cm diameter was more at low density planting compared to high density planting. Baranski *et al*. (2001) defined market roots in garden beet as those roots with 4 to 8 cm diameter. Ijoyah *et al*. (2008) compared the root width of five different beetroot genotypes and reported that the highest root diameter of 7.55 cm was recorded by 'Crosby' which was on par with 'Detroit-243' (6.54 cm). The lowest root width of 4.02 cm was recorded by 'Moronia'. Rekowska and Jurga (2009) evaluated ten cultivars of beet root and reported a range from 4.80 cm ('Rocket') to 8.70 cm ('Egipski') for root diameter.

In fodder beet, root diameters of 15.63 cm and 15.36 cm respectively were recorded for 150 and 200 kg ha^{-1} nitrogen treatments by Albayrak and Yuksel (2010). Ahmad *et al.* (2012) evaluated eleven exotic sugar beet varieties and noticed maximum root diameter (10.05 cm) in 'SAD-12970' followed by 'MiraBella' (9.95 cm) and minimum in 'Ernestina' (8.65 cm).

Sharma (2013) conducted a study on genetic evaluation of 25 beet root genotypes, the maximum root diameter (76.13 mm) being noticed in TNBR-1 followed by 'Detroit Dark Red' (63.19 mm) and Crimson Globe (60.26 mm). The genotype BETA-344 recorded the minimum root diameter of 39.87 mm. The highest root diameter of 5.89 cm was recorded by Szopinska and Gaweda (2013) in beet root cultivated by conventional farming compared to 5.62 cm and 5.29 cm in integrated and organic farming respectively.

According to Kibatu and Mamo (2014) the highest level of vermicompost (7.5 t ha^{-1}) produced the highest root diameter of 91.7 mm, while control the lowest (50.0 mm). Baliram (2015) noticed that different levels of nitrogen and phosphorus had a significant effect on the diameter of root. The maximum root diameter of 7.67 cm and 7.56 cm was recorded from the individual application of 120 kg P_2O_5 ha^{-1} and 70 kg N ha^{-1} respectively.

Gaharwar *et al*. (2017) proposed a scale based on root diameter and reported that beet root with marketable size diameter (4.05 cm to 6.25 cm) was obtained in 30 cm x 10 cm and 45 cm x 10 cm spacing, and that root diameter increased with an increase in spacing. Yasaminshirazi *et al*. (2020) reported that roots with diameter of 5 cm to 13 cm are considered for determining marketable yield of beet root.

2.1.2.4 Root Weight

Goldman (1995) studied the effect of planting density on root weight and recorded an increase of more than 15% at low density compared to medium density, no significant difference being observed between medium and high density for root weight.

Yield performance of four beet root varieties were compared with the local variety Detroit by Ijoyah *et al.* (2008) and reported that 'Crosby' recorded maximum root weight (130.45 g) followed by 'Detroit-243' (120.20 g). The lowest root weight was recorded by 'Moronia' (100.20 g). Straus *et al.* (2012) compared the performance of beet root in different production systems. The highest root weight of 385 g was recorded in conventional farming system, which was on par with integrated (381 g), while the lowest root weight of 174 g was recorded from control.

Genetic evaluation of 25 beet root genotypes was conducted by Sharma (2013) and found that the accessions differed significantly for root weight. 'TNBR-1' recorded the highest root weight of 336.49 g, followed by 'TNBR-5' (271.10 g). 'TNBR-8' recorded the lowest root weight of 144.90 g. Szopinska and Gaweda (2013) compared the yield and quality of beet root cv. 'Regulski Cylinder' cultivated by conventional, integrated and organic method. The study revealed that the highest root weight of 202.38g was recorded by conventional method, followed by 198.52 g and 149.39 g by integrated and organic farming respectively.

Baliram (2015) found that significantly high root weight of 219.22 g and 209.67 g was recorded from the individual application of 70 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} respectively, while the interaction effect was insignificant. Effect of different dates of sowing and spacing on growth and yield of beet root cv. Red queen was studied by Bauskar (2015), and recorded a maximum root weight of 310.33 g in the treatment 16th October with 45 cm × 10 cm plant spacing. Patel *et al*. (2015) studied the influence of planting date, spacing and cultivar on beet root yield. Maximum weight of beet root per plant was observed at 30th October planting and 30 cm x 30 cm spacing. Among cultivars, the highest root weight of 131.43 g was recorded by Crimson Globe. Yasaminshirazi *et al*. (2020) reported that beet root weight among genotypes varied between 214.71 g and 283.33 g.

2.1.2.5 Root: Shoot Ratio (Weight Basis)

Mean values for root: top ratio of different beet root genotypes ranged from 3.07 to 4.96 (Sharma, 2013). The highest root: shoot ratio was recorded by the genotype TNBR-4 (4.96) and the lowest by TNBR-8 (3.07). Basavaraj (2016) recorded a range of 0.89 to 2.14 for root: shoot ratio among carrot genotypes.

2.1.2.6 Root Yield

Benjamin *et al*. (1985) reported that yield per unit area of beet root decreased with increasing plant density. The yield per unit area of small beet root was high at high density planting, whereas maximum yield of large beet root was high at low density planting. Among five beet root cultivars examined for yield performance, maximum yield of 48.65 t ha^{-1} was noticed in the variety Crosby by Ijoyah *et al.* (2008).

Sharma (2013) observed that maximum root yield of 30.29 kg plot^{-1} was recorded by ‘TNBR-1’, which was 27.7 and 44.11 percent more over check cultivars ‘Crimson

Globe' and 'Detroit Dark Red' respectively. Szopinska and Gaweda (2013) compared the yield and quality of red beet roots cultivated using conventional, integrated and organic methods. The total and marketable yields of organically produced red beets were higher (28.80 and 24.85 kg ha^{-1} respectively) than those produced by integrated and conventional methods.

Kumar *et al*. (2014) conducted a study on the effect of microbial inoculants on the yield of beet root and observed that the highest yield of 8.53 kg $plot^{-1}$ was recorded in crop treated with 75 per cent N, P and a full dose of K with *Azotobacter chroccum, Gluconobacter diazotrophicus, Bacillus megaterium and Trichoderma harzianum,* while the lowest yield of 1.90 kg $plot^{-1}$ was recorded in the control.

Magro *et al*. (2015) studied the effect of organic compost and potassium top dressing fertilization on production and quality of beetroot and revealed that application of compost at 49 t ha^{-1} resulted in maximum root yield of 43 t ha^{-1}. Effect of different dates of sowing and spacing on growth and yield of beet root cv. Red queen was studied by Bauskar (2015). The study revealed that sowing on 16^{th} October with 45 cm x 10 cm spacing recorded the highest yield of 39.35 kg per plot. Baliram (2015) found that the effect of nitrogen and phosphorus on yield per plot was significant and that maximum yield per plot of 8.73 kg and 8.66 kg was recorded from the individual application of 70 kg N ha^{-1} and 120 kg P_20_5 ha^{-1} respectively. Effect of planting dates and spacing on yield and quality parameters of two beet root cultivars 'Crimson Globe' and 'Detroit Dark Red' was studied by Patel *et al.* (2015). The results revealed that 'Crimson Globe' recorded the highest root yield of 286.16 q ha^{-1}.

Growth and productivity of beet root as affected by different spacing was studied by Gaharwar *et al*. (2017) and noticed that higher marketable yield (29.30 t ha^{-1}) was obtained when plants were closely planted at 30 cm x 10 cm followed by 30 cm x 20 cm (27.83 t ha^{-1}) . Closer plant spacing gave significantly higher marketable quality beet root yield with the highest net monetary returns. Spacing at the highest level (30 cm × 25cm) with the lowest level of urea (45 g plot^{-1}) was found to be optimum for maximizing root yield (Tamiru *et al.*, 2017).

Kadam *et al*. (2018) evaluated the effect of different spacing and fertilizer levels on yield and economics of beet root. The maximum yield of 8.5 kg plot^{-1} was obtained with the spacing 15 cm × 15 cm and 150 % RDF while the minimum yield per plot of 6.20 kg was obtained under the spacing of 30 cm × 15 cm and 100% RDF.

2.1.3 QUALITY CHARACTERS

2.1.3.1 T.S.S

Effect of sowing date, nitrogen supply and cultivar on yield and quality of beet root was studied by Feller and Fink (2004) and reported that total soluble solid content of beet root ranged from 10.1 ^{0}Brix to 14.3 ^{0}Brix.

Variation in T.S.S content among seven beetroot cultivars was recorded by Pokluda (2013) and observed that T.S.S content ranged from 6.8 ^{0}Brix to 9 ^{0}Brix and that the cultivar 'Betina' recorded the highest T.S.S content. The mean T.S.S content of twenty five genotypes of beet root ranged from 15.81 ^{0}Brix (TNBR-6) to 19.92 ^{0}Brix (TNBR-8) (Sharma, 2013).

Effect of water stress on quality of beet root was studied by Stagnari *et al*. (2014) and reported that T.S.S content ranged from 13.87 ^{0}Brix in 100% water holding capacity to 11.67 ^{0}Brix in 50% and 7.90 ^{0}Brix in 30% water holding capacity.

Baliram (2015) observed the highest T.S.S content of 11.41 % and 11.08 % due to individual application of 120 kg P_2O_5 ha^{-1} and 70 kg N ha^{-1} respectively. Patel *et al.* (2015) found that the T.S.S content of beet root was maximum (12.74 ^{0}Brix) at wider spacing *i.e.* 30 cm x 30 cm. Gaharwar *et al*. (2017) observed that T.S.S content varies with harvesting time and soil moisture while plant spacing had no effect on T.S.S content in table beet root.

2.1.3.2 Carotenoid content

Pokluda (2013) reported that the total carotenoid content in beetroot was 1.3 mg Kg^{-1}. Studies on genetic evaluation of beet root was carried out in twenty five diverse genotypes by Sharma (2013). The carotenoid content ranged from 19.38 µg 100 g^{-1} (‘BETA-340’) to 20.63 µg 100 g^{-1} (‘TNBR-9’). El Beltagi *et al*. (2018) recorded carotenoid content of 1.7 mg 100 g^{-1} in beetroot.

2.1.3.3 Total sugars

Szopinska and Gaweda (2013) reported that soluble sugar content of red beet root produced under organic, integrated and conventional cultivation methods do not differ significantly. Effect of water stress on quality traits of red beet was studied by Stagnari *et al.* (2014) and recorded the highest total sugar content of 27.3 % at 100 % water holding capacity (WHC), followed by 21.3% (50 % WHC) and 14.3% (30 % WHC).

Baliram (2015) recorded the highest total sugar content of 6.72% and 6.67% and reducing sugar content of 0.66% and 0.62% on individual application of 120 kg P_2O_5 ha^{-1} and 70 kg N ha^{-1} respectively. The mean total sugar content of beet root ranged from 18.15 % - 20.94 %, reducing sugars 3.94 % - 8.97 % and non reducing sugars 11.91 % - 14.06%. Kale *et al*. (2018) conducted studies on the physical and chemical composition of beetroot. The study revealed that the mean value of total sugars in beet root was 7.93% and reducing sugars 4.20%. Jagosz (2018) reported that the beet root cultivar ‘Monorubra’ recorded the highest total sugar content of 11.31% and ‘W411 B’ the lowest (6.15%).

Quality characters of 11 beet root varieties before and after storage was studied by Viskelis *et al.* (2019). The total sugar content of beet root before storage ranged from 8.99 % (‘Bona’) to 10.53 % (‘Kestral H’) and after storage from 9.07 % (‘Bona’) to 10.57 % (‘Kestral H’).

2.2 COEFFICIENT OF VARIATION

Srivastava e*t al.* (2000) evaluated nine quantitative traits of 34 accessions of *Beta vulgaris* ssp. *maritima* under subtropical climate of North India. Multivariate analysis suggested variation within and among groups of accessions and the principal component which accounted for 44% of the variability was found to be associated with root weight, root length and crown diameter. The second principal component was associated with top weight, which accounted for 20 % variability.

Baranski *et al*. (2001) studied the diversity in a collection of garden beet group, consisting of 40 accessions. The study revealed that nitrate content (46.3%), leaf yield (34.32%), vulgaxanthine (31.9%), total root yield (28.3%), betanin (27.7%) and market root yield (25.6 %) recorded the highest coefficient of variation. Genetic variability among fifteen carrot genotypes were evaluated by Yadav *et al.* (2009) and observed that PCV and GCV varied from 3.71 % to 22.28% and 2.46 % to 15.75% respectively.

Genetic variability studies in 20 genotypes of carrot was conducted by Jain *et al*. (2010) and reported highest GCV (30.19 %) and PCV (32.52 %) for root weight. Amin and Singla (2010) reported high PCV and GCV for marketable yield (39.91, 37.21), total yield (34.35, 33.06) and root weight (23.19, 21.72) in carrot. Genetic variability studies in 21 varieties of radish was conducted by Ullah *et al.* (2010) and observed high GCV (23.35%) and PCV (24.64%) for root yield.

Kumar *et al*. (2012) assessed variability in temperate radishes and observed high GCV and PCV for leaf length, leaf width, root: top ratio (weight basis and length basis), root length, average root weight, fibre content, total sugar, ascorbic acid content and T.S.S. The variability of 14 characters among 10 genotypes of radish was studied by Sivathanu *et al*. (2014) during rabi, summer and kharif seasons. The study revealed that in all the three seasons, GCV was higher for numbers of leaves, dry weight of the plant, root diameter and fresh weight of root per plant.

Santhi *et al*. (2015) reported that in carrot, the highest estimates of GCV and PCV was observed for root splitting (45.44 %,79.34 %) followed by total chlorophyll (42.38 %, 42.74 %), root carotenoid (35.88 %, 35.90 %), leaf carotenoid (25.54 %, 25.55 %) and root forking percentage (26.93 %, 36.17 %) during Kharif season.

Dhillon *et al*. (2016) recorded the genetic variability for six quality characters in 38 genotypes of carrot. The phenotypic coefficient of variation (PCV) was recorded highest for carotene (33.26). Nagar *et al*. (2016) evaluated genetic variability of twenty one genotypes of radish and reported that genotypic coefficients of variation were moderate for root weight without leaves, leaf weight, root weight with leaves, root diameter and root length.

Meghashree *et al*. (2018) evaluated twenty five genotypes of carrot and observed that root weight, root: top ratio (length basis), total yield plot^{-1}, total yield ha^{-1}, cortex thickness, T.S.S, β-carotene content, ascorbic acid content, total phenol, protein, root forking and root splitting showed high GCV and PCV.

2.3 HERITABILITY AND GENETIC ADVANCE

Sklenar *et al.* (1998) recorded high estimates of heritability for root length (70 %) and the lowest for root weight (39 %) in sugar beet. Kaur *et al*. (2005) studied heritability and genetic advance in thirty eight genotypes of carrot and observed that carotene content exhibited the highest heritability (99.77 %) followed by total sugars (99.52 %), dry matter (96.20%), juice yield (89.11 %) and T.S.S. (87.51 %).

Yadav *et al*. (2009) reported high heritability for germination per cent, number of leaves, shoot weight, root weight, T.S.S, beta carotene and yield in carrot, while root: shoot ratio recorded moderate heritability. Jain *et al*. (2010) assessed heritability and genetic advance of 20 genotypes of carrot and revealed high heritability combined with high genetic advance for leaf area, foliage weight, root weight, root length, root diameter, flesh thickness of root, core diameter, total plant weight, chlorophyll content of leaves, leaves: root ratio and root yield per hectare.

Genetic variability, heritability and genetic advance studies in carrot was conducted by Amin and Singla (2010). The highest heritability was observed for plant weight (96.30 %) followed by total yield (92.60 %), root weight (87.70 %) and juice yield (87.70 %). High genetic advance was observed for marketable yield (71.43), total yield (65.58) and plant weight (45.71). Ullah *et al.* (2010) observed high heritability coupled with high genetic advance for root yield, root length, leaf length and leaf width in radish.

Kumar *et al*. (2012) studied genetic variability, heritability and genetic advance in temperate radish genotypes and recorded high heritability estimates for leaf length, leaf width, root: top ratio (weight basis and length basis), root length, root diameter, crown diameter, average root weight, dry matter, fibre content, total sugar, ascorbic acid content and T.S.S.

Sharma (2013) assessed heritability and genetic advance in beet root and reported high heritability coupled with high genetic advance for number of leaves per plant, leaf length, leaf width, root diameter, root length, average root weight, net root weight, root: top ratio (length basis and weight basis), flesh thickness, reducing sugars and yield per plot.

Sivathanu *et al*. (2014) studied heritability and genetic advance of ten genotypes of radish for 14 characters during rabi, summer and kharif seasons. High genetic variability in combination with high heritability and genetic advance in all seasons was exhibited by number of leaves, root diameter, dry weight of plant and fresh weight of plant and root.

Mallikarjunarao *et al*. (2015) reported high heritability associated with high genetic advance as per cent of mean for root weight, total dry matter of root, leaf weight, vitamin C, shoot to root ratio, leaf length, root length, leaf width and leaf number of radish. Total soluble solid had high heritability coupled with moderate genetic advance as per cent of mean. Santhi *et al*. (2015) evaluated sixteen varieties and six hybrids of carrot and observed high heritability for leaf carotene content, root carotene content, root weight, inner core diameter, plant height, leaf width, total chlorophyll, number of leaves and root diameter.

Thirty eight genotypes of carrot were tested to determine the variation in quality characters by Dhillon *et al*. (2016). High heritability was observed for carotene content (98.11%), sugar content (89.62 %), juice content (89.35 %), T.S.S (71.01 %) and dry matter (64.07 %). High genetic advance as percentage of mean was observed for carotene content (67.87 %). Nagar *et al*. (2016) assessed genetic variability, heritability and genetic advance in 21 genotypes of radish and reported that high heritability coupled with moderate genetic gain was observed for root length, root weight with leaves, root weight without leaves, leaf weight and root diameter.

A study was conducted by Meghashree *et al*. (2018) to assess the genetic variability in carrot genotypes in kharif season. The study revealed that the traits like plant height at 60 DAS, plant height at harvest, root weight, core diameter, root: top ratio (length basis), total yield per plot, total yield per ha, core thickness, cortex thickness, T.S.S, β-carotene content, total sugars, ascorbic acid, total phenol, protein, root forking and root splitting recorded high genetic advance as per cent of mean associated with high heritability estimates.

2.4 CORRELATION ANALYSIS AND PATH ANALYSIS

Genotypic and phenotypic correlations for some beet root characteristics was studied by Sklenar *et al*. (1998) and reported that taproot weight was positively and significantly correlated with crown width, crown weight and taproot volume. Correlation and path analysis studies in radish was conducted by Panwar *et al*. (2003) and revealed that shoot height, root length, root diameter, number of leaves, fresh weight of shoot and root, dry biomass per plant, leaf area index and total nitrogen uptake was significantly and positively correlated with root yield per plant.

Yadav *et al.* (2009) conducted correlation studies in fifteen genotypes of carrot and reported that number of leaves, root length, root: shoot ratio and root weight exhibited significant positive correlation with yield. Germination per cent, number of leaves, shoot length, root length, root: shoot ratio, T.S.S, beta carotene and root weight exerted direct positive effect on root yield.

Ullah *et al*. (2010) conducted correlation and path analysis for yield and its contributing traits in 21 varieties of radish. The study revealed that root yield had significant and positive correlation with plant height, days to harvest, root length, root diameter and leaf width. 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. Ahmad *et al.* (2012) evaluated eleven exotic sugar beet genotypes and reported that germination, leaf weight, number of beets and sugar yield had a significant and positive correlation with root yield.

Sharma (2013) studied correlation and path analysis in 25 genotypes of beet root. Yield per plot was significantly and positively correlated with average root weight (0.998), net root weight (0.979), flesh thickness (0.971), root diameter (0.949), dry matter recovery (0.927), reducing sugars (0.909), total sugars (0.860), root length (0.866), leaf width (0.782), leaf length (0.771) and carotenoid content (0.431). The average root weight had a maximum positive direct effect on yield per plot followed by root diameter, root length, root width, net root weight, root: top ratio both on weight and length basis, non reducing sugars, number of leaves, total sugars and carotenoid content.

Sivathanu *et al*. (2014) evaluated ten genotypes of radish for fourteen characters during rabi, summer and kharif. The outcome of the experiment revealed that root length, root diameter and dry weight of root per plant exhibited a direct and positive correlation with root yield in all seasons.

Basavaraj (2016) evaluated fifteen genotypes of carrot and reported that yield per plot had highly significant and positive genotypic correlation with root weight (0.959), foliage weight (0.886), leaf width (0.809), number of leaves per plant (0.739), core size (0.711), leaf length (0.630) and root diameter (0.591). Yield per plot showed significant and negative correlation with root: shoot ratio (-0.380). The highest positive direct genotypic effect on yield was exhibited by foliage weight (4.91), followed by root weight (0.699), leaf width (0.303), core size (0.061) and number of leaves (0.012).

Nagar *et al*. (2016) conducted a study on genetic variability, correlation and path analysis in radish. The outcome of the experiment revealed that yield plot^{-1} had a positive and significant association with root weight with leaves, root weight without leaves, root length, number of leaves and plant height while leaf length and root diameter had significant and negative correlations. Path coefficient analysis revealed that the maximum positive direct effect towards root yield plot^{-1} was contributed by root weight without leaves, length of whole plant, root weight with leaves and number of leaves.

Naseeruddin *et al*. (2018) studied correlation coefficient and path coefficient analysis of twenty genotypes of radish. The experimental results revealed that root yield per plant was positively and significantly correlated with plant height at 40, 50 and 60 days after sowing, number of leaves at 40, 50, 60 and 70 days after sowing, total plant weight and leaf weight after harvesting. Number of leaves at 70 days after sowing, plant height at 70 days after sowing and plant height at 60 days after sowing had high direct effect on yield plant^{-1} in path analysis.

Correlation analysis among growth and yield characters in beet root was conducted by Wotchoko *et al*. (2019) and reported that root weight was significantly and positively correlated with total plant biomass, plant height and number of leaves.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Performance of beet root (*Beta vulgaris* L.) for growth, yield and quality" was carried out at the Department of Vegetable Science, College of Agriculture, Vellayani, during the period October 2019 to February 2020. The study aimed to evaluate beet root in Kerala for growth, yield and quality and thereby its adaptability.

3.1 EXPERIMENTAL SITE, SOIL AND CLIMATE

The experimental site was located at about 8.5^0 North latitude and 76.9^0 East longitude, with an average altitude of 29.00 m above mean sea level. The principal soil type of experimental site was red loam belonging to the Vellayani series, texturally classified as sandy clay loam. The area enjoys a warm humid tropical climate. Weather data for the cropping period is given in Appendix I.

3.2 MATERIALS

Thirty genotypes of beet root consisting of 22 varieties and 8 hybrids were collected from public and private sectors. The details of the beet root varieties and the hybrids used for the experiment are given in Table 1 and Table 2 respectively.

3.3 METHODS

3.3.1 Design and Layout

Seeds of 22 varieties and 8 hybrids of beet root were sown under open field conditions. Preparation of field and formation of raised beds is shown in Plate 1.

The experiment was laid out as follows:

Design : RBD

Treatments : 30 genotypes (22 varieties and 8 hybrids)

Replications : 3

Spacing : 45 cm x 20 cm

Plot size : 4.5 m^2

Plants/ plot : 50

Season : October 2019 – February 2020

Table1. Details of beet root varieties

Treatment number	**Accession number**	**Name of variety**	**Source**
T1	BV 1	Madhur	Namdhari Seeds, Bengaluru
T2	BV 2	Detroit Dark Red	IARI, New Delhi
T3	BV 3	Crimson Globe	IARI, New Delhi
T4	BV 4	Ruby Queen (Nisco)	NISCO, Bengaluru
T5	BV 5	Tetra	Clause, Bengaluru
T6	BV 6	Ruby Queen (Tokita)	Tokita Seeds, Tamil Nadu
T7	BV 7	Mahyco lal II	Mahyco, Maharashtra
T8	BV 8	Royal	Bengaluru
T9	BV 9	K 5340	Kalash Seeds, Jalna, Maharashtra
T10	BV 10	K 5343	Kalash Seeds, Jalna, Maharashtra
T11	BV 11	Red Ruby	Doctors Seeds, Bengaluru
T12	BV 12	Red Star (Condor)	Condor Seeds, Bengaluru
T13	BV 13	K5341	Kalash Seeds, Jalna, Maharashtra
T14	BV 14	Ruby Queen (Suvarna)	Suvarna, Bengaluru
T15	BV 15	Lallan	NISCO Seeds, Bengaluru

Table 1. continued

T16	BV 16	Rachna	Shine Seeds, Bangaluru
T17	BV 17	Ruby Queen (Sulthan)	Sulthan, Bengaluru
T18	BV 18	Indam Ruby Queen	IAHS, Bengaluru
T19	BV 19	Pure Seeds	Pure Seeds, Karnataka
T20	BV 20	BV 20	Jaiva Samrthi Kudumbasree Unit, Thodiyoor, Karunagapally
T21	BV 21	BV 21	Jaiva Samrthi Kudumbasree Unit, Thodiyoor, Karunagapally
T22	BV 22	Ruby Queen (Pradham Seeds)	Pradham Seeds, Karnataka

Table 2. Details of beet root hybrids

Treatment number	**Accession number**	**Name of hybrid**	**Source**
H1	BV 23	F_1 Kingdom	Sakura, Bengaluru
H2	BV 24	F_1 Kestral	Sakura, Bengaluru
H3	BV 25	Red Star (Sakura)	Sakura, Bengaluru
H4	BV 26	Red Horse	R K Seeds, New Delhi
H5	BV 27	RK777	R K Seeds, New Delhi
H6	BV 28	Remo	Ashoka Seeds, Bengaluru
H7	BV 29	Red Bull	Sakura, Bengaluru
H8	BV 30	Ragini	Netra Seeds, Bengaluru

3.3.2 Cultivation

Seeds were sown in protrays filled with growing media composed of coir pith and vermicompost in the ratio 1:1. Twenty one days old seedlings were transplanted into the main field at 45 cm x 20 cm spacing (Plates 2 and 3). The crop was raised according to the package of practices recommendations (KAU, 2016). General view of the experimental field is shown in Plate 4.

3.4 OBSERVATIONS

The observations were recorded from five randomly selected plants from each plot in each replication for the following characters.

3.4.1 Vegetative Characters

3.4.1.1 Plant Height (cm)

The plant height was measured from the ground level to the apex of the longest leaf with the help of a meter scale at harvest and expressed in centimeters.

3.4.1.2 Leaves per Plant

Number of leaves per plant was counted at harvest and recorded.

3.4.1.3 Leaf Length (cm)

Leaf length was measured from the base of petiole to the tip of the leaf and expressed in centimeters.

3.4.1.4 Leaf Breadth (cm)

Leaf breadth was measured at the widest portion of the same leaf used to measure leaf length and expressed in centimeters.

3.4.1.5 Foliage Weight at Harvest

Foliage weight was recorded by using weighing balance at harvest and expressed in grams.

Plate 1. Land preparation and formation of raised beds

Plate 2. Seedlings in protrays

Plate 3. Planting of seedlings

Plate 4. General view of experimental field

3.4.2 Root and yield characters

3.4.2.1 Root Shape

Root shape was recorded as narrow elliptic, elliptic, circular, broad elliptic or narrow obtriangular (IPGRI, 1995).

3.4.2.2 Root Length (cm)

Root length was measured using a scale from the crown to the tip of the root and expressed in centimeters.

3.4.2.3 Root Diameter (cm)

Root diameter (at center) was measured by using scale and expressed in centimeters.

3.4.2.4 Root Weight (g)

Root weight was recorded by using a weighing balance and expressed in grams.

3.4.2.5 Root: Shoot Ratio (Weight Basis)

Root to shoot ratio on weight basis was calculated by using the following formula.

$$\text{Root: shoot ratio} = \frac{\text{Root weight}}{\text{Foliage weight}}$$

3.4.2.6 Yield per Plot (kg)

All the beet roots in a plot were harvested and root weight was recorded in kilograms.

3.4.2.7 Crop Duration (days)

The number of days taken from sowing to harvest was recorded.

3.4.3 Quality Characters

3.4.3.1 Total Soluble Solids (^{0}B)

Fresh sample was crushed with pestle and mortar to extract the juice and total soluble solid content was recorded by placing a small quantity of juice on the prism of Erma Hand Refractometer (range 0-32 ^{0}B). The result was expressed as degree Brix (^{0}B) (Ranganna, 1986).

3.4.3.2 Carotenoid Content (mg 100 g^{-1})

The carotenoid content was estimated by petroleum ether- acetone extraction method (Ranganna, 1997). 1 g of fresh sample was taken and ground in 10 ml acetone with the help of pestle and mortar. Repeat the process till the entire colour of the sample was extracted. The extract was transferred into a separating funnel and 5 per cent sodium sulphate was added. 10-20 ml of petroleum ether was added and the separating funnel was thoroughly shaken before allowing it to stand. The lower layer was discarded and the coloured upper layer was collected in a 100 ml volumetric flask. The volume was made upto 100 ml with petroleum ether. The optical density (OD) of this extract was taken at 452 nm by using petroleum ether as blank in a spectrophotometer. The carotenoid content was calculated using the formula.

$$\text{Carotenoids (mg/100 g)} = \frac{\text{Optical density at 452 nm} \times \text{ final volume}}{\text{Weight of sample}} \text{ x } 1000$$

3.4.3.3 Reducing Sugars (%)

25 g sample was ground using mortar and pestle and 100 ml water was added to it. The solution was neutralized with 1 N NaOH using phenolphthalein as an indicator. 2 ml of 45 per cent lead acetate was added to it and kept for 10 min. Excess of lead acetate was removed from the sample by adding 2 ml of 22 per cent potassium oxalate into the volumetric flask. The volume was made upto 250 ml and the solution was filtered. The clear filtrate was taken to estimate reducing sugars by titrating against 10 ml of Fehling’s

mixture and methylene blue as an indicator to a brick red precipitate as the end point (Lane and Eyon, 1923).

Reducing sugars were estimated as per cent and calculated as shown below:

$$\text{Reducing sugars (\%)} = \frac{0.05 \text{ x Dilution}}{\text{Titre value x Weight of sample}} \text{ x } 100$$

3.4.3.4 Total Sugars (%)

Total sugar content was estimated by adding 5 g of citric acid to 25 ml clarified sample solution and heating it for 10 min, for complete inversion of sugars, followed by neutralizing with NaOH (40%) using phenolphthalein as an indicator. The volume was made upto 250 ml and the filtrate was titrated against 10 ml Fehling's mixture and Methylene blue used as an indicator to brick red precipitate as the endpoint. The result was expressed as per cent total sugar content and calculated using the formula:

$$\text{Total sugars (\%)} = \frac{0.05}{\text{Titre value}} \text{ x} \frac{250}{25} \text{ x} \frac{250}{25} \text{ x } 100$$

3.4.3.5 Non Reducing Sugars (%)

The non-reducing sugars was calculated by taking the difference between total sugars and reducing sugars.

Non reducing sugars (%) = Total sugars (%) - Reducing sugars (%)

3.4.4 Pest and Disease Incidence

The crop was monitored for the incidence of major pests and diseases and corrective measures were taken.

3.4.5 Sensory Evaluation

Organoleptic evaluation of beet root was done using a score card method by a panel of ten judges. The test was carried out for raw beet roots immediately after harvest.

The sensory parameters namely appearance, colour, taste and overall acceptability were assessed, in which ten score was given for excellent, nine for best, eight for better, seven for good, six for average and less than five for poor for each of the characters (Baliram, 2015). The score used for the evaluation of beet root varieties and hybrids are given in Appendix II and III respectively. The score was statistically analyzed using Kruskal-Wallis test (Chi square value) and ranked.

3.5 STATISTICAL ANALYSIS

Statistical analysis was carried out for varieties and hybrids individually using MS-Excel, WASP 2.0, OPSTAT and WINDOSTAT. For estimation of different statistical parameters, following procedure and formulae were adopted:

3.5.1 Analysis of Variance

The mean values observed for vegetative, root and yield characters of fifteen plants were recorded and tabulated. The observations recorded were subjected to ANOVA (Panse and Sukhatme, 1985) for comparison among various treatments and to estimate variance components.

ANOVA for each character

Sources of variation	Degrees of freedom	Mean sum of squares	F ratio
Replication	r-1	MSR	MSR/MSE
Treatment	t-1	MST	MST/MSE
Error	(r-1) (t-1)	MSE	
Total	rt-1		

Where,

r = number of replications

t = number of treatments

MSR= mean sum of replication

MST= mean sum of treatments

MSE= mean sum of error

$$\text{Critical difference (CD)} = t\alpha \sqrt{\frac{2MSE}{r}}$$

Where, t = Student's 't' table value at error degrees of freedom at α level of significance.

3.5.2 Estimation of Genetic Parameters

3.5.2.1 Genetic component of variance

The phenotypic and genotypic variances were calculated by utilizing the respective mean square values (Johnson *et al*., 1955).

i) Genotypic variance (VG)

$$VG = \frac{MST - MSE}{r}$$

ii) Environmental variance (VE)

$$VE = MSE$$

iii) Phenotypic variance (VP)

$$VP = VG + VE$$

3.5.2.2 Coefficient of variation

The genotypic and phenotypic coefficients of variation were calculated as per Burton (1952).

i) Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{V_P}}{\bar{X}} \times 100$$

ii) Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{V_G}}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = General mean of characters

Categorization of the range of variation was followed as proposed by Sivasubramanyan and Menon (1973).

Low : Less than 10 per cent

Moderate : 10 to 20 per cent

High : More than 20 per cent

3.5.2.3 Heritability

Heritability in the broad sense refers to the proportion of genotypic variance to the total observed variance in the total population. Heritability in broad sense was estimated for various characters and expressed in percentage (Allard, 1960).

$$\text{Heritability } (H^2) = \frac{V_G}{V_P} \times 100$$

As suggested by Johnson *et al*. (1955) heritability in broad sense estimates were categorized as,

Low : Less than 30 per cent

Moderate : 30 to 60 per cent

High : More than 60 per cent

3.5.2.4 Genetic Advance

Genetic advance refers to the expected genetic gain or improvement in the next generation by selecting superior individuals under a certain amount of selection pressure. It depends upon standardized selection differential, heritability and phenotypic standard deviation (Allard, 1960). The genetic advance was calculated in per cent by the formulae suggested by Johnson *et al*. (1955).

$$\text{Genetic advance (GA)} = k \times H^2 \sqrt{V_P}$$

$$\text{GA as percentage of mean} = \frac{GA}{\bar{X}} \times 100$$

Where,

k = standardized selection differential (2.06 at 5% selection intensity)

H^2 = heritability

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et al*. (1955).

Low : Less than 10 per cent

Moderate : 10 to 20 per cent

High : More than 20 per cent

3.5.2.5 Correlation Analysis

Phenotypic and genotypic correlation coefficients were calculated using the respective variance and covariance of the characters which showed significant variation in ANOVA.

$$\text{Phenotypic correlation coefficient, } (r_{PX,Y}) = \frac{Cov_P\,(X, Y)}{\sqrt{(V_P(X), V_P(Y))}}$$

$$\text{Genotypic correlation coefficient, } (r_{GX,Y}) = \frac{Cov_G\,(X, Y)}{\sqrt{(V_G\,(X), V_G(Y))}}$$

Where,

Cov_P (X, Y) = phenotypic variance between two traits X and Y

Cov_G (X, Y) = genotypic variance between two traits X and Y

V_P (X) and V_P (Y) = phenotypic variance for X and Y respectively

V_G(X) and V_G(Y) = genotypic variance for X and Y respectively

3.5.2.6 Path Coefficient Analysis

To study the cause and effect relationship of yield and its component characters, direct and indirect effects were analyzed using path coefficient analysis as suggested by Dewey and Lu (1959).

3.5.3 Selection Index

The selection index developed by Smith (1937) using the discriminant function of Fisher (1936) was used to discriminate the genotypes based on selected characters.

The selection index is described by the function, $I = b_1\, x_1 + b_2\, x_2 + \ldots\ldots. + b_k$ xk and the merit of a plant is described by the function, $H = a_1\, G_1 + a_2\, G_2 + \ldots\ldots + b_k$

G_k where x1, x2…….xk are the phenotypic values and G_1, G_2…..G_k are the genotypic values of the plants for the characters, x_1, x_2,……x_k and H is the genetic worth of the plant. It is assumed that the economic weight assigned to each character is equal to unity *i.e,* a_1, a_2….a_k=1

The regression coefficients (b) are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form, $b = p^{-1} Ga$ where P is the phenotypic variance-covariance matrix and G is the genotypic variance-covariance matrix.

RESULTS

4. RESULTS

The present investigation was conducted at the Department of Vegetable science, College of Agriculture, Vellayani from October 2019 to February 2020 to evaluate the performance of beet root varieties and hybrids for growth, yield and quality characteristics. The experimental data were analyzed statistically and the results are presented below.

4.1 MEAN PERFORMANCE OF BEET ROOT VARIETIES AND HYBRIDS

The results pertaining to the analysis of variance (ANOVA) for the experimental design indicated that the mean sum of squares (MS) due to genotypes were significant at $P \leq 0.05$ for all the characters studied. The mean sum of squares for ten characters of thirty genotypes comprising of 22 varieties and 8 hybrids is presented in Table 3 and Table 4 respectively.

4.1.1 Vegetative Characters

The mean performance of 22 beetroot varieties and 8 hybrids for vegetative characters like plant height, leaves per plant, leaf length, leaf breadth and foliage weight at harvest were recorded and are presented in Table 5 and Table 6 respectively.

4.1.1.1 Plant height (cm)

Significant difference was observed among the varieties for plant height. The average plant height ranged from 20.43 cm to 38.32 cm. Tetra recorded the highest plant height of 38.32cm. Pure Seeds recorded the lowest plant height of 20.43 cm.

There was significant difference among the hybrids for plant height. The mean plant height of hybrids was 28.38 cm. Ragini was the tallest with a height of 31.07 cm and Remo (30.77 cm) was on par with it. The lowest plant height was observed in Red Bull (26.61 cm).

4.1.1.2 Leaves per Plant

The varieties varied significantly for leaves per plant, which ranged from 7.10 to 13.45, with an overall mean of 9.78. The highest number of leaves was recorded in Ruby Queen (Pradham Seeds) (13.45). BV 21 (12.96) and Tetra (12.65) were on par with it. Minimum number of leaves was observed in Red Ruby (7.10).

Significant difference was observed among hybrids for number of leaves. The highest number of leaves was recorded in Remo (9.79) and Red Star (Sakura) (9.70) was on par it. Red Bull recorded the lowest number of leaves (7.63).

Table 3. Analysis of variance for characters in beet root varieties

Source of variation	Replication	Genotypes	Error
Plant height	4.638	49.837**	1.113
Leaves per plant	0.036	9.681**	0.539
Leaf length	3.668	41.785**	1.278
Leaf length	0.155	4.720**	0.136
Foliage weight at harvest	0.506	214.772**	1.842
Root length	0.063	2.914**	0.050
Root diameter	0.025	2.014**	0.013
Root weight	18.530	2317.977**	1.033
Root shoot ratio	0.022	3.804**	0.024
Yield per plot	0.001	4.607**	0.021

Data represent mean sum of squares; * significant at $P \leq 0.05$; **significant at $P \leq 0.01$

Table 4. Analysis of variance for characters in beet root hybrids

Source of variation	Replication	Genotypes	Error
Plant height	0.763	8.579**	0.807
Leaves per plant	0.427	1.665**	0.063
Leaf length	2.849	12.446**	0.236
Leaf breadth	0.301	2.358**	0.166
Foliage weight at harvest	0.264	33.842**	2.379
Root length	0.014	2.699**	0.011
Root diameter	0.029	2.177**	0.031
Root weight	1.564	1159.044**	1.017
Root shoot ratio	0.001	2.701**	0.019
Yield per plot	0.005	3.051**	0.010

Data represent mean sum of squares; * significant at $P \leq 0.05$; **significant at $P \leq 0.01$

4.1.1.3 Leaf Length (cm)

There was significant difference among the varieties and the hybrids for leaf length. The length of leaf ranged from 18.72 cm to 35.61 cm for varieties, with a mean of 25.84 cm. The highest leaf length was recorded in Tetra (35.61 cm), while the lowest was recorded in Pure Seeds (18.72 cm).

Among hybrids, the highest leaf length of 27.93 cm was recorded in Ragini and the lowest leaf length in F_1 Kingdom (20.90 cm).

4.1.1.4 Leaf Breadth (cm)

Significant difference was observed among the varieties for leaf breadth. Leaf breadth varied from 3.52 cm to 7.75 cm, with a mean of 5.77 cm. The highest leaf breadth of 7.75 cm was recorded in Crimson Globe and the lowest in Pure Seeds (3.52 cm).

The average leaf breadth of hybrids varied from 4.09 cm to 7.00 cm, with a mean of 5.58 cm. The highest leaf breadth was recorded in Ragini (7.00 cm), which was on par with RK 777 (6.60 cm). The lowest leaf breadth was recorded in Red Bull (4.09 cm).

4.1.1.5 Foliage Weight at Harvest (g)

Foliage weight at harvest was found significantly different among the varieties and among the hybrids. Foliage weight ranged from 21.77 g to 62.75 g, with a mean of 27.95 g. Tetra recorded the highest foliage weight at harvest (62.75 g). The lowest foliage weight was recorded by Lallan (21.77 g).

The average foliage weight of hybrids varied from 19.31 g to 31.00 g with a mean of 24.69 g. The highest foliage weight of 31.00 g was recorded in RK 777 and the lowest in Red Bull (19.31 g).

Table 5. Mean performance of beet root varieties for vegetative characters

Treatments		Plant height (cm)	Leaves per plant	Leaf length (cm)	Leaf breadth (cm)	Foliage weight at harvest (g)
V1	Madhur	29.87	8.43	25.33	6.71	27.03
V2	Detroit Dark Red	27.42	7.77	22.06	6.62	22.41
V3	Crimson Globe	32.92	8.90	28.73	7.75	31.88
V4	Ruby Queen (Nisco)	29.66	9.54	26.71	6.90	26.48
V5	Tetra	38.32	12.65	35.61	7.06	62.75
V6	Ruby Queen (Tokita)	32.82	10.68	30.72	6.84	27.12
V7	Mahyco Lal II	32.38	11.03	26.88	6.31	37.71
V8	Royal	29.38	8.01	26.24	6.95	23.91
V9	K 5340	22.51	9.65	20.69	5.32	24.40
V10	K 5343	30.51	9.01	24.69	6.03	25.33
V11	Red Ruby	28.60	7.10	27.11	6.80	22.98
V12	Red Star (Condor)	28.08	8.71	24.90	5.62	25.95

Table 5. continued

V13	K5341	27.56	8.36	24.38	5.63	24.51
V14	Ruby Queen (Suvarna)	31.52	8.81	27.95	5.86	25.31
V15	Lallan	24.56	8.11	23.42	4.00	21.77
V16	Rachna	29.89	8.73	25.51	6.60	25.01
V17	Ruby Queen (Sulthan)	27.57	10.42	26.07	4.30	27.56
V18	Indam Ruby Queen	32.09	8.99	30.51	6.09	26.62
V19	Pure Seeds	20.43	10.9	18.72	3.52	24.56
V20	BV 20	29.07	12.16	27.85	3.87	26.03
V21	BV 21	24.74	12.96	23.38	4.28	27.93
V22	Ruby Queen (Pradham Seeds)	22.63	13.45	21.06	3.94	27.67
	MEAN	28.75	9.78	25.84	5.77	27.95
	SEm (±)	0.61	0.42	0.92	0.21	0.78
	CD (0.05)	1.74	1.21	1.86	0.61	2.24

Table 6. Mean performance of beet root hybrids for vegetative characters

Treatments		Plant height (cm)	Leaves per plant	Leaf length (cm)	Leaf breadth (cm)	Foliage weight at harvest (g)
H1	F_1 Kingdom	27.49	9.28	20.90	5.34	26.01
H2	F_1 Kestral	27.28	8.47	24.43	5.31	22.25
H3	Red Star (Sakura)	28.50	9.70	24.79	5.45	25.32
H4	Red Horse	26.98	8.60	23.51	5.32	23.59
H5	RK777	28.33	9.33	23.09	6.60	31.00
H6	Remo	30.77	9.79	25.51	5.51	24.44
H7	Red Bull	26.61	7.63	25.03	4.09	19.31
H8	Ragini	31.07	8.42	27.93	7.00	25.62
MEAN		28.38	8.90	24.40	5.58	24.69
SEm(±)		0.52	0.15	0.28	0.24	0.89
CD (0.05)		1.57	0.44	0.85	0.715	2.70

4.1.2 Root and Yield Characters

Table 7 and Table 8 presents the mean values for root and yield characters like root shape, root length, root diameter, root weight, root: shoot ratio, crop duration and yield per plot of varieties and hybrids respectively (Plate 5 and Plate 6).

4.1.2.1 Root Shape

Among the 22 varieties, fifteen genotypes *viz.*, Madhur, Detroit Dark Red, Ruby Queen (Nisco), Tetra, Ruby Queen (Tokita), Mahyco Lal II, K 5340, K 5343, Red Ruby, Red star (Condor), K 5341, Ruby Queen (Suvarna), Rachna, Ruby Queen (Sulthan) and Indam Ruby Queen exhibited circular shaped root, five genotypes *viz.*, Lallan, Pure seeds, BV 20, BV 21 and Ruby Queen (Pradham Seeds) exhibited narrow elliptic shaped roots and two genotypes *viz.*, Crimson Globe and Royal displayed broad elliptic shaped roots.

Differences were observed among the hybrids for root shape. Four hybrids *viz.*, F_1 Kingdom, Red Star (Sakura), RK 777, and Ragini exhibited broad elliptic shaped roots while four genotypes *viz.*, F_1 Kestral, Red Horse, Remo and Red Bull displayed narrow elliptic shaped roots.

4.1.2.2 Root Length (cm)

The varieties and the hybrids differed significantly for root length. Among varieties, longest root of 7.43 cm was recorded by Madhur, while the shortest by Lallan (3.03 cm).

Among hybrids, longest root of 7.41 cm was recorded by Red Star (Sakura) while the shortest by Red Bull (3.43 cm).

4.1.2.3 Root Diameter (cm)

Significant difference was observed among the varieties and among the hybrids for root diameter. The highest root diameter was observed for Madhur (5.33) and Ruby Queen (Tokita) (5.25 cm), Detroit Dark Red (5.16 cm) and Mahyco Lal II (5.15 cm) were statistically on par with it. The lowest diameter of 2.77 cm was recorded in Lallan. The mean root diameter was 4.33 cm.

The average root diameter of hybrids ranged from 3.02 cm to 5.50 cm, with a mean of 4.36 cm. The highest root diameter was recorded in Red Star (Sakura) 5.50 cm, which was on par with Ragini (5.32 cm). The lowest root diameter of 3.02 cm was recorded in Red Bull.

4.1.2.4 Root Weight (g)

There was significant difference among varieties and hybrids with respect to root weight. Values ranged from 20.52 g to 118.05 g for varieties, with an overall mean of 57.63 g. The highest root weight was observed in Madhur (118.05 g), while the lowest in Lallan (20.52 g).

Among the hybrids, the root weight ranged from 29.70 g to 91.27g with a mean of 62.80 g. The highest root weight was recorded in Red Star (Sakura) (91.27 g) and lowest in Red Bull (29.70 g).

4.1.2.5 Root: Shoot Ratio (Weight Basis)

Significant difference was observed among the varieties and among the hybrids for root: shoot ratio. The highest root: shoot ratio was recorded by Madhur (4.42) and the lowest by BV 21 (0.77).

Among hybrids, the highest root: shoot ratio of 3.61 was recorded by Red Star (Sakura) and the lowest by Red Bull (1.54).

Madhur

Detroit Dark Red

Crimson Globe

Ruby Queen (Nisco)

Tetra

Ruby Queen (Tokita)

Mahyco Lal II

Royal

K 5340

Plate 5. Variability in root characters of beet root varieties

K 5343

Red Ruby

Red Star (Condor)

K 5341

Ruby Queen (Suvarna)

Rachna

Sulthan (Ruby Queen)

Indam Ruby Queen

Plate 5. Variability in root characters of beet root varieties

(continued)

Table 7. Mean performance of beet root varieties for root and yield characters

Treatments		Root shape	Root length (cm)	Root diameter (cm)	Root weight (g)	Root: shoot Ratio	Yield plot^{-1} (kg)	Crop duration (Days)
V1	Madhur	Circular	7.43	5.33	118.05	4.42	5.68	96
V2	Detroit Dark Red	Circular	6.19	5.16	80.93	3.66	4.04	98
V3	Crimson Globe	Broad elliptic	6.03	4.30	62.33	1.98	3.12	110
V4	Ruby Queen (Nisco)	Circular	5.54	4.27	56.38	2.14	2.82	110
V5	Tetra	Circular	5.55	4.85	63.82	1.22	3.19	96
V6	Ruby Queen (Tokita)	Circular	6.21	5.25	85.65	3.16	4.78	96
V7	Mahyco Lal II	Circular	6.07	5.15	80.39	2.27	4.02	98
V8	Royal	Broad elliptic	6.05	5.11	77.13	3.23	3.86	98
V9	K 5340	Circular	5.30	4.28	48.58	1.99	2.43	110
V10	K 5343	Circular	5.32	4.60	61.11	2.41	3.06	98
V11	Red Ruby	Circular	4.97	3.56	55.11	2.41	2.76	110

Table 7. continued

V12	Red Star (Condor)	Circular	4.82	3.68	53.82	2.07	2.68	110
V13	K5341	Circular	4.78	4.89	56.78	2.31	2.81	110
V14	Ruby Queen (Suvarna)	Circular	5.75	4.43	61.17	2.42	3.09	110
V15	Lallan	Narrow elliptic	3.03	2.77	20.52	0.94	1.03	130
V16	Rachna	Circular	5.23	4.48	58.49	2.34	2.93	130
V17	Ruby Queen (Sulthan)	Circular	5.10	4.63	59.25	2.15	2.97	130
V18	Indam Ruby Queen	Circular	6.10	4.93	78.46	2.95	3.85	110
V19	Pure Seeds	Narrow elliptic	3.55	4.72	22.83	0.93	1.14	130
V20	BV 20	Narrow elliptic	4.21	3.33	23.51	0.90	1.20	130
V21	BV 21	Narrow elliptic	4.20	2.85	21.56	0.77	1.07	130
V22	Ruby Queen (Pradham Seeds)	Narrow elliptic	4.76	2.80	22.08	0.80	1.08	130
MEAN			5.28	4.33	57.63	2.16	2.14	
SEm(±)			0.13	0.06	0.83	0.09	0.08	
CD (0.05)			0.37	0.18	1.67	0.25	0.24	

F_1 Kingdom

F_1 Kestral

Red Star (Sakura)

Red Horse

RK777

Remo

Red Bull

Ragini

Plate 6. Variability in root characters of beet root hybrids

Table 8. Mean performance of beet root hybrids for root and yield characters

Treatments		Root shape	Root length (cm)	Root diameter (cm)	Root weight (g)	Root: shoot ratio	Yield plot^{-1} (kg)	Crop duration (Days)
H1	F_1 Kingdom	Broad elliptic	6.03	4.50	69.21	2.69	3.33	110
H2	F_1 Kestral	Narrow elliptic	4.74	3.76	43.02	1.93	2.06	110
H3	Red Star (Sakura)	Broad elliptic	7.41	5.50	91.27	3.61	4.27	98
H4	Red Horse	Narrow elliptic	6.50	4.88	77.23	3.27	3.82	98
H5	RK777	Broad elliptic	5.39	4.17	61.38	1.98	3.00	98
H6	Remo	Narrow elliptic	4.08	3.74	42.23	1.72	2.05	110
H7	Red Bull	Narrow elliptic	3.43	3.02	29.70	1.54	1.67	130
H8	Ragini	Broad elliptic	7.11	5.32	84.23	3.29	4.09	110
MEAN			5.59	4.36	62.80	2.05	3.04	
SEm(±)			0.06	0.1	0.58	0.08	0.06	
CD (0.05)			0.18	0.31	1.77	0.24	0.177	

4.1.2.6 Yield Plot^{-1} (kg)

Significant difference was observed among the varieties and among the hybrids for yield plot^{-1}. The highest yield plot^{-1} of 5.68 kg was recorded by Madhur and the lowest by Lallan (1.03 kg). The mean yield plot^{-1} was 2.14 kg.

The average yield plot^{-1} of hybrids ranged from 1.67 kg to 4.27 kg with a mean of 3.04 kg. The highest yield plot^{-1} was recorded by Red Star (Sakura) (4.27 kg) and the lowest by Red Bull (1.67 kg).

4.1.2.7 Crop Duration (Days)

The varieties and the hybrids differed significantly for crop duration. The crop duration of varieties ranged from 96 days to 130 days. Early crop of 96 days duration was observed in Madhur, Tetra and Ruby Queen (Tokita). The varieties, Ruby Queen (Pradham Seeds), BV 20, BV 21, Pure Seeds, Ruby Queen (Sulthan), Rachna and Lallan were late to harvest (130 days).

Among the hybrids, Red Star (Sakura), Red Horse and RK 777 recorded early crop (98 days) and Red Bull, late (130 days).

4.1.3 Quality Characters

Mean values for quality characters like total soluble solids (T.S.S), carotenoid content, reducing sugars, non reducing sugars and total sugars of varieties and hybrids are presented in Table 9 and Table 10 respectively.

4.1.3.1 T.S.S

T.S.S content varied among different varieties. The highest T.S.S content was recorded by K 5340 (15.70 ^{0}B) followed by Tetra (15.60 ^{0}B) and the lowest by Pure Seeds (6.50 ^{0}B).

Among hybrids, the highest T.S.S content of 14.50 ^{0}B was recorded by RK 777 followed by Remo (14.10 ^{0}B) and the lowest by F_1 Kestral (8.10 ^{0}B).

Table 9. Mean performance of beet root varieties for quality characters

Treatments		T.S.S (^{0}B)	Carotenoid content (mg 100 g^{-1})	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)
V1	Madhur	13.40	1.42	0.42	6.03	6.45
V2	Detroit Dark Red	12.20	1.25	0.65	5.58	6.23
V3	Crimson Globe	7.80	1.28	1.00	4.22	5.22
V4	Ruby Queen (Nisco)	11.40	1.05	0.33	5.61	5.94
V5	Tetra	15.60	0.96	0.47	4.94	5.41
V6	Ruby Queen (Tokita)	11.20	1.02	0.61	5.42	6.03
V7	Mahyco Lal II	12.20	1.50	0.85	5.32	6.17
V8	Royal	12.50	1.42	0.59	5.49	6.08
V9	K 5340	15.70	0.98	0.54	5.08	5.62
V10	K 5343	9.20	0.79	0.52	5.34	5.86
V11	Red Ruby	8.50	1.37	0.58	5.33	5.91
V12	Red Star (Condor)	10.40	1.27	0.51	4.79	5.30

Table 9. continued

V13	K5341	12.90	0.85	0.54	5.17	5.71
V14	Ruby Queen (Suvarna)	15.40	0.94	0.52	4.55	5.07
V15	Lallan	12.20	0.84	0.42	4.09	4.51
V16	Rachna	12.80	1.31	0.52	5.28	5.80
V17	Ruby Queen (Sulthan)	13.40	1.23	0.61	5.62	6.23
V18	Indam Ruby Queen	11.50	1.35	0.55	5.79	6.34
V19	Pure Seeds	6.50	0.46	0.49	4.74	5.23
V20	BV 20	9.70	1.11	0.51	4.85	5.36
V21	BV 21	9.20	0.27	0.50	4.64	5.14
V22	Ruby Queen (Pradham Seeds)	7.10	0.28	0.41	4.37	4.78

4.1.3.2 Carotenoid Content

The varieties differed with regard to carotenoid content. Among the varieties, the highest carotenoid content was obtained in Mahyco Lal II (1.50 mg 100 g^{-1}) followed by Madhur and Royal (1.42 mg 100g^{-1}) and the lowest in BV 21 (0.27 mg 100 g^{-1}).

Carotenoid content varied among different hybrids. The highest carotenoid content was obtained in Red Horse (1.74 mg 100 g^{-1}) and the lowest in Red Bull (1.05 mg 100 g^{-1}).

Table 10. Mean performance of beet root hybrids for quality characters

Treatments		T.S.S (^{0}B)	Carotenoid content (mg 100 g^{-1})	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)
H1	F_1 Kingdom	12.00	1.21	0.54	5.57	6.11
H2	F_1 Kestral	8.10	1.13	0.54	5.76	6.00
H3	Red Star (Sakura)	11.00	1.61	0.46	6.04	6.50
H4	Red Horse	13.10	1.74	0.50	5.74	6.24
H5	RK777	14.50	1.54	1.00	4.12	6.30
H6	Remo	14.10	1.40	0.52	4.52	5.04
H7	Red Bull	11.30	1.05	0.49	5.13	5.62
H8	Ragini	10.10	1.45	0.54	4.60	5.14

4.1.3.3 Reducing Sugars

Observation on reducing sugar content showed that there was difference among the varieties and hybrids. Among varieties, Crimson Globe registered highest reducing sugar content (1.00%) and the lowest was recorded by Ruby Queen (Nisco) (0.33 %).

Among hybrids, RK 777 recorded the highest and Red Star (Sakura) the lowest reducing sugars (1.00% and 0.46 % respectively).

4.1.3.4 Non Reducing Sugars

The varieties and hybrids differed with regard to non reducing sugar content. Among the varieties, the highest non reducing sugar content was observed in Madhur (6.03%) and the lowest in Lallan (4.09%).

Among hybrids, Red Star (Sakura) recorded the highest non reducing sugars of 6.04% and RK 777 the lowest (4.12%).

4.1.3.5 Total Sugars

Variation was observed among the varieties and among hybrids with respect to total sugars. The highest total sugar content was recorded by Madhur (6.45 %) followed by Indam Ruby Queen (6.34 %) and the lowest by Lallan (4.51 %).

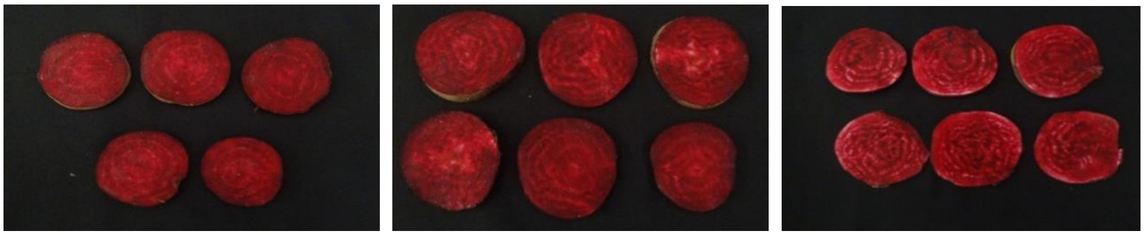
Among hybrids, the highest total sugar content was recorded by Red Star (Sakura) (6.50 %) and the lowest by Remo (5.04 %).

4.2 ORGANOLEPTIC EVALUATION OF BEET ROOT VARIETIES AND HYBRIDS

Sensory parameters *viz*., appearance, colour, taste and overall acceptability were statistically analyzed using Kruskal - Wallis test and was observed that both the varieties and the hybrids showed significant difference for organoleptic qualities and acceptability (Table 11 and Table 12).

Among beet root varieties, Madhur recorded the highest mean score for appearance, colour, and taste (Plate 7). The variety Detroit Dark Red ranked second in appearance and colour. Ruby Queen (Tokita) ranked second in taste. Detroit Dark Red and Indam Ruby Queen ranked third in taste and appearance respectively. Regarding overall acceptability, the highest mean score was recorded by the Madhur (9.40) followed by Detroit Dark Red (9.30) and Ruby Queen (Tokita) (9.20).

Among hybrids, Red Star (Sakura) recorded the highest mean score for colour, appearance and taste (Plate 8). Ragini ranked second in appearance and taste. Red Horse ranked second for colour and third for appearance and taste. RK 777 ranked third in colour. The highest mean score for overall acceptability was recorded in Red Star (Sakura) (9.30) followed by Ragini (9.20) and Red Horse (8.70).



Madhur Detroit Dark Red Ruby Queen (Tokita)

Plate 7. Cross section of beet root varieties

Red Star RK 777 Red Horse

Plate 8. Cross section of beet root hybrids

Table11. Evaluation of sensory parameters of beet root varieties

Treatments		Sensory parameters							
		Appearance		Colour		Taste		Overall Acceptability	
		Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
V1	Madhur	9.40	1	9.80	1	9.30	1	9.40	1
V2	Detroit Dark Red	9.30	2	9.70	2	9.20	3	9.30	2
V3	Crimson Globe	8.20	9	8.20	8	8.00	8	8.20	6
V4	Ruby Queen (Nisco)	7.40	15	7.70	13	7.50	13	6.40	15
V5	Tetra	9.10	5	9.40	4	8.70	6	8.80	5
V6	Ruby Queen (Tokita)	9.20	4	9.40	3	9.20	2	9.20	3
V7	Mahyco Lal II	9.10	6	9.30	5	8.90	4	8.00	7
V8	Royal	7.70	12	7.10	17	6.90	16	7.50	8
V9	K 5340	7.70	14	7.50	14	7.30	15	7.00	14
V10	K 5343	8.00	10	7.90	11	7.70	11	7.50	9
V11	Red Ruby	7.80	11	8.10	9	7.90	9	7.40	10
V12	Red Star (Condor)	7.70	13	7.50	15	7.30	14	7.30	13
V13	K5341	6.90	16	7.70	12	7.50	12	6.30	16
V14	Ruby Queen (Suvarna)	5.10	17	7.10	16	6.90	17	6.00	17

Table.11 continued

V15	Lallan	5.10	18	6.20	18	6.00	18	3.30	19
V16	Rachna	8.90	7	8.00	10	7.80	10	7.40	11
V17	Ruby Queen (Sulthan)	8.60	8	8.40	7	8.20	7	7.40	12
V18	Indam Ruby Queen	9.20	3	9.00	6	8.90	5	9.10	4
V19	Pure Seeds	5.00	19	6.10	19	5.90	19	4.10	18
V20	BV 20	4.80	20	6.00	21	5.80	21	2.80	21
V21	BV 21	3.90	22	5.80	22	5.60	22	2.60	22
V22	Ruby Queen (Pradham Seeds)	4.10	21	6.10	20	5.90	20	3.00	20
KW value		198.0169**		180.115**		170.220**		193.221**	
Chi Square value (0.05)		32.67							

** Significant at 5 per cent level

Table 12. Evaluation of sensory parameters of beet root hybrids

Treatments		Sensory parameters							
		Appearance		Colour		Taste		Overall acceptability	
		Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
H1	F_1 Kingdom	8.60	4	8.20	5	8.10	5	8.10	5
H2	F_1Kestral	7.00	6	7.10	7	7.10	7	6.90	6
H3	Red Star (Sakura)	9.20	1	9.50	1	9.30	1	9.30	1
H4	Red Horse	8.80	3	9.20	2	8.80	3	8.70	3
H5	RK777	8.20	5	9.00	3	8.10	4	8.70	4
H6	Remo	6.50	7	7.60	6	7.60	6	6.60	7
H7	Red Bull	5.40	8	6.80	8	6.80	8	5.10	8
H8	Ragini	9.00	2	8.90	4	9.20	2	9.20	2
KW value		63.068**		58.71**		48.765**		63.677**	
Chi Square value (0.05)		14.07							

** Significant at 5 per cent level

4.3 PEST AND DISEASE INCIDENCE

The crop was observed for the incidence of pests and diseases during the cropping period (Plate 9). During seedling stage, incidence of damping off caused by *Rhizoctonia solani* was observed and was effectively managed by spraying Folio gold (Metalaxyl-M and Chlorothalonil) 2 ml L^{-1}. Incidence of cercospora leaf spot was also observed during initial stages of crop growth and was controlled by spraying Mancozeb 2g L^{-1}. Severe incidence of web blight was observed 2 months after transplanting and was controlled by rotational spraying of Bavistin (Carbendazim) (2g L^{-1}) and Saaf (Carbendazim + Mancozeb) (1g L^{-1}) at weekly intervals.

There was incidence of leaf webber in all varieties and was effectively managed by spraying Coragen (Chloantraniliprole) 3 ml 10 L^{-1}.

4.4 GENETIC VARIABILITY PARAMETERS

The genetic variability parameters such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance of twenty two varieties and eight hybrids were studied. The population means, range, GCV, PCV, heritability and genetic advance of varieties and hybrids are presented in Table 13 and Table 14 respectively.

4.4.1 Vegetative Characters

4.4.1.1 Varieties

Plant height exhibited moderate PCV (14.49) and GCV (14.02) with high estimates of heritability (93.58 %) and high genetic advance (27.93).

Moderate PCV and GCV values (19.43 and 17.91 respectively) coupled with high heritability (84.96 %) and high genetic advance (34.00) were recorded for leaves per plant.

Damping off

Cercospora leaf spot

Web blight

Leaf webber

Plate 9. Pests and diseases

Leaf length exhibited moderate PCV and GCV (14.88 and 14.22 respectively) with high heritability (91.36 %) and genetic advance (28.00).

High PCV and GCV values (22.34 and 21.41 respectively) coupled with high heritability (91.85 %) and high genetic advance (42.27) was evident for leaf breadth.

Foliage weight at harvest exhibited high PCV (30.53) and GCV (30.14) values with high heritability (97.47 %) as well as genetic advance (61.30).

4.4.1.2 Hybrids

Low PCV and GCV values (6.50 and 5.67 respectively) coupled with high heritability (76.24 %) and moderate genetic advance (10.20) were recorded for plant height.

Leaves per plant exhibited low PCV (8.68) and GCV (8.21) with high estimates of heritability (89.37 %) and moderate genetic advance (15.98).

Low PCV and GCV values (8.50 and 8.27) coupled with high heritability (94.52%) and high genetic advance (16.56) were recorded for leaf length.

Leaf breadth exhibited moderate PCV (16.98) and GCV (15.32) with high heritability of 81.44% and high genetic advance (28.48).

Moderate PCV (14.53) and GCV (13.11) coupled with high heritability 81.51% and high genetic advance (24.39) was recorded for foliage weight at harvest.

Table 13. Estimates of genetic parameters for various characters in beet root varieties

	Range	Mean	PCV	GCV	Heritability (%)	Genetic Advance	GA as per cent of mean
Plant height	17.89	28.75	14.49	14.02	93.58	8.03	27.93
Leaves per plant	5.55	9.74	19.43	17.91	84.96	3.31	34.00
Leaf length	16.89	25.84	14.88	14.22	91.36	7.24	28.00
Leaf breadth	4.23	5.77	22.34	21.41	91.85	2.44	42.27
Foliage weight at harvest	40.95	27.95	30.53	30.14	97.47	17.13	61.30
Root length	4.4	5.28	18.97	18.50	95.02	1.96	37.15
Root diameter	2.56	4.33	19.02	18.84	98.15	1.67	38.46
Root weight	97.53	50.14	45.22	44.69	97.67	1.96	90.98
Root Shoot Ratio	3.65	1.96	42.95	42.83	99.48	50.73	88.01
Yield per plot	4.65	2.89	43.06	42.76	98.60	2.53	87.47

Table 14. Estimates of genetic parameters for various characters in beet root hybrids

	Range	Mean	PCV	GCV	Heritability (%)	Genetic Advance	GA as per cent of mean
Plant height	28.46	28.38	6.50	5.67	76.24	2.89	10.20
Leaves per plant	2.16	8.90	8.68	8.21	89.37	1.42	15.98
Leaf length	7.03	24.40	8.50	8.27	94.52	4.04	16.56
Leaf breadth	2.91	5.58	16.98	15.32	81.44	1.59	28.48
Foliage weight at harvest (g)	11.69	24.69	14.53	13.11	81.51	6.02	24.39
Root length	3.98	5.17	25.69	25.66	99.77	2.95	52.81
Root diameter	2.48	4.10	19.63	19.46	98.31	1.73	39.76
Root weight	61.57	50.33	35.53	35.57	99.79	45.53	73.11
Root Shoot Ratio	2.07	2.17	32.66	32.15	96.92	1.63	65.21
Yield per plot	2.60	3.04	33.31	33.15	99.00	2.06	67.94

4.4.2 Root and Yield Characters

4.4.2.1 Varieties

Moderate PCV and GCV were recorded (18.97 and 18.50 respectively) with high heritability (95.02 %) and high genetic advance (37.15) for root length.

PCV and GCV were moderate for root diameter (19.02 and 18.84 respectively) with high heritability (98.15%) and high genetic advance (38.46).

Root weight exhibited high PCV and GCV (45.22 and 44.69 respectively) along with high heritability estimate (97.67%) and high genetic advance (90.98).

High PCV of 42.95 and GCV of 42.83 were recorded for root: shoot ratio with high estimates of both heritability (99.48%) and genetic advance (88.01).

Yield per plot exhibited high PCV and GCV (43.06 and 42.76 respectively) along with high heritability (98.60 %) and high genetic advance (87.47).

4.4.2.2 Hybrids

The estimates of PCV (25.69) and GCV (25.66) were high for root length along with high estimates of heritability (99.77 %) and high genetic advance (52.81).

Root diameter exhibited a moderate PCV (19.63) and GCV (19.46) with high estimates of heritability (98.31%) and genetic advance (39.76).

High PCV and GCV (35.53 and 35.57 respectively) along with higher heritability (99.79 %) and genetic advance (73.11) was expressed for root weight.

The estimates of PCV (32.66) and GCV (32.15) were high for root: shoot ratio. High heritability (96.92 %) and genetic advance (65.21) were also recorded.

High PCV (33.31) and GCV (33.15) were observed with high heritability (99.00 %) and high genetic advance as per cent of mean (67.94) for yield per plot.

4.5 CORRELATION ANALYSIS

Genotypic and phenotypic correlation coefficients between root weight and various yield components and inter-relationship among the traits of varieties were computed and are presented in Table 15 and Table 17 respectively. Genotypic and phenotypic correlation coefficients between root weight and various yield components of hybrids are presented in Table 16 and Table 18.

4.5.1 Genotypic Correlation

4.5.1.1 Varieties

Root weight had significant positive association at genotypic level with plant height (0.605), leaf length (0.418), leaf breadth (0.770), root diameter (0.821), root length (0.936), root: shoot ratio (0.928) and yield per plot (0.996). Root weight had a significant but negative correlation with number of leaves (-0.449).

Plant height had a significant positive genotypic correlation with root weight (0.605), leaf length (0.934), leaf breadth (0.746), foliage weight at harvest (0.626), root length (0.606), root diameter (0.476), root: shoot ratio (0.364) and yield per plot (0.618).

Leaves per plant exhibited significant positive genotypic correlation with foliage weight (0.505) while, it had a significant negative correlation with root weight (-0.449), leaf breadth (-0.496), root diameter (-0.317), root length (-0.270), root: shoot ratio (-0.651) and yield per plot (-0.436).

Leaf length was positively correlated with root weight (0.418), plant height (0.934), leaf breadth (0.578), foliage weight (0.645), root diameter (0.291), root length (0.426) and yield per plot (0.439).

Leaf breadth had significant positive genotypic correlation with root weight (0.770), plant height (0.746), leaf length (0.578), foliage weight at harvest (0.282), root diameter (0.592), root length (0.791), root: shoot ratio (0.675) and yield per plot (0.775). Leaf breadth had a significant negative relationship with leaves per plant (-0.496).

Foliage weight exhibited significant positive correlation with plant height (0.626), leaves per plant (0.505), leaf length (0.645) and leaf breadth (0.282) at genotypic level.

Root diameter manifested a significant positive correlation with root weight (0.821), plant height (0.476), leaf length (0.291), leaf breadth (0.592), root length (0.724), root: shoot ratio (0.740) and yield per plot (0.828) at genotypic level. Root diameter had a significant negative relationship with leaves per plant (-0.317).

At genotypic level, root length had highly significant positive correlation with root weight (0.936), plant height (0.606), leaf length (0.426), leaf breadth (0.791), root diameter (0.724), root: shoot ratio (0.848) and yield per plot (0.931), while significant negative correlation with leaves per plant (-0.270)

Root: shoot ratio showed highly significant positive correlation with root weight (0.928) plant height (0.364), leaf breadth (0.675), root diameter (0.740), root length (0.848) and yield per plot (0.925) at genotypic level. The genotypic correlation was significant and negative with leaves per plant (-0.651).

Yield per plot exhibited significant positive correlation with root weight (0.996), plant height (0.618), leaf length (0.439), leaf breadth (0.775), root diameter (0.828), root length (0.931) and root: shoot ratio (0.925) at genotypic level. But a significant negative correlation was associated with leaves per plant (-0.436).

Table 15. Genotypic correlation coefficients between root weight and yield components of varieties

	Root weight	Plant height	Leaves per plant	Leaf length	Leaf breadth	Foliage weight at harvest	Root diameter	Root length	Root: shoot ratio	Yield per plot
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X 1	1.000									
X 2	0.605**	1.000								
X3	-0.449**	-0.076NS	1.000							
X4	0.418**	0.934**	0.074NS	1.000						
X5	0.770**	0.746**	-0.496**	0.578**	1.000					
X6	0.137NS	0.626**	0.505**	0.645**	0.282*	1.000				
X7	0.821**	0.476**	-0.317**	0.291*	0.592**	0.194NS	1.000			
X8	0.936**	0.606**	-0.270*	0.426**	0.791**	0.189NS	0.724**	1.000		
X9	0.928**	0.364**	-0.651**	0.175NS	0.675**	-0.213NS	0.740**	0.848**	1.000	
X10	0.996**	0.618**	-0.436**	0.439**	0.775**	0.134NS	0.828**	0.931**	0.925**	1.000

Table 16. Genotypic correlation coefficients between root weight and yield components of hybrids

	Root weight	Plant height	Leaves per plant	Leaf length	Leaf breadth	Foliage weight at harvest	Root diameter	Root length	Root: shoot ratio	Yield per plot
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.000									
X2	0.265^{NS}	1.000								
X3	0.373^{NS}	0.456^{*}	1.000							
X4	0.028^{NS}	0.670^{**}	-0.279^{NS}	1.000						
X5	0.574^{**}	0.698^{**}	0.383^{NS}	0.309^{NS}	1.000					
X6	0.502^{*}	0.360^{NS}	0.688^{**}	-0.257^{NS}	0.780^{**}	1.000				
X7	0.991^{**}	0.346^{NS}	0.382^{NS}	0.129^{NS}	0.590^{**}	0.446^{*}	1.000			
X8	0.992^{**}	0.234^{NS}	0.314^{NS}	0.045^{NS}	0.575^{**}	0.459^{*}	0.990^{**}	1.000		
X9	0.966^{**}	0.176^{NS}	0.214^{NS}	0.089^{NS}	0.405^{*}	0.263^{NS}	0.974^{**}	0.970^{**}	1.000	
X10	0.997^{**}	0.243^{NS}	0.313^{NS}	0.036^{NS}	0.558^{**}	0.476^{*}	0.981^{**}	0.987^{**}	0.971^{**}	1.000

4.5.1.2 Hybrids

At genotypic level, root weight had highly significant positive correlation with root yield per plot (0.997), root: shoot ratio (0.966), root length (0.992), and root diameter (0.991). Leaf breadth (0.574) and foliage weight (0.502) also had significant positive relation to root weight.

Plant height exhibited significant positive correlation with number of leaves per plant (0.456), leaf length (0.670) and leaf breadth (0.698).

Leaves per plant showed a positive significant correlation for plant height (0.456) and foliage weight (0.688) at genotypic level.

Leaf length had significant positive correlation with plant height (0.670). Leaf breadth had significant correlation with root weight (0.574), plant height (0.698), foliage weight at harvest (0.780), root diameter (0.590), root length (0.575), root: shoot ratio (0.405) and root yield per plot (0.558).

Foliage weight had significantly high correlation with root weight (0.502), leaves per plant (0.688), root diameter (0.446), root length (0.459) and root yield per plot (0.476).

Root diameter had significant positive interaction with root weight (0.991), leaf breadth (0.590), foliage weight at harvest (0.446), root length (0.990), root: shoot ratio (0.974) and yield per plant (0.981) at genotypic level.

Root length showed a significant positive interaction with root weight (0.992), leaf breadth (0.575), foliage weight (0.459), root diameter (0.990), root: shoot ratio (0.970) and yield per plot (0.987).

Root: shoot ratio was significantly correlated with root weight (0.966), leaf breadth (0.405), root diameter (0.974), root length (0.970) and yield per plot (0.971) at genotypic level.

Root yield per plot was significantly and positively correlated with root weight (0.997), leaf breadth (0.558), foliage weight at harvest (0.476), root diameter (0.981), root length (0.987) and root: shoot ratio (0.971).

4.5.2 Phenotypic Correlation

4.5.2.1 Varieties

Root weight had significant positive association at phenotypic level with yield per plot (0.994), root: shoot ratio (0.920), root diameter (0.812), root length (0.911), plant height (0.584), leaf length (0.404) and leaf breadth (0.740), while leaves per plant (-0.418) had a negative significant relationship with root weight.

Plant height had a significant positive phenotypic correlation with root weight (0.584), leaf length (0.921) leaf breadth (0.709), foliage weight (0.606), root diameter (0.464), root length (0.581), root: shoot ratio (0.345) and yield per plot (0.602).

Leaves per plant had significant positive phenotypic correlation with foliage weight (0.475), while it had significant negative association with root weight (-0.418), leaf breadth (-0.410), root diameter (-0.284), root: shoot ratio (-0.608) and yield per plot (-0.395).

Leaf length was positively correlated with root weight (0.404), plant height (0.921), leaf breadth (0.542), foliage weight (0.627), root diameter (0.293), root length (0.407) and yield per plot (0.431).

Leaf breadth had significant positive phenotypic correlation with root weight (0.740), plant height (0.709), leaf length (0.542), foliage weight at harvest (0.270), root diameter (0.558), root length (0.746), root: shoot ratio (0.639) and yield per plot (0.750). Leaf breadth had significant negative correlation with leaves per plant (-0.410).

Foliage weight exhibited a significant correlation with plant height (0.606), leaves per plant (0.475), leaf length (0.627) and leaf breadth (0.270).

At phenotypic level, root diameter had highly significant positive correlation with root weight (0.812), plant height (0.464), leaf length (0.293), leaf breadth (0.558), root length (0.702), root: shoot ratio (0.722) and yield per plot (0.816) while negative correlation with leaves per plant (-0.284).

Root length manifested a significant positive phenotypic correlation with root weight (0.911), plant height (0.581), leaf length (0.407), leaf breadth (0.746), root diameter (0.702), root: shoot ratio (0.815) and yield per plot (0.906).

Root: shoot ratio exhibited significant positive correlation with root weight (0.920), plant height (0.345), leaf breadth (0.639), root diameter (0.722), root length (0.815) and yield per plot (0.913) at phenotypic level. But a significant negative correlation was associated with number of leaves (-0.608).

Yield per plot showed a significant positive correlation for root weight (0.994), plant height (0.602), leaf length (0.431), leaf breadth (0.750), root diameter (0.816), root length (0.906), root: shoot ratio (0.913) and significant negative correlation observed with leaves per plant (-0.395).

4.5.2.2. Hybrids

Root weight had significant positive association at phenotypic level with leaf breadth (0.520), foliage weight (0.459), root diameter (0.986), root length (0.992), root: shoot ratio (0.949), root yield per plot (0.995).

Plant height had significant positive phenotypic correlation with leaf length (0.595) and breadth (0.643).

Table 17. Phenotypic correlation coefficients between root weight and yield components of varieties

	Root weight	Plant height	Leaves per plant	Leaf length	Leaf breadth	Foliage weight	Root diameter	Root length	Root: shoot ratio	Yield per plot
	XI	X2	X3	X4	X5	X6	X7	X8	X9	X10
XI	1.000									
X2	0.584**	1.000								
X3	-0.418**	-0.045NS	1.000							
X4	0.404**	0.921**	0.067NS	1.000						
X5	0.740**	0.709**	-0.410**	0.542**	1.000					
X6	0.137NS	0.606**	0.475**	0.627**	0.270*	1.000				
X7	0.812**	0.464**	-0.284*	0.293*	0.558**	0.197NS	1.000			
X8	0.911**	0.581**	-0.227NS	0.407**	0.746**	0.182NS	0.702**	1.000		
X9	0.920**	0.345**	-0.608**	0.162NS	0.639**	-0.223NS	0.722**	0.815**	1.000	
X10	0.994**	0.602**	-0.395**	0.431**	0.750**	0.136NS	0.816**	0.906**	0.913**	1.000

Table 18. Phenotypic correlation coefficients between root weight and yield components of hybrids

	Root weight	Plant height	Leaves per plant	Leaf length	Leaf breadth	Foliage weight at harvest	Root diameter	Root length	Root: shoot ratio	Root yield per plot
	XI	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.000									
X2	0.234^{NS}	1.000								
X3	0.356^{NS}	0.366^{NS}	1.000							
X4	0.030^{NS}	0.595**	-0.248^{NS}	1.000						
X5	0.520**	0.643**	0.284^{NS}	0.257^{NS}	1.000					
X6	0.459*	0.355^{NS}	0.572**	-0.249^{NS}	0.790**	1.000				
X7	0.986**	0.325^{NS}	0.363^{NS}	0.133^{NS}	0.557**	0.431*	1.000			
X8	0.992**	0.210^{NS}	0.300^{NS}	0.046^{NS}	0.523**	0.421*	0.985**	1.000		
X9	0.949**	0.123^{NS}	0.210^{NS}	0.098^{NS}	0.298^{NS}	0.161^{NS}	0.941**	0.953**	1.000	
X10	0.995**	0.211^{NS}	0.300^{NS}	0.040^{NS}	0.513*	0.445*	0.978**	0.984**	0.947**	1.000

Leaves per plant exhibited significant positive phenotypic correlation with foliage weight (0.572). Leaf length had significant positive phenotypic correlation with plant height (0.595).

Leaf breadth had significant positive phenotypic correlation with root weight (0.520), plant height (0.643), foliage weight (0.790), root diameter (0.557) root length (0.523) and yield per plot (0.513).

Foliage weight at harvest exhibited positive and significant correlation with root weight (0.459), leaves per plant (0.572), leaf breadth (0.790), root diameter (0.431), root length (0.421) and yield per plot (0.445).

Root diameter manifested a highly significant positive phenotypic correlation with root weight (0.986), leaf breadth (0.557), foliage weight (0.431), root length (0.985), root: shoot ratio (0.941) and root yield per plot (0.978).

At phenotypic level, root length had highly significant positive correlation with root weight (0.992), leaf breadth (0.523), foliage weight (0.421), root diameter (0.985), root: shoot ratio (0.953) and root yield per plot (0.984).

Root: shoot ratio exhibited highly significant positive correlation with root weight (0.949), root diameter (0.941), root length (0.953) and yield per plant (0.947).

Yield per plot exhibited significant high positive correlation with root weight (0.995), leaf breadth (0.513), foliage weight (0.445), root diameter (0.978), root length (0.984) and root: shoot ratio (0.947).

4.6 PATH COEFFICIENT ANALYSIS

Genotypic correlation coefficients of root weight with yield contributing characters were partitioned into different components to find out the direct and indirect contribution of each character on root weight. Plant height, leaves per plant, leaf length, leaf breadth, foliage weight, root diameter, root length, root: shoot ratio and root weight were selected for path coefficient analysis in beet root. The results are presented in Table 19 and Table 20 respectively.

4.6.1 Varieties

Among the various components, root: shoot ratio (0.687) exerted the highest positive direct effect on root weight followed by root length (0.306), foliage weight (0.244), plant height (0.137) and root diameter (0.059). Leaves per plant (-0.097), leaf length (-0.028) and leaf breadth (-0.175) exhibited negative direct effect on root weight.

Regarding the indirect effects, plant height had positive effects through leaves per plant (0.007), foliage weight (0.153), root diameter (0.028), root length (0.185) and root: shoot ratio (0.251). The negative indirect effects were through leaf length (-0.026) and leaf breadth (-0.130).

Leaves per plant exerted positive indirect effect through leaf breadth (0.087) and foliage weight (0.124) and negative through plant height (-0.010), leaf length (-0.002), root diameter (- 0.019), root length (-0.083) and root: shoot ratio (- 0.448).

The indirect effect of leaf length was positive through plant height (0.128), foliage weight (0.158), root diameter (0.017), root length (0.130) and root: shoot ratio (0.120). The negative indirect effects were through leaf breadth (-0.101) and leaves per plant (-0.007).

Leaf breadth exhibited positive indirect effect through plant height (0.103), leaves per plant (0.048), foliage weight (0.069), root diameter (0.035), root length (0.242), and root: shoot ratio (0.464) and it was negative through leaf length (-0.016).

Table 19. Direct and indirect effects of yield components on root weight of varieties

	Plant height	Leaves per plant	Leaf length	Leaf breadth	Foliage weight at harvest	Root diameter	Root length	Root: shoot ratio
	XI	X2	X3	X4	X5	X6	X7	X8
XI	**0.137**	0.007	-0.026	-0.130	0.153	0.028	0.185	0.251
X2	-0.010	**-0.097**	-0.002	0.087	0.124	-0.019	-0.083	-0.448
X3	0.128	-0.007	**-0.028**	-0.101	0.158	0.017	0.130	0.120
X4	0.103	0.048	-0.016	**-0.175**	0.069	0.035	0.242	0.464
X5	0.086	-0.049	-0.018	-0.049	**0.244**	0.011	0.058	-0.146
X6	0.065	0.031	-0.008	-0.103	0.048	**0.059**	0.221	0.509
X7	0.083	0.026	-0.012	-0.138	0.046	0.042	**0.306**	0.583
X8	0.050	0.063	-0.005	-0.118	-0.052	0.043	0.259	**0.687**

Residual effect = 0.01339

Table 20. Direct and indirect effects of yield components on root weight of hybrids

	Plant height	Leaves per plant	Leaf length	Leaf breadth	Foliage weight at harvest	Root diameter	Root length	Root: shoot ratio
	XI	X2	X3	X4	X5	X6	X7	X8
XI	**-1.535**	0.280	0.186	1.111	-0.138	1.071	-1.015	0.305
X2	-0.700	**0.615**	-0.078	0.609	-0.263	1.182	-1.363	0.370
X3	-1.029	-0.172	**0.278**	0.492	0.098	0.400	-0.196	0.154
X4	-1.072	0.235	0.086	**1.592**	-0.298	1.826	-2.495	0.699
X5	-0.553	0.423	-0.071	1.242	**-0.383**	1.380	-1.99	0.453
X6	-0.532	0.235	0.036	0.94	-0.171	**3.094**	-4.294	1.682
X7	-0.360	0.193	0.013	0.916	-0.176	3.065	**-4.335**	1.675
X8	-0.271	0.132	0.025	0.644	-0.100	3.014	-4.205	**1.727**

Residual effect = 0.01308

Foliage weight exhibited positive indirect effect through plant height (0.086), root diameter (0.011) and root length (0.058). It was negative through leaves per plant (-0.049), leaf length (-0.018), leaf breadth (-0.049) and root: shoot ratio (-0.146).

Root diameter positively influenced root weight indirectly through plant height (0.065), leaves per plant (0.031), foliage weight (0.048), root length (0.221), root: shoot ratio (0.509) and was negative through leaf length (-0.008) and leaf breadth (-0.103).

Root length exerted positive indirect effect through plant height (0.083), leaves per plant (0.026), foliage weight (0.046), root diameter (0.042), root: shoot ratio (0.583) and was negative through leaf length (-0.012) and leaf breadth (-0.138).

The indirect effect of root: shoot ratio was positive through plant height (0.050), number of leaves (0.063), root diameter (0.043) and root length (0.259). The indirect effect was negative through leaf length (-0.005), leaf breadth (-0.118) and foliage weight (-0.052).

4.6.2 Hybrids

Among different components, root diameter (3.094) exerted maximum direct effect on root weight followed by root: shoot ratio (1.727), leaf breadth (1.592), leaves per plant (0.615), and leaf length (0.278). Plant height (-1.535), foliage weight (-0.383) and root length (-4.335) exerted negative direct effect to root weight.

Plant height exhibited positive indirect effect through leaves per plant (0.280), leaf length (0.186), leaf breadth (1.111), root diameter (1.071) root: shoot ratio (0.305) and negative indirect effect through foliage weight (-0.138) and root length (-1.015).

The indirect effect of number of leaves was positive through leaf breadth (0.609), root diameter (1.182) and root: shoot ratio (0.370) and it was negative through plant height (-0.700), leaf length (-0.078), foliage weight (-0.263) and root length (-1.363).

The indirect effect of leaf length was positive through leaf breadth (0.492), foliage weight (0.098), root diameter (0.400) and root: shoot ratio (0.154) and negative through plant height (-1.029), leaves per plant (-0.172) and root length (-0.196).

Leaf breadth exhibited positive indirect effect through number of leaves per plant (0.235), leaf length (0.086), root diameter (1.826) and root: shoot ratio (0.699). It was negative through plant height (-1.072), foliage weight (-0.298) and root length (-2.495).

Foliage weight exerted positive indirect effect through leaves per plant (0.423), leaf breadth (1.242), root diameter (1.380) and root: shoot ratio (0.453) and negative through plant height (-0.553), leaf length (-0.071) and root length (-1.990).

Root diameter positively influenced root weight indirectly through leaves per plant (0.235), leaf length (0.036), leaf breadth (0.940) and root: shoot ratio (1.682). The root weight effect was negative through plant height (-0.532) and foliage weight (-0.171).

Regarding the indirect effects, root length had positive effects through leaves per plant (0.193) leaf length (0.013), leaf breadth (0.916), root diameter (3.065) and root: shoot ratio (1.675). The negative indirect effects were through plant height (-0.360) and foliage weight (-0.176).

The indirect effect of root: shoot ratio was positive through leaves per plant (0.132), leaf length (0.025), leaf breadth (0.644) and root diameter (3.014). The indirect effect was negative through plant height (-0.271), foliage weight (-0.100) and root length (-4.205).

4.7 SELECTION INDEX

Selection index of the varieties and hybrids were computed based on characters having a positive direct effect on root weight, high heritability and high genetic advance as per cent mean. The index value for each variety was determined based on 6 characters *viz.*, plant height (X1), foliage weight (X2), root diameter (X3), root length (X4), root weight (X5) and root: shoot ratio (X6) and the varieties were ranked. The index value for each hybrid was determined based on 6 characters *viz.*, leaves per plant (X1), leaf length (X2), leaf breadth (X3), root diameter (X4), root weight (X5) and root: shoot ratio (X6) and they were ranked. The values obtained for the varieties and the hybrids based on the selection index are given in Table 21 and Table 22 respectively.

Based on the selection index, Madhur ranked first among varieties with a value of 192.52, followed by Tetra (176.69), Mahyco lal II (164.01) and Ruby Queen (Tokita) (160.48) (Plate 10). The lowest value was obtained for Lallan (73.96).

Among the hybrids, Red Star (Sakura) ranked first with a value of 148.90 followed by Ragini (145.91), Red Horse (134.01) and F_1 Kingdom (121.70) (Plate 11). The lowest value was obtained for Red Bull (80.87).

Table 21. Beet root varieties ranked according to selection index

	Varieties	Score	Rank
V1	Madhur	192.52	1
V2	Detroit Dark Red	146.58	6
V3	Crimson Globe	139.69	8
V4	Ruby Queen (Nisco)	124.92	13
V5	Tetra	176.69	2
V6	Ruby Queen (Tokita)	160.48	4
V7	Mahyco Lal II	164.01	3
V8	Royal	145.40	7
V9	K 5340	107.76	17
V10	K 5343	129.66	10
V11	Red Ruby	118.16	16
V12	Red Star (Condor)	118.81	15
V13	K5341	121.28	14
V14	Ruby Queen (Suvarna)	131.04	9
V15	Lallan	73.96	22
V16	Rachna	125.87	12
V17	Ruby Queen (Sulthan)	126.63	11
V18	Indam Ruby Queen	151.48	5

V19	Pure Seeds	77.59	21
V20	BV 20	87.47	18
V21	BV 21	82.59	19
V22	Ruby Queen (Pradham Seeds)	81.43	20

Table 22. Beet root hybrids ranked according to selection index

	Hybrids	Score	Rank
H1	F_1 Kingdom	121.70	4
H2	F_1 Kestral	95.27	7
H3	Red Star (Sakura)	148.90	1
H4	Red Horse	134.01	3
H5	RK777	116.12	5
H6	Remo	98.94	6
H7	Red Bull	80.87	8
H8	Ragini	145.91	2


Madhur


Tetra


Mahyco Lal II


Ruby Queen (Tokita)

Plate 10. Better performed varieties

Red Star (Sakura)

Ragini

Red Horse

F_1 Kingdom

Plate 11. Better performed hybrids

DISCUSSION

5. DISCUSSION

The present investigation was carried out at the Department of Vegetable Science, College of Agriculture, Vellayani, during 2019-2020 to evaluate beet root varieties and hybrids for adaptability in Kerala based on growth, yield and quality. The degree of variability, heritability of the commercially important characters, genetic advance under selection and correlation among the traits were assessed with a view to suggest measures to bring about genetic improvement for yield and its components. The most important results of the present investigation are discussed under the following headings.

5.1 Mean performance of beet root varieties and hybrids

5.2 Coefficient of variation

5.3 Heritability and genetic advance

5.4 Correlation analysis

5.5 Path coefficient analysis

5.6 Selection index

5.1 MEAN PERFORMANCE OF BEET ROOT VARIETIES AND HYBRIDS

5.1.1 Vegetative Characters

In the present study, significant variation was recorded among the varieties and hybrids for all the vegetative characters *viz*. plant height, leaves per plant, leaf length, leaf breadth and foliage weight at harvest.

There was significant difference among the varieties for plant height with a range from 20.43 cm in the variety Pure Seeds to 38.32 cm in Tetra. Among hybrids, Ragini was the tallest (31.07), Remo (30.77) was on par with it and Red Bull, the shortest (26.61cm). This is in agreement with Wotchoko *et al*. (2019) that mean plant height of beet root ranges from 15.51cm to 36.04 cm. Plant height is an indicator of plant vigour, which might contribute to greater productivity.

In the present study, among varieties, the highest number of leaves was recorded by Ruby Queen (Pradham Seeds) (13.45) and the lowest by Red Ruby (7.10). Similar varietal variation in leaves per plant, ranging from 7.95 to 13.41 was reported by Sharma (2013) in beet root. Among hybrids, the highest number of leaves was recorded by Remo (9.79) and the lowest by Red Horse (7.63). Similar varietal variation in plant height and leaves per plant was also reported by Coutinho *et al.* (2018) in beet root, Khogali *et al*. (2012) in fodder beet, Basavaraj (2016) in carrot, Pervez *et al*. (2003) and Dongarwar *et al*. (2018) in radish, which might be attributed to the inherent genetic makeup of the plant and its expression to the growing soil and environmental conditions.

Significant variation was observed among varieties for leaf length which ranged from 18.72 cm in Pure Seeds to 35.61 cm in Tetra. Among hybrids, the highest leaf length of 27.93 cm was recorded in Ragini and the lowest in F_1 Kingdom (20.90 cm). Variation in leaf length from 12.28 to 25.22 cm in beetroot was recorded by Sharma (2013). Taller genotypes had longer leaves compared to shorter ones, both in the varieties and hybrids. There was significant difference among the varieties for leaf breadth, which ranged from 3.52 (Pure Seeds) to 7.75 cm (Crimson Globe). Among the hybrids, the highest leaf breadth was recorded in Ragini (7.00 cm) and the lowest in Red Bull (4.09 cm). Sharma (2013) reported similar variation in leaf breadth of beet root which ranged from 5.26 cm to 9.80 cm.

Number of leaves per plant, leaf length and leaf breadth play an important role in foliage weight. Among varieties, Tetra recorded the highest foliage weight at harvest (62.75 g) and Lallan the lowest (21.77 g). Among hybrids, the highest foliage weight of 31.00 g was recorded in RK 777 and the lowest in Red Bull (19.31 g). Wide variation in shoot weight in diverse carrot genotypes has been recorded by Poleshi *et al.* (2017). Leaf characters give the photosynthetic efficiency of the plant.

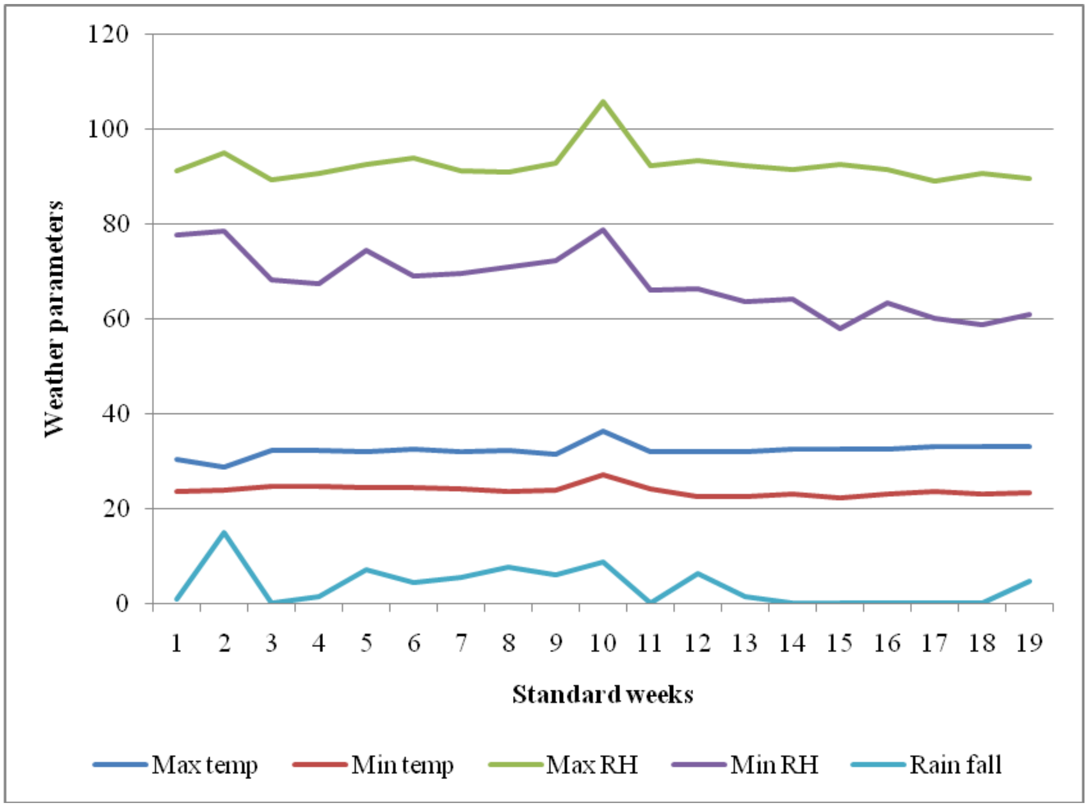


Fig 1. Weather parameters in open field during cropping period (October 2019 to February 2020)

5.1.2 Root and Yield Characters

Significant difference was observed among the varieties and among hybrids for root and yield characters such as root shape, root length, root diameter, root weight, root: shoot ratio, yield per plot and crop duration.

Twenty two varieties exhibited different root shapes *viz*. circular, broad elliptic and narrow elliptic. The hybrids exhibited two root shapes *viz*., broad elliptic and narrow elliptic. Pink (1993) and Ruboczki *et al*. (2015) reported sufficient variation among genotypes for root shape in beet root. Most of the varieties were circular in shape. According to Ruboczki *et al.* (2015), regular spherical shape in beet root is favoured by not only processing industry but also fresh market. Baranski *et al*. (2001) studied the diversity in a collection of 40 accessions of garden beet and reported circular root shape as the most common.

Among the varieties, the longest root of 7.43 cm was recorded by Madhur, while the shortest by Lallan (3.03 cm). Among hybrids, the longest root of 7.41 cm was recorded by Red Star (Sakura) while the shortest by Red Bull (3.43 cm). These results are in consonance with Patel *et al.* (2015) and Coutinho *et al.* (2018) that considerable differences occur among beet root cultivars for length of root.

Among varieties, root diameter ranged from 2.77 cm in Lallan to 5.33 cm in Madhur. Among hybrids, the highest root diameter was recorded in Red Star (Sakura) 5.50 cm, which was on par with Ragini (5.32 cm). The lowest root diameter of 3.02 was recorded in Red Bull. Varietal variation for root diameter in beet root was earlier reported by Coutinho *et al.* (2018). Root diameter has a positive effect on root yield, which is in line with the findings of Dongarwar *et al.* (2018) in radish. Yasaminshirazi *et al*. (2020) reported that roots with a diameter of 5 cm to 13 cm are considered for determining marketable yield in beet root. According to Baranski *et al*. (2001), market roots in garden beet defined roots with 4 to 8 cm diameter. The rapid increase in root width in radish is attributed by Alam *et al*. (2010) to translocation of more photosynthates from leaves to root.

Root weight is a primary character to be considered in any crop improvement programme, as it directly contributes towards yield. Yield is influenced by growth and potential of a cultivar or hybrid. Root weight of varieties ranged from 20.52 g to 118.05 g, the highest being recorded by Madhur and the lowest by Lallan (Fig. 2). Among hybrids, the root weight ranged from 29.70 g (Red Bull) to 91.27g Red Star (Sakura) (Fig. 4). Among the varieties and hybrids, the genotype with the longest root and the highest root diameter recorded the highest root weight also. This is in conformity with the results of Yasaminshirazi *et al.* (2020). Maximum root weight might be because of the genetic capacity of the genotype to make available higher assimilates for root development.

The cultivar differences in root length, root diameter and root weight are in line with the results obtained by Ijoyah *et al.* (2008); Patel *et al*. (2015) and Sharma (2013) in beet root, Basavaraj (2016) and Poleshi *et al*. (2017) in carrot, Pervez *et al*. (2003); Alam *et al.* (2010); Poudel *et al.* (2018) and Dongarwar *et al*. (2018) in radish. This could be due to the difference in genetic makeup of the different varieties and ecological conditions. The varieties Ruby Queen (Pradham seeds) and BV 21 which recorded the highest number of leaves were poor yielders. This conforms with the findings of Coutinho *et al.* (2018) that cultivars with increased number of leaves and lower heights can result in self shadowing, consequently showing a reduction in productivity. In the case of hybrids, higher root weight per plant was due to more number of leaves for photosynthesis and efficient utilization of these photosynthates, might have enhanced the better root length, root width and root yield per plant. This is in agreement with the findings of Patel *et al.* (2015) in beet root and Alam *et al.* (2010) in radish.

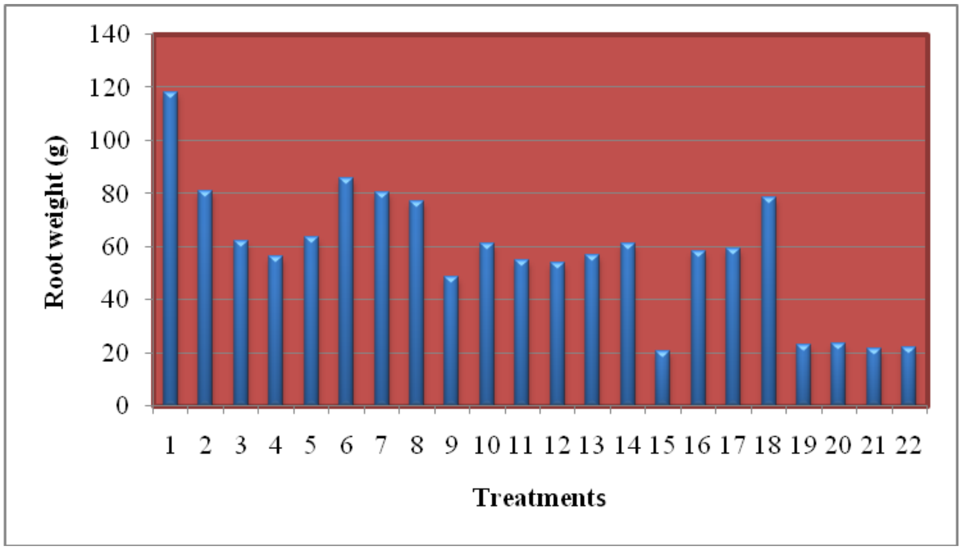


Fig 2. Mean performance of beet root varieties for root weight (g)

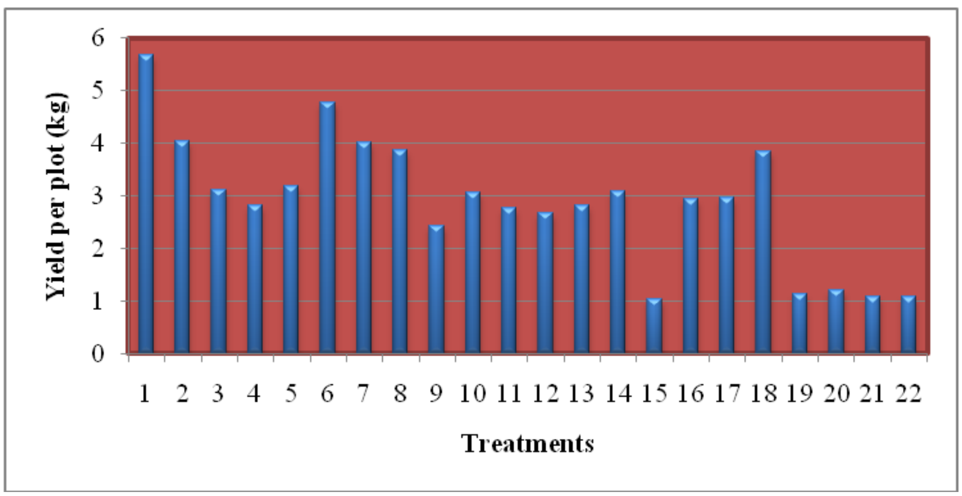


Fig 3. Mean performance of beet root varieties for yield plot^{-1} (kg)

X axis: 1. Madhur 2. Detroit Dark Red 3. Crimson Globe 4. Ruby Queen (Nisco) 5.Tetra 6. Ruby Queen (Tokita) 7. Mahyco Lal II 8. Royal 9. K5340 10. K 5343 11.Red Ruby 12. Red Star (Condor) 13. K5341 14. Ruby Queen (Suvarna) 15. Lallan 16. Rachna 17. Ruby Queen (Sulthan) 18. Indam Ruby Queen 19. Pure Seeds 20. BV 20 21. BV 21 22.Ruby Queen (Pradham Seeds)

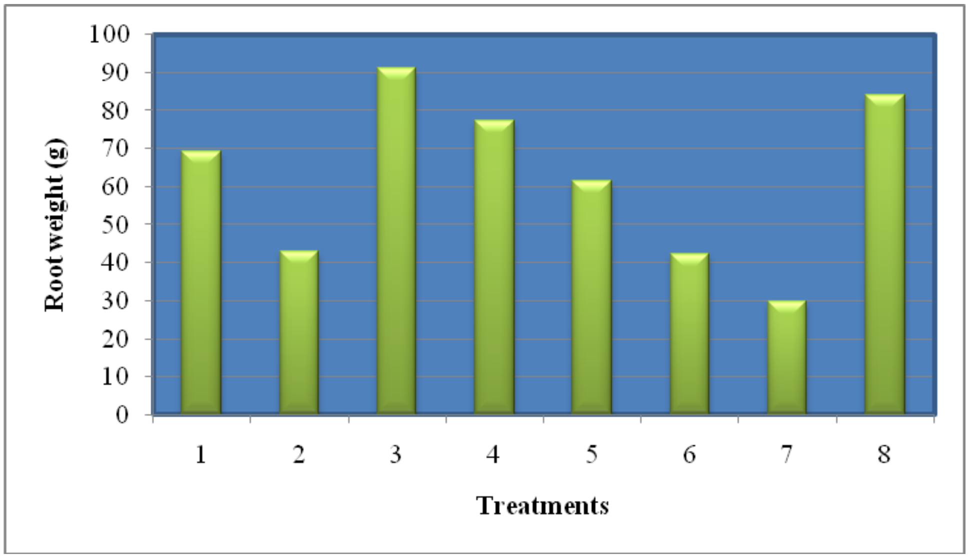


Fig 4. Mean performance of beet root hybrids for root weight (g)

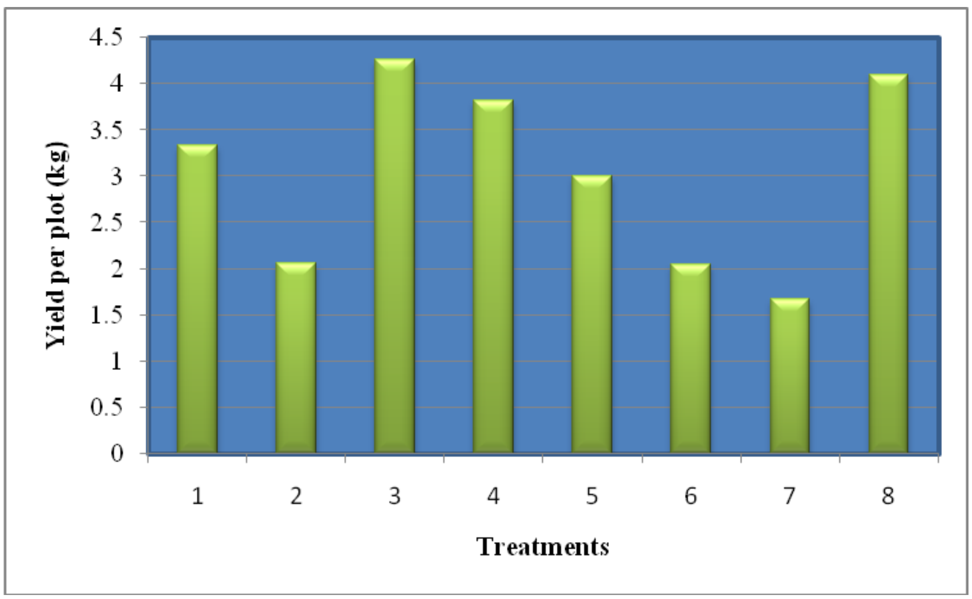


Fig 5. Mean performance of beet root hybrids for yield plot $^{-1}$ (kg)

X axis: F_1 Kingdom 2. F_1 Kestral 3. Red Star (Sakura) 4. Red Horse 5. RK 777 6. Remo 7. Red Bull 8. Ragini

The highest root: shoot ratio was recorded by Madhur (4.42) and the lowest by BV 21 (0.77). Among the hybrids, the highest root: shoot ratio of 3.61 was recorded by Red Star (Sakura) and the lowest by Red Bull (1.54). Similar varietal variation in root: shoot ratio was reported by Sharma (2013) in beet root, Basavaraj (2016) and Poleshi *et al*. (2017) in carrot.

According to Sharma (2013), root yield per plot is one of the most desirable traits attaining highest consideration in any beet root breeding programme. Significant difference was observed among the varieties for root yield per plot. The highest yield plot^{-1} of 5.68 kg was recorded in Madhur and the lowest in Lallan (1.03 kg) (Fig.3). Among hybrids, the highest yield plot^{-1} was recorded by Red Star (Sakura) (4.27 kg) and the lowest by Red Bull (1.67 kg) (Fig.5). Similar varietal variation in root yield per plot was observed by Alam *et al.* (2010) and Dongarwar *et al.* (2018) in radish and Basavaraj (2016) in carrot. Significant variation in yield plot^{-1} might be due to difference in root length, root diameter and root weight, which are the important components of yield. These findings are in line with those of earlier workers - Sharma (2013) in beet root and Basavaraj (2016) in carrot.

Among varieties, Madhur, Tetra and Ruby Queen (Tokita) were early with a crop duration of 96 days. Ruby Queen (Pradham Seeds), BV 20, BV 21, Sulthan, Rachna and Lallan were late with a crop duration of 130 days. Among hybrids, Red Star (Sakura), Red Horse and RK 777 recorded early crop (98 days) and Red Bull, late (130 days). Difference in the crop duration may be due to genetic composition of the genotypes. Ijoyah *et al.* (2008) linked the time of maturity to the genetic control of the beet root varieties, thus the difference in the length of time taken to remain at the vegetative phase before roots are initiated and become matured.

5.1.3 Quality Characters

The varieties and the hybrids recorded significant difference for quality characters such as total soluble solids (T.S.S), carotenoid content, reducing sugars, non reducing sugars and total sugars.

T.S.S is an important quality character, which quantify the concentration of reducing sugars *viz*. fructose and glucose and the non reducing sugars, sucrose which are in correlation with the sweet taste of the root. T.S.S content in beet root is a desirable character since it can be used as salad vegetable. In the present study, the variety K 5340 recorded the highest T.S.S content of 15.70 ^{0}B and Pure Seeds the lowest (6.50 ^{0}B) (Fig. 6). Among hybrids, the highest T.S.S content of 14.50 ^{0}B was recorded by RK 777 and F_1 Kestral (8.10 ^{0}B), the lowest (Fig. 8). These results are in agreement with Sharma (2013). Patel *et al*. (2015) reported T.S.S content of 12.74 ^{0}B and Baliram (2015) 10.42 ^{0}B in beet root.

The variety Mahyco Lal II recorded the highest carotenoid content of 1.5 mg 100 g^{-1} and the lowest was recorded by BV 21 (0.27 mg 100 g^{-1}) (Fig. 7). The carotenoid content of hybrids were in the range of 1.05 mg 100 g^{-1} (Red Bull) to 1.74 mg 100 g^{-1} (Red Horse) (Fig. 9). This difference in carotenoid content could be attributed to the inherent character of the genotypes and environmental conditions. El Beltagi *et al*. (2018) recorded carotenoid content of 1.7 mg 100 g^{-1} in beetroot. Similar reports were made by Sharma (2013) in beet root.

Total sugars varied significantly among varieties and hybrids, which ranged from 4.51 % to 6.45 % and 5.04 % to 6.50 % respectively. The reducing sugar content of varieties ranged from 0.33 % to 1 % and hybrids ranged from 0.46 % to 1 %. Among varieties, Madhur recorded the highest non reducing sugar content of 6.03% and Lallan, the lowest (4.09 %). Among hybrids, Red Star (Sakura) recorded highest non reducing sugar content of 6.04 % and RK 777 the lowest (4.12 %). The variation in quality characters of beet root can be due to the genetic makeup of the cultivars and the environmental conditions. Baliram (2015) reported maximum total sugars 6.27 %, reducing sugars 0.66 % and non reducing sugars 5.67 % in beet root.

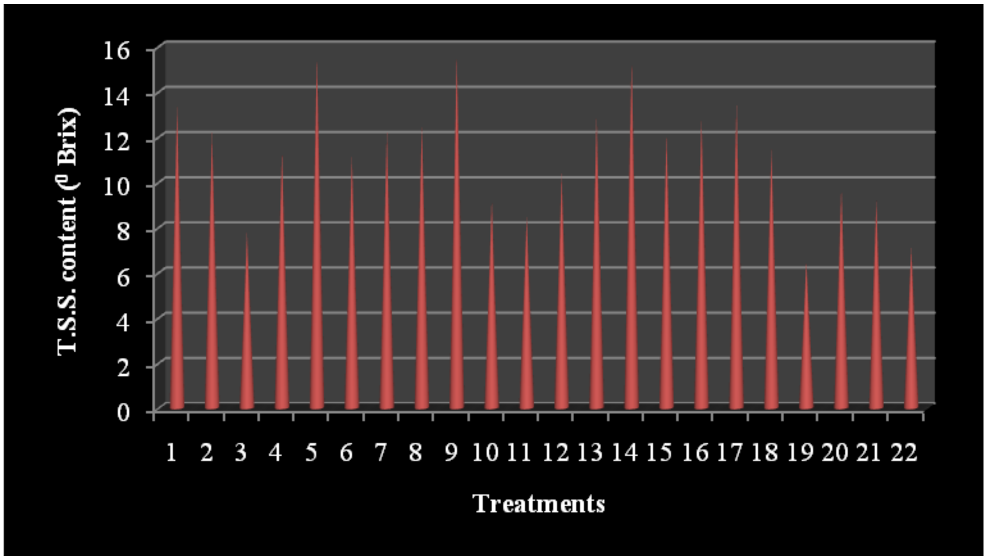


Fig 6. Mean performance of beet root varieties for T.S.S. content (^{0}B)

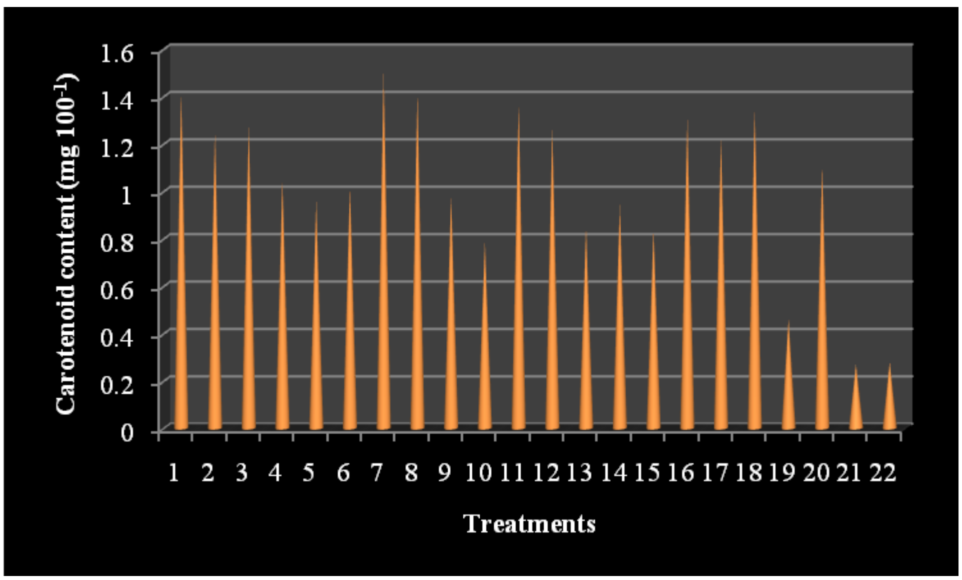


Fig 7. Mean performance of beet root varieties for carotenoid content (mg 100 g^{-1})

X axis: X axis: 1. Madhur 2. Detroit Dark Red 3. Crimson Globe 4. Ruby Queen (Nisco) 5.Tetra 6. Ruby Queen (Tokita) 7. Mahyco Lal II 8. Royal 9. K5340 10. K 5343 11.Red Ruby 12. Red Star (Condor) 13. K5341 14. Ruby Queen (Suvarna) 15. Lallan 16. Rachna 17. Ruby Queen (Sulthan) 18. Indam Ruby Queen 19. Pure Seeds 20. BV 20 21. BV 21 22.Ruby Queen (Pradham Seeds)

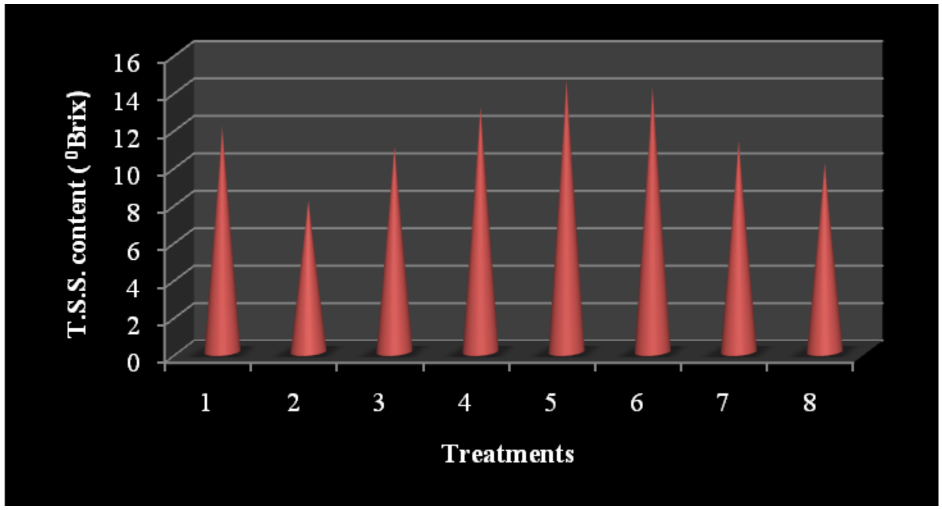


Fig 8. Mean performance of beet root hybrids for T.S.S. content (^{0}B)

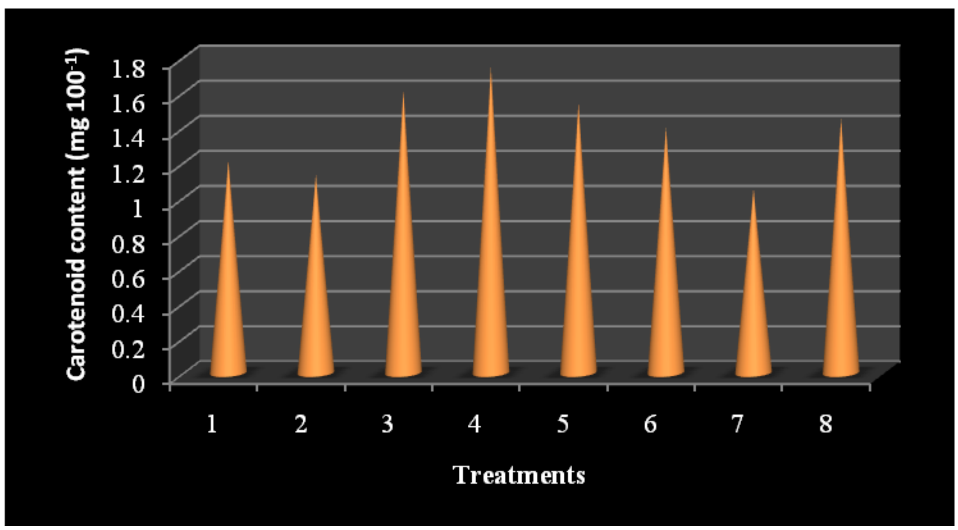


Fig 9. Mean performance of beet root hybrids for carotenoid content (mg100^{-1})

X axis: F_1 Kingdom 2. F_1 Kestral 3. Red Star (Sakura) 4. Red Horse 5. RK777 6. Remo 7. Red Bull 8. Ragini

5.1.4 Organoleptic Evaluation of Beet Root Varieties and Hybrids

The factors critical to consumer acceptance are colour, flavour, texture and nutritional value, in the case of fresh-cut fruits and vegetables (Barrett *et al*., 2010). Instrumental and sensory measurements are used for determining critical quality attributes. According to Bach (2012), sensory analysis is a technique that uses human senses in the evaluation of product qualities.

The sensory analysis of beet root varieties and hybrids were conducted and chi-square test conformed significant difference among the varieties and hybrids. Mean sensory score values revealed that the variety Madhur was superior to other varieties in organoleptic qualities like appearance, taste, colour and overall acceptability. Among the hybrids, Red Star (Sakura) recorded the highest mean score for appearance, colour, taste and overall acceptability.

Hajos and Ruboczki (2012) conducted sensory evaluation of 15 beet root varieties sown under different sowing dates based on inner colour intensity, white ring and taste. Consumer acceptability test in beetroot, as influenced by various levels of nitrogen and phosphorus, was conducted by Baliram (2015) based on appearance, colour, size, taste and softness of root.

5.1.5 Pest and Disease Incidence

During the course of study, the important biotic factors observed were damping off (*Rhizoctonia solani*), cercospora leaf spot (*Cercospora beticola*), web blight (*Rhizoctonia solani*) and leaf webber. Various workers have reported similar pests and diseases in beet root *ie*., damping off caused by *Rhizoctonia solani* by Goldman and Navazio (2003), Kikkert *et al*. (2010); cercopora leaf spot caused by *Cercospora beticola* by Vaghefi *et al.* (2016), Pethybridge *et al.* (2017), Knight *et al*. (2018), Coutinho *et al*. (2018); webblight by *Rhizoctonia solani* by Galvez *et al.* (1989); leaf webber by Nottingham, S. (2004).

5.2 COEFFICIENT OF VARIATION

Estimation of variability in a population provides the base for effective selection. The degree of variability of characters can be determined by values of genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV). In the present study, even though phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the characters, only a small difference was observed between PCV and GCV. This revealed that the existing variability was mainly due to their genetic makeup and greater stability of the characters against environmental fluctuation. Hence selection based on phenotypic characters are more dependable. This similarity between PCV and GCV was reported earlier by Sharma (2013) in beet root, Amin and Singla (2010); Santhi *et al*. (2015); Kur and Jamwal (2015) and Meghasree *et al*. (2018) in carrot, Ullah *et al*. (2010); Kumar *et al.* (2012); Sivathanu *et al*. (2014) and Mallikarjunarao *et al*. (2015) in radish.

High GCV and PCV were recorded for root weight, root: shoot ratio and yield per plot in both the varieties and hybrids. In addition to this, leaf breadth and foliage weight at harvest of varieties and leaf length of hybrids also recorded high GCV and PCV. This indicates that selection based on these characters are more reliable. Root weight recorded the highest GCV and PCV for both varieties and hybrids. High estimates of GCV and PCV was recorded for total yield and root weight by Jain *et al*. (2010); Amin and Singla (2010) and Meghasree *et al.* (2018) in carrot. Kumar *et al*. (2012) reported high coefficients of variability for average root weight and root: top ratio while Mallikarjunarao *et al.* (2015) for yield and root weight in radish.

Moderate PCV and GCV were recorded for plant height, number of leaves, leaf length, root diameter and root length of varieties. Hybrids exhibited moderate GCV and PCV for leaf breadth, foliage weight at harvest and root diameter. These findings are in agreement with the reports of Sharma (2013) in beet root.

Low PCV and GCV were recorded for plant height, number of leaves and leaf length of hybrids. This is consistent with the findings of Santhi *et al*. (2015) and Meghasree *et al*. (2018) in carrot.

5.3 HERITABILITY AND GENETIC ADVANCE

The genotypic coefficient of variation is not enough to estimate the variation that is heritable. Burton (1952) suggested that the GCV, together with high heritability and genetic advance, would provide the best estimate on extent of advance expected from selection. High heritability, combined with high GA, would be more useful in predicting performance of progenies of selected lines and effective selection based on phenotypic performance (Johnson *et al.,* 1955).

In the present investigation, high heritability was observed for all the characters studied. The magnitude of heritability of varieties ranged from 84.96 to 99.48% and the highest heritability was recorded for root: shoot ratio followed by yield per plot, root diameter, root weight, foliage weight at harvest, plant height, leaf breadth, leaf length and number of leaves. The magnitude of heritability of hybrids ranged from 76.24 to 99.79% and the highest heritability was observed for root weight followed by root length, yield per plot, root diameter, root: shoot ratio, leaf length, foliage weight at harvest, leaf breadth, number of leaves and plant height. High heritability points out that phenotype of the character is the expression of genotypic constitution of that character. So, consistent selection could be made for these traits on the basis of phenotypic expression. These results are in line with Sharma (2013) in beet root, Amin and Singla (2010); Jain *et al*. (2010) and Meghasree *et al*. (2018) in carrot, Ullah *et al*. (2010) and Kumar *et al*. (2012) in radish.

High heritability combined with high genetic advance as per cent of mean was observed for all characters in varieties and the characters *viz*., leaf breadth, foliage weight, root diameter, root length, root: shoot ratio and yield per plot in hybrids. All these characters are controlled by additive genes and least influenced by environmental factors.

So these characters can be easily improved by selection methods. This result is in compliance with earlier researchers like Sharma (2013) in beet root, Ullah *et al.* (2010); Kumar *et al*. (2012) and Mallikarjunarao *et al*. (2015) in radish, Amin and Singla (2010); Sivanthanu *et al*. (2014) and Meghasree *et al*. (2018) in carrot.

High heritability combined with moderate genetic advance as per cent of mean was observed for plant height, number of leaves and leaf length in beet root hybrids. Similar result was reported by Amin and Singla (2010) in carrot. This indicates the predominance of non-additive gene action and influence of environment. So these characters can be partially improved by selection methods.

5.4 CORRELATION STUDIES

Yield is a result of interactions of numerous organized characters. Yield improvement and selection become more worthwhile when it is based on these component characters. Information on the magnitude and direction of component characters with root yield and interrelation among themselves is useful in formulating effective selection criteria for yield improvement (Breese and Haywards, 1972).

In the current study, for most of the characters the genotypic correlation coefficient was higher in magnitude than the corresponding phenotypic correlation coefficient. This indicates the low effect of environment on the character expression as reported by Sharma (2013) and Naseeruddin *et al*. (2018). In a few cases, phenotypic correlation coefficient was higher than genotypic correlation indicating suppressing effect of the environment which modified the expression of the characters at phenotypic level (Ullah *et al*. 2010).

Root weight of varieties was found to be significantly and positively associated with leaf length, leaf breadth, root diameter, root length, root: shoot ratio, yield per plot whereas significantly and negatively with number of leaves at genotypic and phenotypic levels. Root weight of hybrids recorded significant positive correlation with foliage weight, root length, root diameter, root: shoot ratio and yield per plot at genotypic and phenotypic levels. Significant positive correlation of root weight with root length and root diameter has also been reported by Sharma (2013) in beet root, Ullah *et al*. (2010) and Panwar *et al*. (2003) in radish, Kur and Jamwal (2015) and Basavaraj (2016) in carrot.

Plant height was significantly and positively correlated with root weight. This is in agreement with the findings of Ullah *et al*. (2010) and Naseeruddin *et al*. (2018) in radish. The correlation of root weight with leaf length and leaf breadth was positive and significant, in consonance with the reports of Sharma (2013) in beet root, Ullah *et al*. (2010) in radish, Basavaraj (2016) in carrot. Significant positive correlation of root weight with root: shoot ratio and yield per plot has also been reported by Sharma (2013) in beet root and Kur and Jamwal, (2015) in carrot. Correlation of yield per plot with plant height, root weight, root length and root diameter were significant and positive. This is in agreement with Sharma (2013) in beet root, Basavaraj (2016) in carrot, Nagar *et al*. (2016) in radish. Foliage weight exhibited significant positive correlation with root weight. This conforms with Basavaraj (2016) and Naseeruddin *et al*. (2018) in carrot.

5.5 PATH COEFFICIENT ANALYSIS

A simple measure of correlation between characters with yield is inadequate, as it reflects only the positive and negative associations of different characters with yield and also among themselves. Path analysis was applied to partition correlation into direct and indirect effects (Dewey and Lu, 1959).

In this study, path coefficient analysis was used to separate the genotypic correlation coefficients of root weight of varieties and the hybrids with plant height, leaves per plant, leaf length, leaf breadth, foliage weight, root diameter, root length and root: shoot ratio into direct and indirect effects.

Among yield attributes of the varieties, root: shoot ratio (0.687) exhibited the highest positive direct effect on root weight followed by root length (0.306). Root: shoot ratio and root length also showed positive correlation with root weight. This indicated that direct selection based on root: shoot ratio and root length would result in appreciable improvement of root weight. These findings are in agreement with Sharma (2013) in beet root.

Root diameter and plant height exerted a positive direct effect on root weight which is in accordance with Ullah *et al*. (2010) in radish. Number of leaves per plant exerted negative correlation on root weight which is in conformity with Teli *et al*. (2017) in carrot. Leaf length and leaf breadth had negative direct effect on root weight which is in compliance with Ullah *et al.* (2010) in radish. Path coefficient analysis revealed that root: shoot ratio and root length had the highest indirect positive effect on root weight through root length and root: shoot ratio respectively.

Among yield attributes of hybrids, root diameter (3.094) followed by root: shoot ratio (1.727) exhibited highest positive direct effect on root weight. Root diameter and root: shoot ratio showed positive correlation with root weight. This indicated that direct selection based on root diameter and root: shoot ratio would result in considerable improvement of root weight. These findings are in agreement with Sharma (2013) in beet root and Ullah *et al.* (2010) in radish.

Leaf number and leaf length had positive direct effects on root weight which was in accordance with Mallikarjunarao *et al*. (2015). The characters like plant height, foliage weight and root length showed negative direct effects with root weight of hybrids which is in conformity with Ullah *et al.* (2010); Nagar *et al*. (2016) and Naseeruddin *et al*. (2018) in radish. Root diameter and root: shoot ratio had the highest indirect positive effect on root weight through root: shoot ratio and root diameter respectively. The indirect effects suggested that selection for any of these two characters would improve the yield through the associated character.

Therefore, it can be concluded that the foremost yield contributing characters in varieties were root: shoot ratio and root length, whereas that in hybrids were root: shoot ratio and root diameter because of its high, positive direct effect and positive correlation with root weight. Since these characters also have high level of heritability and genetic advance, they can be considered for improvement of yield in beet root.

5.6 SELECTION INDEX

Selection index helps to select the best suitable genotypes in any breeding programme based on a minimum number of reliable and effective characters. Fisher (1936) developed discriminant function analysis, which provides information on the proportionate weightage to be given to yield components. According to Hazel (1943), the selection index based on a suitable index was more competent than individual selection based on individual characters.

In the present investigation, selection index of the varieties and hybrids were computed based on characters having a positive direct effect on root yield, high heritability and high genetic advance as per cent mean. The index value for each variety was determined based on 6 characters *viz.*, plant height, foliage weight, root diameter, root length, root weight and root: shoot ratio. Based on the selection index values, top ranking varieties namely Madhur (192.52), Tetra (176.69), Mahyco Lal II (164.01) and Ruby Queen (Tokita) (160.48) were identified as superior ones. The characters used for constructing selection index of hybrids were leaves per plant, leaf length, leaf breadth, root diameter, root weight and root: shoot ratio. Ranking based on the selection index showed Red Star (Sakura) (148.90) was the most superior one followed by Ragini (145.91), Red Horse (134.01) and F_1 Kingdom (121.70).

SUMMARY

6. SUMMARY

The present investigation entitled "Performance of beet root (*Beta vulgaris* L.) for growth, yield and quality" was carried out at the Department of Vegetable Science, College of Agriculture, Kerala Agricultural University, Vellayani, during 2019-2020 with the objective to test the adaptability of beet root in Kerala based on growth, yield and quality.

In the experiment, thirty genotypes consisting of 22 varieties and 8 hybrids of beet root, collected from public and private sectors, were evaluated for growth, yield and quality. The evaluation was done in RBD with three replications. The degree of variability, heritability and genetic advance of important characters were assessed. The magnitude and direction of association between various characters and the direct and indirect effects of various components on yield were also analysed. The salient findings of the investigation are summarized below.

Observations were recorded on vegetative, root and yield characters *viz.,* plant height, leaves per plant, leaf length, leaf breadth, root shape, root length, root diameter, root weight, root: shoot ratio, yield per plot and crop duration. In addition, the quality characters *viz.*, T.S.S, carotenoid content, total sugars, reducing sugars and non reducing sugars were also recorded.

The results on the analysis of variance for the experimental design revealed that the mean sum of squares due to genotypes were significant for all the characters studied. Among the varieties, Tetra recorded the highest plant height of 38.32 cm and among hybrids, Ragini was the tallest (31.07 cm) and Remo (30.77 cm) was on par with it. The highest number of leaves was recorded in Ruby Queen (Pradham Seeds) (13.45) among varieties. BV 21 (12.96) and Tetra (12.65) were on par with it. Among hybrids, Remo (9.79) recorded the highest number of leaves, Red Star (Sakura) (9.70) being on par with it. The highest leaf length was recorded in Tetra (35.61 cm) among varieties and Ragini (27.93 cm) among hybrids. The highest leaf breadth of 7.75 cm was recorded in Crimson Globe among varieties. Among hybrids, the highest leaf breadth of 7.00 cm was recorded in Ragini, which was statistically on par with RK 777 (6.60 cm). The highest foliage weight at harvest was recorded by Tetra (62.75 g) among varieties and RK 777 (31.00 g) among hybrids.

Among the 22 varieties, fifteen varieties *viz.*, Madhur, Detroit Dark Red, Ruby Queen (Nisco), Tetra, Ruby Queen (Tokita), Mahyco Lal II, K 5340, K 5343, Red Ruby, Red star (Condor), K 5341, Ruby Queen (Suvarna), Rachna, Ruby Queen (Sulthan) and Indam Ruby Queen exhibited circular shaped root, five varieties *viz*., Lallan, Pure Seeds, BV 20, BV 21 and Ruby Queen (Pradham Seeds) exhibited narrow elliptic shaped roots and two varieties *viz*., Crimson Globe and Royal displayed broad elliptic shaped roots. Four hybrids *viz.*, F_1 Kingdom, Red Star (Sakura), RK 777, and Ragini exhibited broad elliptic shaped roots, while four hybrids *viz*., F_1 Kestral, Red Horse, Remo and Red Bull displayed narrow elliptic shaped roots. Madhur recorded the highest root length of 7.43 cm among varieties and Red Star (Sakura) among hybrids (7.41 cm). The highest root diameter was observed for Madhur (5.33) among varieties and Ruby Queen (Tokita) (5.25 cm), Detroit Dark Red (5.16 cm) and Mahyco Lal II (5.15 cm) were statistically on par with it. Among hybrids, the highest root diameter was recorded in Red Star (Sakura) 5.50 cm, which was on par with Ragini (5.32 cm). The highest root weight of 118.05 g was observed in Madhur among varieties and Red Star (Sakura) among hybrids (91.27 g). The highest root: shoot ratio was recorded by Madhur (4.42) among varieties and Red Star (Sakura) (3.61) among hybrids. Madhur recorded the highest yield plot^{-1} of 5.68 kg among varieties and Red Star (Sakura) among hybrids (4.27 kg). An early crop of 96 days duration was observed in Madhur, Tetra and Ruby Queen (Tokita). The varieties, Ruby Queen (Pradham Seeds), BV 20, BV 21, Pure seeds, Ruby Queen (Sulthan), Rachna and Lallan were late to harvest (130 days). Among the hybrids, Red Star (Sakura), Red Horse and RK 777 recorded early crop (98 days) and Red Bull, late (130 days).

T.S.S content was the highest for the variety K 5340 (15.70^{0}B) and hybrid RK 777 (14.50^{0}B). The highest carotenoid content was recorded for Mahyco Lal II among varieties (1.50 mg 100g^{-1}) and Red Horse among hybrids (1.74 mg 100g^{-1}). Madhur recorded the highest non reducing sugars (6.03 %) and total sugars (6.45%) among varieties, while Sakura Red Star among hybrids (6.04 % and 6.50 % respectively). Among varieties, Crimson Globe recorded the highest reducing sugars (1 %) and RK 777 (1 %) among hybrids. Incidence of damping off, cercospora leaf spot, web blight and leaf webber were the major problems observed during the study. Sensory evaluation revealed the superiority of the variety Madhur and the hybrid Red Star (Sakura) for appearance, colour, taste and overall acceptability over other varieties and hybrids.

High phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for the characters *viz*. leaf breadth (22.34 and 21.41), foliage weight (30.53 and 30.14), root weight (45.22 and 44.69), root: shoot ratio (42.95 and 42.83) and yield per plot (43.06 and 42.76) among varieties. For hybrids, high PCV and GCV was observed for root length (25.69 and 25.66), root weight (35.53 and 35.57), root: shoot ratio (32.66 and 32.15) and yield per plot (33.31 and 33.15). For both varieties and hybrids, GCV was near to PCV for all the characters, which revealed that the existing variability was mainly due to their genetic makeup and greater stability of the characters against environmental fluctuation. For both the varieties and hybrids, high estimates of heritability coupled with moderate to high genetic advance as per cent of mean was recorded for all the yield components, indicating additive gene action.

Root weight of varieties had significant positive association at genotypic and phenotypic level with yield per plot (0.996 and 0.994), root: shoot ratio (0.928 and 0.920), plant height (0.605 and 0.584), root length (0.936 and 0.911), root diameter (0.821 and 0.812), leaf breadth (0.770 and 0.740) and leaf length (0.418 and 0.404). Root weight had a significant but negative correlation with number of leaves (-0.449 and -0.418). Root weight of hybrids had significant positive correlation at genotypic and phenotypic level with root yield per plot (0.997 and 0.995), root: shoot ratio (0.966 and 0.949), root length (0.992 and 0.992), root diameter (0.991 and 0.986), leaf breadth (0.574 and 0.520) and foliage weight (0.502 and 0.459).

Path coefficient analysis of varieties revealed that root: shoot ratio (0.687) exerted the highest positive direct effect on root weight followed by root length (0.306), foliage weight (0.244), plant height (0.137) and root diameter (0.059). Among different components, root diameter (3.094) exerted a maximum direct effect on root weight of hybrids followed by root: shoot ratio (1.727), leaf breadth (1.592), leaves per plant (0.615) and leaf length (0.278).

The varieties were ranked based on selection index score considering the characters *viz*. plant height, foliage weight, root length, root diameter, root weight, root: shoot ratio and yield per plot. Based on the selection index values, top ranking varieties namely Madhur (192.52), Tetra (176.69), Mahyco Lal II (164.01) and Ruby Queen (Tokita) (160.48) were identified as superior ones. The hybrids were ranked based on selection index score considering the characters *viz*. leaves per plant, leaf length, leaf breadth, root diameter, root weight and root: shoot ratio. Ranking based on the selection index showed Red Star (Sakura) (148.90) as the most superior one followed by Ragini (145.91), Red Horse (134.01) and F_1 Kingdom (121.70).

Based on the mean performance of the varieties and the hybrids for various characters and selection index score, the top ranking varieties Madhur, Tetra, Mahyco Lal II and Ruby Queen (Tokita) and the hybrids Red Star (Sakura), Ragini, Red Horse and F_1 Kingdom were found suitable for growing under Kerala conditions.

FUTURE LINE OF WORK

The superior varieties identified Madhur, Tetra, Mahyco Lal II and Ruby Queen (Tokita) and hybrids Red Star (Sakura), Ragini, Red Horse and F_1 Kingdom can be grown in the open field in a larger area for confirmation of the results and if found superior can be recommended for commercial cultivation in Kerala.

REFERENCES

7. REFERENCES

Ahmad, S., Zubair, M., Iqbal, N., Cheema, N. M., and Mahmood, K. 2012. Evaluation of sugar beet hybrid varieties under Thal-Kumbi soil series of Pakistan. *Int. J. Agric. Biol.* 14(4): 605-608.

Alam, M. K., Farooque, A. M., Nuruzzaman, M., and Uddin, A. F. M. J. 2010. Effect of sowing time on growth and yield of three radish (*Raphanus sativus* L.) varieties. *Bangladesh Res. Pub. J.* 3(3): 998-1006.

Albayrak, S. and Yuksel, O. 2010. Effects of nitrogen fertilization and harvest time on root yield and quality of fodder beet (*Beta vulgaris* var. *crassaMans*f.). *Turkish J. Field Crops* 15(1): 59-64.

Allard, R. W. 1960. Hybrid vigour and genetic control of some quantitative traits of tomato (*Solanum lycopersicum* L.). *Open J. genet*. 4(1): 485.

Amin, A. and Singla, J. 2010. Genetic variability, heritability and genetic advance studies in Carrot (*Daucus carota* var. *sativa* L.). *Electr. J. Plant Breed.* 1(6): 1504-1508.

Bach, V. 2012. Sensory quality and chemical composition of culinary preparations of root crops. PhD thesis, Aarhus University, Denmark, 68p.

Baliram, S. S. 2015. Effect of nitrogen and phosphorus on growth, yield and quality of beet root (*Beta Vulgaris* L.*)*. M.Sc. (Hortic.) thesis, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, 55p.

Baranski, R., Grzebelus, D., and Frese, L. 2001. Estimation of genetic diversity in a collection of the garden beet group. *Euphytica* 122(1): 19-29.

Barrett, D. M., Beaulieu, J. C., and Shewfelt, R. 2010. Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement, and the effects of processing. *Crit. Rev. food sci. nutr.* 50(5): 369-389.

Basavaraj, V. S. 2016. Performance evaluation and standardization of planting time in carrot *(Daucus carota*L.*)*. PhD. thesis, Kerala Agricultural University, Thrissur, 210p.

Bauskar, A. 2015. Effect of different dates of sowing and spacing on growth and yield of beet root (*Beta vulgaris* L.) cv. Red Queen. M.Sc. (Hortic.) thesis, Rajmata VijayarajeScindia Krishi Vishwa Vidyalaya, Gwalior, 45p.

Benjamin, L. R., Sutherland, R. A., and Senior, D. 1985. The influence of sowing rate and row spacing on the plant density and yield of red beet. *J. Agric. Sci.* 104(3): 615-624.

Bhat, K. L. 2007. *Minor vegetables- Untrapped potential*. Kalyani publishers, New Delhi, 145p.

Biancardi, E., Panella, L. W., and Lewellen, R. T. 2012. *Beta maritime: The origin of beets*, Springer, New York, USA. 7p.

Breese, E. L. and Hayward M. D. 1972. The genetic basis of present breeding methods in forage crops. *Euphytica* 21: 324-336.

Burton, G. W. 1952. Variability, heritability and genetic advance in mulberry (*Morus* spp.) for growth and yield attributes. *Open J. genet.* 1: 277-283.

Campbell, G.K.G. 1979. *Sugar beet in evolution of crop plants,* (Simmonds, N.W., Ed.). Longmans, N.Y. Green, London. 130p.

Chawla, H., Parle, M., Sharma, K., and Yadav, M. 2016. Beetroot: A health promoting functional food. *Inventi. Rapid: Nutraceuticals* 1(1):0976-3872.

Chhikara, N., Kushwaha, K., Sharma, P., Gat,Y., and Panghal, A. 2018. Bioactive compounds of beetroot and utilization in food processing industry: a critical review. *Food Chem*. 272:192-200.

Clifford, T., Howatson, G. West, D. J., and Stevenson, E. J. 2015. The potential benefits of red beetroot supplementation in health and disease. *Nutrients* 7(4): 2801–2822.

Coutinho, P. W., Echer, M. M., Oliveira, P. S., Dalastra, G. M., Cadorin, D. A., and Vanelli, J. 2018. Productivity and qualitative characteristics of varieties of beets. *J. Agri. Sci.* 10(6): 327-333.

Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J*. 51: 515-518.

Dhillon, H. S., Dhillon, T. S., and Devi, R. 2016. Quality characterization in carrot (*Daucus carota* L.) germplasm. *Indian J. Ecol.* 43(1):010-013.

Dongarwar, L. N. Sumedh, R., Kashiwar, S. R., Ghawade, S. M., and Dongarwar, U. R. 2018. Varietal Performance of Radish (*Raphanus sativus* L.) Varieties in Black Soils of Vidharbha – Maharashtra. *Int. J. Curr. Microbiol. App. Sci*. 7(1): 491-501.

El Sherbeny, M. R. and Da Silva, J. A. T. 2013. Foliar treatment with proline and tyrosine affect the growth and yield of beetroot and some pigments in beetroot leaves. *J. Hortic. Res.* 21(2): 95-99.

El Beltagi, H. S., Mohamed, H. I., Megahed, B. M., Gamal, M., and Safwat, G. 2018. Evaluation of some chemical constituents, antioxidant, antibacterial and anticancer activities of *Beta vulgaris* L. root. *Freseius Environ. Bull*. 27 (9): 6369-6378.

Feller, C. and Fink, M. 2004. Nitrate content, soluble solids content, and yield of table beet as affected by cultivar, sowing date and nitrogen supply. *Hort. Sci.* 39(6):1255-1259.

Fisher, R. H. 1936. The use of multiple measurements in taxonomic problems. *Ann. Eugenics* 7: 179-188.

Gaharwar, A. M., Ughade, J. D., and Patil, N. V. 2017. Growth and productivity of beet root (*Beta vulgaris* L.) with monetary returns as affected by different spacings. *Asian J. Bio Sci.* 12(2): 189-193.

Galvez, G. E., Mora, B., and Pastor-Corrales, M. A. 1989. Web blight. *Bean production problems in the tropics.* CIAT, Cali, pp. 195-259.

Georgiev, V. G., Weber, J., Kneschke, E. M., Denev, P. N., Bley, T., and Pavlov, A. I. 2010. Antioxidant activity and phenolic content of betalain extracts from intact plants and hairy root cultures of the red beetroot *Beta vulgaris* cv. Detroit dark red. *Plant foods hum. nutr.* 65(2): 105-111.

Goldman, I. L. 1995. Differential effect of population density on shape and size of cylindrical red beet genotypes. *J. Amer. Soc. Hort. Sci.* 120(6):906-908.

Goldman, I. L. and Navazio, J. P. 2003. History and breeding of table beet in the United States. *Plant Breed. Rev.* 22: 357-388.

Gujar, G. M. 2013. Studies on dual inoculation of Gluconactobacter and Vesicular Arbuscular Mycorrhiza on growth, nutrient uptake and yield of beet root (*Beta vulgaris* L.). M.Sc (Hortic.) thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri. 97p.

Hajos, M. T. and Ruboczki, T. 2012. Effects of environmental factors on morphological and quality parameters of table beet root. *Int. J. Hortic. Sci.* 18(2): 139-146.

Hazel, L. N. 1943. The genetic basis for constructing selection index. *Genet*. 28: 476-490.

Ijoyah, M. O., Sophie, V. L., and Rakotomavo, H. 2008. Yield performance of four beetroot (*Beta vulgaris* L.) varieties compared with the local variety under open field conditions in Seychelles. *Agro. Sci.* 7(2): 139-142.

IPGRI [International Plant Genetic Recourses Institute]. 1995. *Descriptors for Beta* (*Beta* spp.). Rome, Italy, 37p.

Jagosz, B. 2018. Research on nutritive value of selected mono-and multigerm breeding lines and cultivars of red beet roots. *J. Elementology* 23(3): 838-847

Jain, Y. P., Dod, V. N., Nagare, P. K., and Kale, V. S. 2010. Genetic variability in carrot (*Daucus carota* L.). *Asian J. Hortic.* 5(2): 514-516.

Johnson, H. W., Robinson, H. F., and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soyabeans. *Agron. J.* 47: 314-318.

Kadam, V. D., Shinde, S. J., and Satav, D. C. 2018. Effect of different spacing and fertilizer levels on yield and economics of beet root *(Beta vulgaris* L.). *J. Pharmacognosy and Phytochemistry* 7(6): 31-35.

Kale, R., Sawate, A., Kshirsagar, R., Patil, B., and Mane, R. 2018. Studies on evaluation of physical and chemical composition of beetroot (*Beta vulgaris* L.). *Int. J. Clin. Sci*. 6 (2): 2977-79.

Kanner, J., Harel, S., and Granit, R. 2001. Betalains a new class of dietary cationized antioxidants. *J. Agric. Food chem.* 49(11): 5178-5185.

KAU [Kerala Agricultural University]. 2016. *Package of Practices Recommendations*: *Crops* (15th Ed.) Kerala Agricultural University, Thrissur. 393 p.

Kaur, P., Cheema, D. S., and Chawla, N. 2005. Genetic variability, heritability and genetic advance for quality traits in carrot (*Daucus Carota* L.). *J. Appl. Hortic.* 7(2): 130-132.

Khogali, M. E., Dagash, Y. M., and EL-Hag, M.G. 2012. Effect of nitrogen and spacing on growth of fodder beet (*Brassica vulgaris* L. var. *Crassa*) cultivar under Sudan condition. *J. Pharma. sci. innovation* 2(5): 791-798.

Kibatu, T. and Mamo, M. 2014. Vermicompost and vermiwash on growth, yield and yield components of beetroot (*Beta vulgaris* L.). *World Appl. Sci. J*. 32(2): 177-182.

Kikkert, J. R., Reiners, S., and Gugino, B. K. 2010. Row width, population density, and harvest date effects on marketable yield of table beet. *Hort. Technol*. 20(3): 560-567.

Knight, N. L., Vaghefi, N., Hansen, Z. R., Kikkert, J. R., and Pethybridge, S. J. 2018. Temporal genetic differentiation of *Cercosporabeticola* populations in New York table beet fields. *Plant Dis.* 102(11): 2074-2082.

Kumar, A. J., Rangaswamy, E., Khanagoudar, S., and Sreeramulu, K. R. 2014. Effect of microbial inoculants on the nutrient uptake and yield of beet root (*Beta vulgaris* L.). *Curr. Agri. Res.* 2(2): 123- 130.

Kumar, R., Sharma, R., Gupta, R. K., and Singh, M. 2012. Determination of genetic variability and divergence for root yield and quality characters in temperate radishes. *Int. J. Veg. Sci.* 18(4): 307-318.

Kur, N. T. and Jamiwal, R. 2015. Correlation coefficient and path analysis study in european carrot (*Daucus carota* L.). *An. Biol.* 31(1): 97-100.

Lane, J. H. and Eynon, L. 1923. Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *J. Soc. Chem. Ind. Trans.* 32-36.

Lundberg, J. O., Weitzberg, E., and Gladwin, M. T. 2008. The nitrate-nitrite-nitric oxide pathway in physiology and therapautics. *Nat. Rev.Drug Discovery* 7(2): 156-167.

Magro, F.O., da Silva, E.G., Takata, W.H.S., Cardoso, A.I.I., Fernandes, D.M., and Evangelista, R. M. 2015. Organic compost and potassium top dressing fertilization on production and quality of beetroot. *Aust. J. Crop Sci.* 9 (10): 962.

Mallikarjunarao, K., Singh, P. K., Vaidya, A., Pradhan, R., and Das, R. K. 2015. Genetic variability and selection parameters for different genotypes of radish (*Raphanus sativus* L.) under Kashmir valley. *Ecol. Environ. Conserv*. 21(4): 361-364.

Mbithi, M. A., Mwanarusi, S., and Mwangi, M. 2015. Effect of different rates of vermicompost on growth and yield of beetroot (*Beta vulgaris* L.). *Egerton J. Sci. Technol*. 15: 30- 43.

Meghashree, J. R., Hanchinamani, C. N., Hadimani, H. P., Nishani, S., Ramanagouda, S. H., and Kamble, C. 2018. Genetic variability studies for different attributes in carrot genotypes (*Daucus carota* L.) under Kharif Season. *Int. J. Curr. Microbiol. App. Sci*. 7 (12): 3419-3426

Murumkar, A. R., Umesha, B., Palanisamy, D., Bosu, S. S., and Durairaj, C. D. 2012. Evaluation of soil less media for beet root under protected cultivation. *Environ. Ecol.* 30(2): 332-335.

Mtsweni, D. 2019. Effect of plant density on production of *Beta vulgaris* grown in sacks. [Online].Available:http://www.academia.edu/download/60820646/Effect_of_plant_density_on_Beta_vulgaris_planted_in_sacks20191007-113619-1gk2hs3.pdf. [24 Aug. 2020]

Nagar, S. K., Paliwal, A., Tiwari, D., Upadhyay, S., and Bahuguna, P. 2016. Genetic variability, correlation and path study in radish (*Raphanus sativus* L.) under near temperate conditions of Garhwal hills. *Int. J. Sci. Res. Dev*. 4(9):174-176.

Naseeruddin, K. H., Singh, V., Pant, S. C., and Rana, D. K. 2018. Association and path correlation studies in radish (*Raphanus sativus* L.) under valley condition of Uttarakhand. *J. Pharmacognosy Phytochemistry* 7(1): 2298-2302.

Nath, P., Velayudhan, S., and Singh, D. P. 1987. *Vegetables for the tropical region*. ICAR, New Delhi, pp. 60-61.

Neha, P., Sk, J., Nk, J., and Hk, J. 2018. Chemical and functional properties of Beetroot (*Beta vulgaris* L.) for product development: A review. *Int. J. Chem. Stud*. 6:3190-3194.

Nilson, T. 1973.The pigment content in Beet root with regard to cultivar, growth development and growth conditions. *Sweidsh J. Agric. Res.* 3: 197-200.

Nottingham, S. 2004. *Stephen Nottingham's meticulously researched online book*, *Beetroot* [e-book]. Available: http://www.stephennottingham.co.uk/beetroot6.htm. [30 Aug. 2020].

Panse, V. G. and Sukhatme, P. V. 1985. *Statistical Methods for Agricultural Workers* (4^{th} Ed.). Indian Council of Agricultural Research, New Delhi, 347p.

Panwar, A. S., Kashyap, A. S., and Bawaja, H. S. 2003. Correlation between yield and yield parameters in radish (*Raphanus sativus*). *Indian J. Hill Farming* 16(2): 53-55.

Patel, H. T., Sharma, M. K., and Varma, L. R. 2015. Effect of planting date and spacing on growth, yield and quality of beet root (*Beta vulgaris* L.) cultivars under North Gujarat climatic conditions. *Int. J. Agric. Sci. Res*. 5(4): 119-125.

Pervez, M. A., Ayyub, C. M., Iqbal, C. Z., and Saleem, B. A. 2003. Growth and yield response of various radish (*Raphanus sativus* L.) cultivars under Faisalabad conditions. *Pak. J. Life Soc. Sci*. 1(2): 155-157.

Pethybridge, S. J., Vaghefi, N., and Kikkert, J. R. 2017. Horticultural characteristics and susceptibility of table beet cultivars to Cercospora leaf spot in New York. *Hort. Technol.* 27(4): 530-538.

Pink, D. A. C. 1993. Beetroot: *Beta vulgaris subsp. vulgaris*. In: *Genetic Improvement of Vegetable Crops*, Pergamon. pp. 473-477.

Pokluda, R. 2013. Selected nutritional aspects of field grown root vegetables in the Czech Republic. In: *Southeast Asia Symposium on Quality Management in Postharvest Systems and Asia Pacific Symposium on Postharvest Quality 989*. pp. 315-322.

Poleshi, C. A., Cholin, S., Manikanta, D. S., and Ambika, D. S. 2017. Genetic variability for root traits in carrot (*Daucus carota* L.) evaluated under tropical condition. *Ann. Hortic.* 10(2): 224-227.

Poudel, K., Karki, S., Sah, M. K., and Mandal, J. L. 2018. Evaluation of radish (*Raphanus sativus* L.) genotypes in Eastern mid-hills condition of Nepal. *World News Nat. Sci.* 19: 155-159.

Ranganna, S. 1986. *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill Publishing Company Limited, New Delhi. 182p.

Ranganna, S. 1997. *Handbook of analysis and quality control for fruits and vegetable products (3rd Ed.).* Tata McGraw and Hill Publication Co. Ltd., New Delhi, 634p.

Rekowska, E. and Jurga, B. A. R. 2009. Evaluation of selected quality traits of storage roots of ten beet cultivars. *Herba Polonica* 55(3): 163-169.

Ruboczki, T., Raczko, V., and Hajos, M. T. 2015. Evaluation of morphological parameters and bioactive compounds in different varieties of beetroot (*Beta vulgaris* L. ssp. *esculenta* GURKE var. *rubra* L.). *Int. J. Hortic. Sci.* 21(4): 31-35.

Santhi, V. P., Priya, P. A., Anita, B., and Selvaraj, N. 2015. Genetic variability, heritability and genetic advance in varieties of carrot (*Daucus carota* L.). 2015. *Int. J. Plant Sci.* 10(2): 136-141.

Sharma, M. 2013. Studies on genetic evaluation of beet root *(Beta vulgaris* L.*).* M.Sc. (Hortic.) thesis, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, 76p.

Singh, B. and Hathan, B. S. 2014. Chemical composition, functional properties and processing of beetroot-a review. *Int. J. Sci. Eng. Res.* 5(1): 679-684.

Sivasubramanian, S. and Menon, M. 1973. Heterosis and inbreeding depression in rice. *Madras Agric. J.* 60: 1139.

Sivathanu, S., Mohammed, Y. G., and Kumar, S. R. 2014. Seasonal effect on variability and trait relationship in radish. *Res. Environ. Life Sci*. 7(4): 275-278.

Sklenar, P., Kovacev, L., Cacic, N., Mezei, S., and Nagl, N. 1998. Genetic and phenotypic correlations for some sugar beet root characteristics. In: *Progress in Botanical Research.* Springer, Dordrecht. pp. 569-572.

Smith, F. H. 1937. A discriminant function for plant selection. *Ann. Eugenics*. 7: 240-250.

Srivastava, H. M., Shahi, H. N., Kumar, R., and Bhatnagar, S. 2000. Genetic diversity in *Beta vulgaris* ssp. *maritima* under subtropical climate of north India. *J. sugar beet res.* 37(3): 79-87.

Stagnari, F., Galieni, A., Speca, S., and Pisante, M. 2014. Water stress effects on growth, yield and quality traits of red beet. *Scientia Hortic*.165:13-22.

Straus, S., Bavec, F., Turinek, M., Slatnar, A., Rozman, C., and Bavec, M. 2012. Nutritional value and economic feasibility of red beetroot (*Beta vulgaris* L. *ssp. vulgaris* Rote Kugel) from different production systems. *Afr. J. Agric. Res.* 7(42): 5653-5660.

Szopinska, A. A. and Gaweda, M. 2013. Comparison of yield and quality of red beet roots cultivated using conventional, integrated and organic method. *J. Hortic. Res.* 21: 107–114.

Tamiru, F., Deba, G., Diriba, G., Defa, G., Gudeta, G., Iticha, A., and Chimdessa, A., 2017. Effect of plant spacing and urea fertilizer on yield and yield components of beetroot (*Beta vulgaris* L.). *Agric. Dev.* 2: 13-21.

Teli, S.K., Kaushik, R.A., Ameta, K.D., Kapuriya, V.K., Mali, D., and Teli, L.K. 2017, Genetic variability, heritability and genetic advance in carrot (*Daucus carota* var. *sativa* L.). *Int. J. Curr. Microbiol. Appl. Sci.* 6(5): 2336-2342.

Ullah, M. Z., Hasan, M. J., Rahman, A. H. M. A., and Saki, A. I. 2010. Genetic variability, character association and path coefficient analysis in radish (*Raphanus sativus* L.). *Agric.* 8(2): 22-27.

Vaghefi, N., Hay, F. S., Kikkert, J. R., and Pethybridge, S. J. 2016. Genotypic diversity and resistance to azoxystrobin of *Cercospora beticola* on processing table beet in New York. *Plant Dis.* 100(7): 1466-1473.

Viskelis, J., Nevidomskis, S., Bobinas, C., Urbonavicienė, D., Bobinaite, R., Karkleliene, R., and Viskelis, P. 2019. Evaluation of beetroot quality during various storage conditions. In: *Conference Proceedings. Foodbalt 2019. 13th Baltic Conference on Food Science and Technology "Food, Nutrition, Well-Being"*, 2-3 May, 2019, Jelgava, Latvia. Latvia University of Life Sciences and Technologies. pp. 170-175.

Weaver, J. E. and Bruner, W. E. 1927. *Root Development of Vegetable Crops*. McGrow- Hill Book Co. Inc, New York, 254p.

Wotchoko, P., Tamfuh, P. A., Nkouathio, D. G., Nono, D. G. K., Bongkem, C. S., Chenyi, M. L., and Bitom, D. 2019. Change in soil fertility and beetroot productivity after single and mixed application of basalt dust, poultry manure and NPK 20-10-10 in Nkwen (Cameroon Volcanic Line). *World* 7(4):137-148.

Yadav, M., Tirkey, S., Singh, D. B., Chaudhary, R., Roshan, R. K., and Pebam, N. 2009. Genetic variability, correlation coefficient and path analysis in carrot. *Indian J. Hortic.* 66(3): 315-318.

Yasaminshirazi, K., Hartung, J., Groenen, R., Heinze, T., Fleck, M., Zikeli, S., and Graeff-Hoenninger, S. 2020. Agronomic performance of different open-pollinated beetroot genotypes grown under organic farming conditions. *Agron*. 10(6): 812.

Zarate, N. A. H., Sangalli, C. D. S., Vieira, M. D.C., Graciano, J. D., Munarin, E. D. O., and Paula, M. D. S. 2010. Soil covering with chicken manure with and without hilling on beetroot yield. *Cienc. Agrotec*. 34: 1598-1603.

APPENDICES

APPENDIX I

Weather parameters in open field during cropping period

(October 2019 - February 2020)

Standard weeks	Temperature(^{0}C)		Relative humidity (%)		Rain fall
	Max temp	Min temp	Max RH	Min RH	
1	30.3	23.6	91.3	77.7	0.8
2	28.8	24.0	95.0	78.7	15.1
3	32.5	24.8	89.3	68.1	0.0
4	32.5	24.6	90.7	67.4	1.3
5	32.1	24.3	92.4	74.4	7.1
6	32.6	24.5	94.0	69.1	4.4
7	32.0	24.1	91.3	69.6	5.4
8	32.2	23.6	91.0	70.9	7.6
9	31.4	24.0	92.9	72.4	5.9
10	36.5	27.2	106.0	78.9	8.6
11	32.2	24.1	92.3	66.1	0.0
12	32.0	22.7	93.4	66.3	6.4
13	32.2	22.5	92.3	63.7	1.4
14	32.7	23.0	91.4	64.1	0.0
15	32.7	22.3	92.7	57.9	0.0
16	32.7	23.2	91.4	63.3	0.0
17	33.2	23.7	89.0	60.0	0.0
18	33.1	23.2	90.6	58.7	0.0
19	33.2	23.4	89.5	61.0	4.7

APPENDIX II

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE, VELLAYANI

DEPARTMENT OF VEGETABLE SCIENCE

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF BEET ROOT VARIETIES

Name of student: Arya P. J. (2018-12-003)

Title of thesis : Performance of beet root (*Beta vulgaris* L.) for growth, yield and quality

CRITERIA	SAMPLES																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Appearance																						
Colour																						
Taste																						
Overall Acceptability																						

Scores

Excellent - 10
Best - 9
Better - 8
Good - 7
Average - 6
Poor - < 5

Name :
Signature :

APPENDIX III

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE, VELLAYANI

DEPARTMENT OF VEGETABLE SCIENCE

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF BEET ROOT HYBRIDS

Name of student: Arya P. J. (2018-12-003)

Title of thesis : Performance of beet root (*Beta vulgaris* L.) for growth, yield and quality

CRITERIA	SAMPLES							
	1	2	3	4	5	6	7	8
Appearance								
Colour								
Taste								
Overall Acceptability								

Scores

Excellent - 10
Best - 9
Better - 8
Good - 7
Average - 6
Poor - < 5

Name:
Signature:

PERFORMANCE OF BEET ROOT (*Beta vulgaris* L.) FOR GROWTH, YIELD AND QUALITY

by

Arya P. J.

(2018 - 12 - 003)

ABSTRACT

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2020

ABSTRACT

The present investigation entitled "Performance of beet root (*Beta vulgaris* L.) for growth, yield and quality" was conducted at the Department of Vegetable Science, College of Agriculture, Vellayani, during October 2019 - February 2020 to evaluate the adaptability of beet root in Kerala based on growth, yield and quality.

The experimental material consisted of 30 beet root genotypes, including twenty two varieties and eight hybrids. The experiment was laid out in RBD with three replications. Analysis of variance revealed significant differences among the twenty two varieties and the eight hybrids for all the characters studied. Among the varieties, Tetra recorded the highest plant height of 38.32 cm and among hybrids, Ragini was the tallest (31.07 cm) and Remo (30.77 cm) was on par with it. The variety Ruby Queen (Pradham Seeds) recorded the highest number of leaves (13.45). BV 21 (12.96) and Tetra (12.65) were on par with it. Among hybrids, Remo (9.79) recorded the highest number of leaves, Red Star (Sakura) (9.70) was on par with it.

Madhur recorded the highest root length of 7.43 cm among varieties and Red Star (Sakura) (7.41 cm) among hybrids. The variety Madhur recorded the highest root diameter of 5.33 cm and Ruby Queen (Tokita) (5.25 cm), Detroit Dark Red (5.16 cm) and Mahyco Lal II (5.15 cm) were statistically on par with it. The hybrid Red Star (Sakura) recorded the highest root diameter of 5.50 cm, which was on par with Ragini (5.32 cm). Among varieties, Madhur recorded the highest root weight (118.05 g), root: shoot ratio (4.42) and yield per plot (5.68 kg) and among hybrids, Red Star (Sakura) recorded the highest root weight (91.27 g), root: shoot ratio (3.61) and yield per plot (4.27 kg). The varieties, Madhur, Tetra and Ruby Queen (Tokita) were early with a crop duration of 96 days, while the hybrids, Red Star (Sakura), Red Horse and RK 777 were early with a crop duration of 98 days.

T.S.S content was the highest for the variety K 5340 (15.70 ^{0}B) and hybrid RK 777 (14.50 ^{0}B). The highest carotenoid content was recorded for Mahyco Lal II among varieties (1.50 mg 100g^{-1}) and Red Horse among hybrids (1.74 mg 100g^{-1}). Madhur

recorded the highest total sugars (6.45 %) and non reducing sugars (6.03 %) among varieties, while Red Star (Sakura) among hybrids (6.50 % and 6.04 % respectively). Among varieties Crimson Globe recorded the highest reducing sugars (1.00 %) and RK 777 (1.00 %) among hybrids. Sensory evaluation revealed the superiority of the variety Madhur and the hybrid Red Star (Sakura) for appearance, colour, taste and overall acceptability over other varieties and hybrids.

High phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for the characters leaf breadth, foliage weight, root weight, root: shoot ratio and yield per plot of varieties. For hybrids, high PCV and GCV was observed for root length, root weight, root: shoot ratio and yield per plot. For both varieties and hybrids, high estimates of heritability coupled with moderate to high genetic advance as per cent of mean were recorded for all the yield components, indicating additive gene action. Root weight had a significant positive correlation at genotypic and phenotypic level with leaf breadth, root length, root diameter, root: shoot ratio and yield per plot, both for varieties and hybrids. Path coefficient analysis of varieties revealed that root: shoot ratio (0.687) exerted the highest positive direct effect on root weight followed by root length, foliage weight, plant height and root diameter. Root diameter (3.094) exerted a maximum direct effect on root weight of hybrids followed by root: shoot ratio, leaf breadth, leaves per plant and leaf length.

The varieties were ranked based on selection index score considering the characters *viz*., plant height, foliage weight, root diameter, root length, root weight and root: shoot ratio. Madhur recorded the highest selection index score of 192.52. The hybrids were ranked based on selection index score considering the characters *viz*. leaves per plant, leaf length, leaf breadth, root diameter, root weight and root: shoot ratio and Red Star (Sakura) recorded the highest score of 148.90.

Based on the mean performance of the varieties and the hybrids for various characters and selection index score, the top ranking varieties Madhur, Tetra, Mahyco Lal II and Ruby Queen (Tokita) and the hybrids Red Star (Sakura), Ragini, Red Horse and F_1 Kingdom were found suitable for growing under Kerala conditions.

സംഗ്രഹം

"വളർച്ച, വിളവ്, ഗുണനിലവാരം എന്നിവയ്ക്കായി ബീറ്റ് റൂട്ടിന്റ (ബീറ്റാ വൾഗാരിസ് എൽ.) പ്രകടനം" എന്ന വിഷയത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷിക കോളേജിലെ പച്ചക്കറി ശാസ്ത്ര വിഭാഗത്തിൽ 2019 ഒക്ടോബർ മുതൽ 2020 ഫെബ്രുവരി വരെയുള്ള കാലയളവിൽ നടത്തി. വളർച്ച, വിളവ്, ഗുണനിലവാരം എന്നിവ അടിസ്ഥാനമാക്കി കേരളത്തിൽ ബീറ്റ് റൂട്ടിന്റ പൊരുത്തപ്പെടൽ വിലയിരുത്തുക എന്നതായിരുന്നു ഈ പഠനത്തിന്റ ഉദ്ദേശ്യം.

ഇരുപത്തിരണ്ട് ഇനങ്ങളും, എട്ട് സങ്കരയിനങ്ങളും ഉൾപ്പെടുന്ന ബീറ്റ് റൂട്ടിന്റ മുപ്പത് ജനിതക ഇനങ്ങളാണ് പഠനത്തിനായി ഉപയോഗിച്ചത്. 30 ട്രീട്മെന്റുകൾ 3 തവണ ആവർത്തിച്ചുകൊണ്ടുള്ള റാൻഡമൈസഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന രീതിയിലാണ് പഠനം നടത്തിയത്. പഠനവിധേയമാക്കിയ എല്ലാ പ്രതീകങ്ങൾക്കും ഇനങ്ങൾ തമ്മിലും, സങ്കരയിനങ്ങളിൽ തമ്മിലും, വ്യത്യാസം കണ്ടെത്തി. ഇനങ്ങളിൽ ടെട്രയും സങ്കരയിനങ്ങളിൽ രാഗിണിയും ഏറ്റവും കൂടുതൽ ചെടിയുടെ ഉയരം കാണിച്ചു. ഏറ്റവും കൂടുതൽ ഇലകൾ ഇനങ്ങളിൽ റൂബി ക്യുനും (പ്രധം സീഡ്സ്), സങ്കരയിനങ്ങളിൽ റെമോയും രേഖപ്പെടുത്തി.

ഇനങ്ങളിൽ വേരിന്റ നീളം, വേരിന്റ വ്യാസം, വേരിന്റ ഭാരം, വേര്: തണ്ട് അനുപാതം, ഓരോ പ്ലോട്ടിൽ നിന്നുമുള്ള വിളവ് എന്നിവയിൽ മധുറും, സങ്കരയിനങ്ങളിൽ റെഡ് സ്റ്റാറും (സകുര) മികച്ചു നിൽക്കുന്നതായി നിരീക്ഷിച്ചു. മധുർ, ടെട്ര, റൂബി ക്വീൻ (ടോകിത) എന്നീ ഇനങ്ങൾക്കും, സ്റ്റാർ (സകുര), റെഡ് ഹോഴ്സ്, ആർ കെ 777 എന്നീ സങ്കരയിനങ്ങൾക്കും കുറഞ്ഞ വിള കാലാവധിയായിരുന്നു ഉണ്ടായിരുന്നത്.

ആകെ ലയിക്കുന്ന ഖരപദാർത്ഥങ്ങൾ, കരോട്ടിന്, പഞ്ചസാര എന്നിവയുടെ അളവിലും ഇനങ്ങൾ തമ്മിലും, സങ്കരയിനങ്ങൾ തമ്മിലും, വ്യത്യാസമുള്ളതായി കണ്ടെത്തി. സെൻസറി ഗുണങ്ങളായ കാഴ്ച്ച, നിറം, രുചി, മൊത്തത്തിയുള്ള സ്വീകാര്യത എന്നിവയിൽ ഇനങ്ങളിൽ മധുറും സങ്കരയിനങ്ങളിൽ റെഡ് സ്റ്റാറും (സകുര) മികച്ചതായി കണ്ടെത്തി.

ഇനങ്ങളുടെ ഇലയുടെ വീതി, ഇലകളുടെ ഭാരം, വേരിന്റ ഭാരം, വേര്: തണ്ട് അനുപാതം, ഓരോ പ്ലോട്ടിൽ നിന്നുമുള്ള വിളവ് എന്നീ പ്രതീകങ്ങൾക്കും,

സങ്കരയിനങ്ങളുടെ വേരിന്റ നീളം, വേരിന്റ വ്യാസം, വേരിന്റ ഭാരം, ഓരോ പ്ലോട്ടിൽ നിന്നുമുള്ള വിളവ് എന്നീ പ്രതീകങ്ങൾക്കും ഉയർന്ന ജീനോട്ടിപിക് കൂടാതെ ഫിനോട്ടിപിക് കോഎഫീസിന്റ് ഓഫ് വേരിയേഷൻ രേഖപെടുത്തി. ഉയർന്ന പൈതൃകവും, ശരാശരി മുതൽ ഉയർന്ന ജനിതക മുന്നേറ്റവും ഇനങ്ങളിലേയും സങ്കരയിനങ്ങളിലെയും എല്ലാ പ്രതീകങ്ങൾക്കും കാണാൻ സാധിച്ചു. ഇനങ്ങളിലും സങ്കരയിനങ്ങളിലും ഇലയുടെ വീതി, വേരിന്റ വ്യാസം, വേരിന്റ നീളം, വേര്: തണ്ട് അനുപാതം എന്നിവ വേരിന്റ ഭാരവുമായി ബന്ധപ്പെട്ടിരിക്കുന്നതായി കണ്ടെത്തി. പാത്ത് കോഫിഫിഷ്യന്റ് വിശകലനത്തിലൂടെ വേര്: തണ്ട് അനുപാതം, വേരിന്റ നീളം, ഇലകളുടെ ഭാരം, ചെടിയുടെ ഉയരം, വേരിന്റ വ്യാസം എന്നിവ ഇനങ്ങളുടെ വേരിന്റ ഭാരവുമായി നേരിട്ട് ബന്ധപ്പെട്ടിരിക്കുന്നു വെന്നും, വേരിന്റ വ്യാസം, വേര്: തണ്ട് അനുപാതം, ഇലയുടെ വീതി, ഇലകളുടെ എണ്ണം, ഇലയുടെ നീളം എന്നിവ സങ്കരയിനങ്ങളുടെ വേരിന്റ ഭാരവുമായി നേരിട്ട് ബന്ധപ്പെട്ടിരിക്കുന്നുവെന്നും കണ്ടെത്തി.

ചെടിയുടെ ഉയരം, ഇലകളുടെ ഭാരം, വേരിന്റ വ്യാസം, വേരിന്റ നീളം, വേരിന്റ ഭാരം, വേര്: തണ്ട് അനുപാതം എന്നീ പ്രതീകങ്ങൾ കണക്കിലെടുത്ത് തിരഞ്ഞടുക്കൽ സൂചിക മാർക്ക് അടിസ്ഥാനമാക്കി ഇനങ്ങൾ റാങ്ക് ചെയ്യപ്പെട്ടു. മധുർ ഏറ്റവും മികച്ച റാങ്ക് നേടി. ചെടിയിലെ ഇലകളുടെ എണ്ണം, ഇലയുടെ നീളം, ഇലയുടെ വീതി,വേരിന്റ വ്യാസം, വേരിന്റ ഭാരം എന്നീ പ്രതീകങ്ങൾ കണക്കിലെടുത്ത് തിരഞ്ഞടുക്കൽ സൂചിക സ്കോർ അടിസ്ഥാനമാക്കി സങ്കരയിനങ്ങൾ റാങ്ക് ചെയ്യപ്പെട്ടു. റെഡ് സ്റ്റാർ (സകുര) മികച്ച റാങ്ക് നേടി. ശരാശരി പ്രകടനത്തിന്റയും, തിരഞ്ഞെടുക്കൽ സൂചിക മാർക്കിന്റയും അടിസ്ഥാനത്തിൽ മികച്ച ഇനങ്ങളായ മധുർ, ടെട്രാ, മഹികോ ലാൽ II, റൂബി ക്വീൻ (ടോകിട) സങ്കരയിനങ്ങളായ റെഡ് സ്റ്റാർ (സകുര), രാഗിണി , റെഡ് ഹോഴ്സ് F_1 കിങ്ഡം എന്നിവയും കേരളത്തിലെ ബീറ്റ് റൂട്ട് കൃഷിയ്ക്ക് അനുയോജ്യമാണെന്ന് കണ്ടെത്തി.